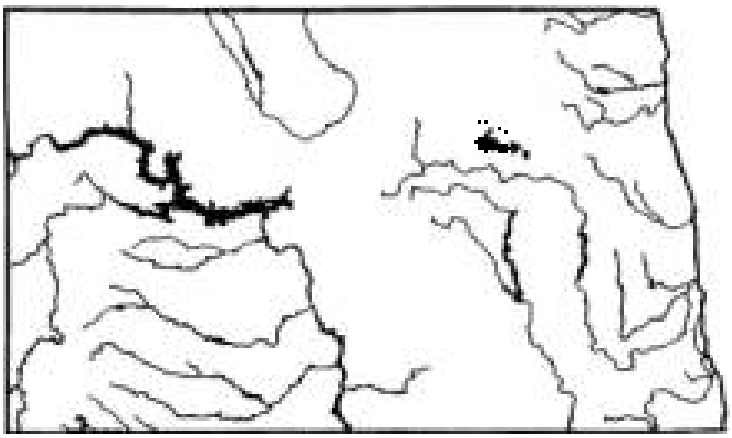

North Dakota Water Resources Research Institute

North Dakota State University
University of North Dakota

ANNUAL REPORT

For the Period March 2005 to February 2006

Fiscal Year 2005 Report to the U.S. Geological Survey

June 2006

Annual Report

Fiscal Year 2005 Report to the U.S. Geological Survey

Award No. 01-HQ-GR-0097
Revised: 01
U.S. Geological Survey

by

North Dakota Water Resources Research Institute
North Dakota State University
Fargo, ND 58105

G. Padmanabhan, Director

June 2006

The activities on which this report is based were financed in part by the Department of Interior, U.S. Geological Survey, through the North Dakota Water Resources Institute.

Table of Contents

INTRODUCTION

This report describes the activities of the North Dakota Water Resources Research Institute (NDWRRI) during the period of March 1, 2005 to February 28, 2006.

The ND WRRI is one of the 54 institutes known collectedly as the National Institutes for Water Resources (NIWR). The NDWRRI was founded in 1965, by authority of Congress (Water Resources Research Acts of 1964, 1972, 1984, and 1990), and is administrated through the United States Geological Survey. Section 104 of the Water Resources Research Act requires the NDWRRI to apply its Federal allotment funds to:

1. Plan, conduct or otherwise arrange for competent research that fosters: (A) the entry of new research scientists into the water resources field, (B) training and education of future water resources scientists, engineers, and technicians; (C) the preliminary exploration of new ideas that address water problems or expand understanding of water and water-related phenomena; and (D) the dissemination of research results to water managers and public.

2. Cooperate closely with other college and universities in the state that have demonstrated the capability for research, information dissemination and graduate training, in order to develop a statewide program designed to resolve State and regional water and related land problems.

3. Cooperate closely with other institutes and other organizations in the region to increase the effectiveness of the Institute and for the purpose of promoting regional cooperation.

This year, NDWRRI once again allocated its 104(B) resources to fund the Gradate Fellowship research projects. The institute also continued its efforts to enhance communications between the State and Federal agency personnel and university faculty and students. The sustained effort on the part of the Director succeeded in having two proposals submitted by the faculty for the National Competitive 104(G) grant program. Both of them were funded, however, one had to be reallocated to another Institute because of the faculty leaving NDSU. NDWRRI also worked closely with the Environmental and Conservation Sciences program of NDSU, Energy and Environmental Research Center at UND, and the International Water Institute, Fargo, ND on water related research issues and collaboration. The Director submitted a proposal “Building Environmental Education Capacity in Indian Reservations” through the Institute to the USEPA. This proposal is a collaborative effort of the Institute and the Environmental and Conservation Sciences Graduate Program of NDSU. The Director also participated in the campus efforts to play a significant part in the NSF NEON initiative.

Program Management

The Institute continued the same administrative mechanism with a director managing the institute program with the help of a State Advisory Committee. Dr. G. Padmanabhan, Professor of Civil Engineering, is the director. Dr. Wei Lin, Associate Professor of Civil Engineering, served as the interim director during the period March 1, 2005 - July 2005 in the absence of Dr. Padmanabhan who was on sabbatical leave. Linda Charlton, a NDSU employee, has been working part-time for the Institute to assist the director with Institute finances, communications and information transfer. The State Advisory Committee consists of three members representing the three principal water agencies in North Dakota: State Water Commission, State Department of Health, and the USGS North Dakota District. In addition, the Institute also has a Technical Advisory Committee consisting of faculty from two universities, UND and NDSU.

State Appropriation

Efforts have been directed to seek state appropriation and other support sources in the past few years. As a result of this continuing effort, the State Water Commission provided 15% matching to the 2005 – 2006 federal 104(B) funding for the GRF program of NDWRRI.

University Support

North Dakota State University and the University of North Dakota administrations consider the NDWRRI activities important and are supportive of its efforts.

Institute Location

The Institute is located in the Administrative Building of the College of Engineering and Architecture of North Dakota State University in Fargo, North Dakota, The director may be reached at:

ND Water Resources Research Institute
North Dakota State University
Department of Civil Engineering
Fargo, ND 58105
Phone: (701) 231-7043
Fax: (701) 231-6185
E-mail: G.Padmanabhan@ndsu.edu

State Advisory Committee

The State Advisory Committee provided guidance on water resources research priorities in the State and region, and participated in the review and evaluation of research proposals and projects. The current committee members are:

Gregg Wiche, District Chief, U.D. Geological Survey, Water Resources Division, Bismarck, North Dakota

William Schuh, Water Appropriation Division, North Dakota State Water Commission, Bismarck North Dakota

David Leo Glatt, Chief, Environmental Health Section, North Dakota Department of Health, Bismarck, North Dakota

Mike T. Sauer, Environmental Health Section, North Dakota Department of Health, Bismarck, North Dakota

The committee members are senior officials in the three agencies in North Dakota responsible for much of the water resources research done outside of NDSU and UND in North Dakota.

RESEARCH PROGRAM

In the past several years NDWRRI has offered competitive fellowships to NDSU and UND graduate students for research on water resources topics under a Graduate Research Fellowship (GRF) program effectively using the modest amount of the 104(B) annual base grant. The program meets the requirements of Section 104 of the Water Resources Research Act of 1984. The fellowship program encourages entry of young university faculty and new research scientists into the water resources field; provides training and education to future water resource scientists and engineers; promotes exploration of new ideas that address water problems or expand understanding of water quantity, quality and related phenomena; and engages university faculty in collaborative research programs and seeking supports from entities concerned with water problems.

This year, the NDWRRI continued the GRF program and applied bulk of the federal allotment to it. The GRF program is administrated and monitored by the director. Applications are invited from the graduate students and their advisors of the two research universities of the State. A rigorous review by the State Advisory Committee and other water professionals in the state determines the awards. Active participation of the academic advisors of the students in meeting matching requirement and seeking co-funding from local, state and other sources is a positive aspect of the program. Periodical review of the progress of the students in meeting the fellowship expectations is ensured

by seeking reports from the students and by encouraging them to make presentations in local and regional technical seminars and conferences.

Guidelines for the 2005-2006 Graduate Research Fellowship competition were posted on the Institute website in September 2004, and the competition was announced in the faculty news publications of the two university campuses in October. The following is the request for application that was published on the UND and NDSU campus newsletters, and distributed by e-mail lists:

ND WRRI graduate research fellowship applications sought

The North Dakota Water Resources Research Institute (WRRI) is accepting applications for its 2005 graduate research fellowship program.
NDSU and University of North Dakota graduate students who are conducting or planning research in water resources areas may apply for the fellowships.

Fellowships vary in length from a three-month summer to one year, with monthly stipends ranging from $800-$1,400. Fellowship funds must be used between March 2005 and February 2006. Projects proposed for fellowship support should relate to water resources research issues in the state or region. Regional, state or local collaborations and co-funding proposals are encouraged.

Applications should be sent to Wei Lin, interim director, N.D. Water Resources Research Institute, P.O. Box 5285, Fargo, N.D. 58105 by the Nov. 19 deadline.

For program background and application guidelines, visit the institute Web site at www.ce.nodak.edu/wrri, or contact Lin at 1-6288 or wei.lin@ndsu.nodak.edu.

NDWRRI GRADUATE RESEARCH FELLOWSHIPS (104-B)

Nine fellowships were awarded in FY2005. The titles of the fellowship projects awarded are given below and details are provided for each project under separate project sections. Four of the selected fellowships are renewals, one M.S. and three Ph.D. These renewals are Brajesh Gautam, Jennifer Newbrey, Michael Newbrey, and Tedros Tesfay.

2005-06 Fellows and their projects:

- **Michael Newbrey,**
  Ph.D. candidate, Geology, NDSU
  Comparative Study of Fossil and Extant Fish Growth: Including Analyses of Mean Annual Temperature in the Geologic Record
  Advisor: Dr. Allan Ashworth, Professor, Geology, NDSU

- **Tedros Tesfay,**
  Ph.D. candidate, Geology, UND
  Modeling Groundwater Denitrification by Ferrous Iron Using PHREEQC
  Advisor: Dr. Scott Korom, Associate Professor, Geology and Geological Engineering, UND

- **Jennifer Newbrey,**
  Ph.D. candidate, Biological Sciences, NDSU
  Effects of West Nile Virus Infection, Immune Function, and Age on Female Yellow-headed Blackbird
  Advisor: Dr. Wendy Reed, Assistant Professor, Biology, NDSU

- **Brajesh Gautam,**
  M.S. program, Civil Engineering, NDSU
  Analysis and Model Simulation of Storm Water Runoff – A Study of Land Use and System Design on Discharge Flow Rates and Water Quality
  Advisor: Dr. Wei Lin, Associate Professor of Civil Engineering, NDSU

- **Kendall Goltz,**
  M.S. program, Natural Resource Management, NDSU
  Impact of Wetlands and Wetland Easements on North Dakota Land Values
  Advisor: Dr. Jay Leitch, Professor of Agricultural Economics, NDSU

- **Ali Gene Tackett,**
  M.S.program, Environmental and Conservation Sciences, NDSU
  Molecular Phylogeoraphy of Etheostoma nigrum (Rafinesque) in the Upper Midwest
  Advisor: Dr. Craig Stockwell, Assistant Professor, Biological Sciences, NDSU

- **Dan McEwen,**
  PhD program, Department of Biological Sciences, NDSU,
  Benthic macroinvertebrate stoichiometric implications for North Dakota and Minnesota fisheries
  Advisor: Malcolm Butler, Professor of Zoology Department of Biological Sciences, NDSU

- **Chistina Melaas,**
  M.S. program, Natural Resource Management, NDSU
  Evaluation of an Index of Plant Community Integrity for Assessing Wetland Plant Communities in the Prairie Pothole Region
  Advisor: Dr. Don Kirby, Department of Animal and Range Sciences, NDSU

- **William Lenarz,**
  M.S. program,Geology Department,UND
  Effect of flow path processes on the geochemistry and quality of water discharged along the seepage face at Pigeon Point, Sheyenne Delta aquifer, Ransom County, North Dakota
  Advisor: Dr. Phil Gerla, Geology and Geological Engineering, UND

NATIONAL COMPETITIVE PROGRAM (104-G)

The Director, G. Padmanabhan, encouraged several faculty members from NDSU and UND to submit good proposals for the NIWR-USGS National Competitive Grant program (104-G). Two proposals were submitted through the ND Institute and both of them - one by Robert Hearne and another by Steve Shultz - were funded. However, Steve Shultz left NDSU and so the project went with him

INFORMATION DISSEMINATION

Information dissemination is done through an annual newsletter initiated in 1992, a website initiated in 1999, and presentations and publications by grant and fellowship recipients. The institute's website address is http://www.ndsu.edu/wrri. The newsletter is usually issued in the month of December of each year. Past newsletters can be accessed through the institute web site.

NDWRRI continued its sponsorship of the Biotic Resources Seminar Series at North Dakota State University. Since 1987 it has brought about 70 biology-oriented speakers to the campus. Under this multidisciplinary program, visiting scientists are hosted by the faculty and graduate students from several departments in the College of Science and Mathematics, and College of Agriculture, Food Systems and Natural Resources. Seminar topics range widely, with the common thread being organismal/environmental biologies in the broadest sense. On April 22, 2005, Dr. Martin Berg of Loyola University made a presentation on "Ecological Impacts of Invasive Species in the Laurentian Great Lakes." He also discussed productivity of aquatic insects in stream ecosystems. On October 21, 2005 we had Dr. Gordon Goldsborough, University of Manitoba, talk on "Studies on the Coastal Marshes of Manitoba's Great Lakes." He also discussed Canadian Wetland Resources.

NDWRRI co-sponsored the Second International Water Conference titled "Research Education in an International Watershed: Implications for Decision Making" in Winnipeg, Manitoba, Canada in April 2005. The conference organized by the Red RiverBasin Institute brought administrators, researchers, professionals and educators to Winnipeg, ManitobaCanada to discuss water resources, flood control and water quality management issues related to the RedRiver of the North.

NDWRRI co-sponsored a talk "Water at Risk - Transport of Antibiotics and Pharmaceuticals in Surface and Ground Water from Urban and Agricultural Sources: New Approaches and What It Means" by Dr. Michael T. Meyer, Director of the Organic Geochemistry Laboratory, USGS, Kansas on April 26, 2005. Other co-sponsors were USGS, NDSU Environmental and Conservation Sciences Graduate Program, and International Water Institute, Fargo, North Dakota.

Research results of NDWRRI Graduate Research Fellows were published and presented in various conferences.

PUBLICATIONS AND PRESENTATIONS

From 2005-06 Fellows and PIs

Journal papers

- Newbrey, M.G., M.V.H. Wilson, and A.C. Ashworth. 2005. Growth characteristics of Cretaceous and Cenozoic North American Esociformes: Implications for systematics. In Fourth International Meeting on Mesozoic Fishes - Systematics, Homology, and Nomenclature, Extended Abstracts; edited by F.J. Poyato-Ariza; Madrid, Servicio de Publicaciones de la Universidad Autónoma de Madrid / UAM Ediciones. pp. 201-204.
- Newbrey, M.G., M.V.H. Wilson, and A.C. Ashworth. 2005. Growth characteristics of North American Hiodontidae (Teleostei) from the Late Cretaceous to Recent. Society of Vertebrate Paleontology 65 th Annual Meeting. Journal of Vertebrate Paleontology 25(supplement to 3). Presented in Phoenix, AZ, October 19-22.

- Hearne R. 2005. “Evolving Water Management Institutions In The Red River Basin.” Under Review Environmental Management

Presentations

- Newbrey, M.G., M.V.H. Wilson, and A.C. Ashworth. 2005. Growth characteristics of Cretaceous and Cenozoic North American Esociformes: Implications for systematics. Presented in Fourth International Meeting on Mesozoic Fishes, Miraflores de la Sierra, Madrid, Spain, August 8-13.
- Newbrey, M.G. and A.C. Ashworth. 2005. If fossil fish could talk we would hear stories about drought: An examination of a late Pleistocene deposit near Jamestown, North Dakota. Presented at North Dakota Geological Society Meeting, Bismarck, North Dakota. May 17th.
- Newbrey, M.G., A.C. Ashworth, and M.V.H. Wilson. 2005. Geographic trends in North American Freshwater Fishes from the Cretaceous to the Pliocene: A climatic effect? Presented at Northern Plains Biological Symposium, Fargo, North Dakota.

- Newbrey, M.G. and M.V.H. Wilson. 2005. Recognition of annular growth on centra of Teleostei with application to Hiodontidae of the Cretaceous Dinosaur Park Formation. Poster at Dinosaur Park Symposium, Royal Tyrrell Museum, Drumheller, Alberta.

- Tesfay, T. and Korom, S. F. and. 2006. The relative roles of electron donors in aquifer denitrification reactions: insights from geochemical modeling. 40th annual meeting, North-Central section, the Geological Society of America, University of Akron, Akron, Ohio, April 20-21, 2006.

- Newbrey, J.L., and W.L. Reed. 2005. Effects of nest contents and minimum daily temperature on female Yellow-headed Blackbird nest attentiveness. Presented in Wilson Ornithological Society and Association of Field Ornithologists Joint Meeting.
- Newbrey, J.L., and W.L. Reed. 2004. West Nile virus antibodies in central North Dakota icterids. Cooper Ornithological Society 74th Annual Meeting.
- Newbrey, J.L. 2004. West Nile virus antibodies in central North Dakota icterids: Implications for ecology and management. Poster presentation in North Dakota Chapter of the Wildlife Society Annual Meeting.
- Somayajula. S., Gautam, B., Martin, J. and Lin, W. (2005). "Application of Water Quality Modeling in Red River Fecal Coliform TMDL Development." Presented at 'Research and Education in an International Watershed: Implications for Decision Making', Second International Water Conference, April 6-7, 2005, Winnipeg, Canada.

- Martin, J., Somayajula, S., Gautam, B., Lin, W., Fredrick, J., and Ell, M. (2005). "Stormwater Sampling and Analysis for Red River Fecal Coliform and Turbidity TMDL Development." Presented at 'Research and Education in an International Watershed: Implications for Decision Making', Second International Water Conference, April 6-7, 2005, Winnipeg, Canada

- Hargiss, C.L.M., E.S. DeKeyser, D. Kirby. 2006. Development and Evaluation of an Index of Plant Community Integrity for Assessing Wetland Plant Communities. 2006 Annual Society of Range Management Meeting, Vancouver, BC.
- Hargiss, C.L.M., E.S. DeKeyser, D. Kirby. 2005. Evaluation of an Index of Plant Community Integrity for Assessing Wetland Plant Communities. 2005 Annual Society of Range Management Meeting, Fort Worth, TX.

- Hearne R. 2005. "A Review of Water Management Institutions in The Red River of the North Basin." Paper presented at the W-1190, Western Water Multistate Research Project Meeting. Las Cruces, NM. October 17-19, 2005.
- Hearne R. 2005. Criteria and Indicators for Effective Water Management Institutions Presented at the Red River Basin Conference Winnipeg, Manitoba, January 12, 2006

- Hearne R. 2006. Water Quality Monitoring Among Local Agencies in the Red River Basin. Presented at the 2006 National Water Quality Monitoring Conference. San José CA. May 9 2006.

From Prior Fellows and PIs

Journal papers

- **Kirby, D. R**., Krabbenhoft, K. D., Sedivic, K. K., and **DeKeyser, E. S**. 2002. Wetlands in Northern Plains Prairies: benefiting wildlife and livestock. Rangelands. Vol. 24 (2) pp. 21-24.
- **Kirby, D**. R., Krabbenhoft, K. D., Sedivic, K. K., and **DeKeyser, E. S**. 2002. Wetlands in Northern Plains Prairies: offer societal values too. Rangelands. Vol. 24 (2) pp. 25-28.
- **DeKeyser, E.S**., **D.R. Kirby**, and M.J. Ell. 2003. An index of plant community integrity: Development of the methodology for assessing prairie wetland plant communities. Ecological Indicators. Vol. 3(2) pp. 119-133.
- Phillips, R.L., O. Beeri, and **E.S. DeKeyser**. 2005. Remote wetland assessment for Missouri Coteau prairie glacial basins. Wetlands. Vol. 25(2) pp. 335-349.

- **Fawley, M.W., Fawley, K.P**., and Buchheim, M.A. 2004. Molecular diversity among communities of freshwater microchlorophytes. Microbial Ecology 48:489-499
- W. J. Henley, J. L. Hironaka, L. Guillou, M. A. Buchheim, J. A. Buchheim, **M. W. Fawley and K. P. Fawley**. 2004. Phylogenetic analysis of the "Nannochloris-like" algae and diagnoses of Picochlorum oklahomensis gen. et sp. nov. (Trebouxiophyceae, Chlorophyta). Phycologia 43:641-652.
- **M.W. Fawley**, M. L. Dean, S. K. Dimmer, and **K. P. Fawley**. Evaluating the morphospecies concept in the Selenastraceae (Chlorophyceae, Chlorophyta). 2006. Journal of Phycology, in press.

- J. R. Williams, W. L. Harman, M. Magre, **U. Kizil**, J. A. Lindley, **G. Padmanabhan**, and E. Wang. APEX Feedlot Water Quality Simulation, Transactions of American Society of Agricultural and Biological Engineers, Vol. 49(1): 69-73, January 2006

- **U. Kizil, J. A. Lindley, and G. Padmanabhan**. 2006**.** Verification of Nutrient Transport Modelling of a Bison Feedlot, Biosystems Engineering, Vol. 94 (3): 453-460**.**

Conference Papers

- KIZIL U., J.A. LINDLEY. 2005. Development of a GIS Database and Spatial Evaluations for North Dakota Feedlots. 2005 ASAE International Meeting, Tampa, Florida July 17-20, 2005. Paper No. 051073
- KIZIL U., J.A. LINDLEY. 2005. Development of a Software for Feedlot Hydrology/Nutrient Management. 2005 ASAE International Meeting, Tampa, Florida July 17-20, 2005. Paper No. 054086

Presentations

- Fawley, K.P. and Fawley, M.W. 2004. "Diversity and ecology of freshwater Nannochloropsis (Eustigmatophyceae)." Phycological Scociety of America Annual Meeting, Williamsburg, VA, August 2004.
- Fawley, M.W. and Fawley, K.P. 2004. "The challenge of green algal diversity." Phycological Scociety of America Annual Meeting, Williamsburg, VA, August, 2004.
- P. Metzger, K.P. Fawley, M.W. Fawley. 2005. "Lipid composition of some picophytoplanktonic Choricystis species from freshwater lakes. New insight into biomarkers from genetic studies." 22nd International Meeting on Organic Geochemistry (22nd IMOG), Seville, Spain,12-16 September 2005.

THESES AND DISSERTATION

- Hargiss, Christina Louise Melaas, 2005. Evaluation of an Index of Plant Community Integrity for Assessing Wetland Plant Communities in the Prairie Pothole Region, M.S thesis, Department of Animal and Range Sciences; School of Natural Resources Management; College of Agriculture, Food Systems, and Natural Resources; North Dakota State University, Fargo, North Dakota.

PROJECTS

WRRI Graduate Research Fellowship project and the 104(G) project reports follow:

COMPARATIVE STUDY OF FOSSIL AND EXTANT FISH GROWTH: INCLUDING ANALYSES OF MEAN ANNUAL TEMPERATURE IN THE GEOLOGIC RECORD

GRF Project 2003ND25B
Fellow: Michael Newbrey
Adviser: Allan Ashworth
Department of Geosciences
North Dakota State University
Fargo, ND 58105

DESCRIPTION OF THE REGIONAL WATER PROBLEM

It is important to consider the implications of climatic change on surface water resources in light of potential consequences of global warming. North Dakota boasts some of the best long-term data sets in the form of a fossil record to measure the effect of climatic warming on a single population of fish. Very little is known about growth and the life history characteristics of fish in the fossil record. Fossils can provide valuable information about growth of extinct forms of fish, thereby providing insight into their life histories and ecology. A fossil lake bed near Jamestown, ND will provide perhaps thousands of years of continuous data of fish growth during a warming climate. This research will provide insight for fishery biologists and wetland ecologists concerning the long-term response of contemporary fish growth in North Dakota given potential climatic changes.

PROJECT OBJECTIVES

The project entails an examination of the relationships between age, growth, longevity, and climate on a geologic scale. The objectives of this study are to: 1). examine the age and growth patterns of fossil freshwater hiodontids, esocids, and the percid, *Perca flavescens* from all fossil localities known to produce these taxa in North America; and 2). quantify patterns of growth of extant hiodontids, esocids, and the percid, *Perca flavescens* from a range of latitudes and ambient mean annual temperatures (MAT) to understand the effects of MAT on fish growth; 3) contrast the growth patterns from fossil fish to that of extant populations to examine evolutionary patterns.

PROGRESS

In previous research, we have contrasted growth of living forms of pike (*Esox*) to that of fossils. More recently, we have been working with yellow perch (*Perca flavescens*). The research has shown that growth of living and extinct closely related species are similar. By examining the growth patterns of contemporary pike and yellow perch across their ranges, we found that mean annual air temperature describes variation in growth. Furthermore, changes in age and growth of Esociformes and Hiodontiformes since the Cretaceous show trends in time that are correlated with climate change.

Pleistocene fossils can also be used to examine the effects of climate change on fish. We reexamined a well-preserved late Pleistocene to early Holocene fossil fish assemblage from lake deposits on the Missouri Coteau, near Buchanan, North Dakota. Our findings were published in the Canadian Journal of Fisheries and Aquatic Sciences. We reported that fossil fish abundance, stratigraphy, pollen, and charcoal provided information about postglacial colonization and the subsequent population fluctuations during a time of climatic warming. The fossil fish included complete specimens of *Perca flavescens, Hybognathus hankinsoni, Notropis heterolepis, Fundulus diaphanous, and Culaea inconstans*. The sequence of colonization for each species was correlated with individual thermal and relative water velocity tolerances. We found that fish abundance fluctuates six times during an approximate 1000 year depositional history. Charcoal abundance, representing fires, was inferred to represent episodic droughts during which nutrient levels were reduced and fish abundance declined. The fluctuations followed an overall trend to increased abundance during a time when the lake-margin vegetation changed from a spruce to a deciduous forest in response to climatic warming. The research provides insight into the effects of a changing climate on fish populations and demonstrates the potential of using fossils to examine long-term processes regarding contemporary fish species.

SIGNIFICANCE

Ultimately, this research will document the changes in evolution of growth of extinct species during climate change and help to understand how contemporary species respond to climate change.

MODELING GROUNDWATER DENTRIFICATION BY FERROUS IRON USING PHREEQC

GRF Project 2003ND27B
Fellow: Tedros Tesfay
Adviser: Scott Korom
Department of Geology and Geological Engineering
University of North Dakota
Grand Forks, ND 58202

PROBLEM DESCRIPTION

Nitrate is one of the most common groundwater contaminants. Denitrification converts nitrate irreversibly into harmless nitrogen gas. It is a natural process that requires an anaerobic environment, denitrifying bacteria, and sufficient and reactive electron donating species. Numerous researchers show that the availability of electron donors within aquifer sediments limits the denitrification potential of aquifers. The three common electron donors for denitrification are organic carbon, sulfide (usually as pyrite), and ferrous iron. Reduced manganese may also contribute to denitrification, but it has never been shown to be a significant electron donor for denitrification in an aquifer. Our denitrification research team show organic carbon and sulfide are active electron donors for denitrification in North Dakota and Minnesota. We also believe ferrous iron is an active electron donor; however, the geochemical evidence for ferrous iron is more difficult to demonstrate and requires comprehensive knowledge of the hydrogeochemistry of the research sites.

SCOPE AND OBJECTIVES

Denitrification in aquifers involves numerous hydrogeochemical processes with both the water and sediment phases. Theses include dilution, ion exchange, dissolution, precipitation, and oxidation-reduction reactions. Knowledge of the above reactions will enable us to decipher the denitrification capacity of aquifers, particularly when ferrous iron minerals are involved. Therefore, our objective is to use PHREEQC in order to gain a more comprehensive understanding of the hydrogeochemical environment that governs denitrification by ferrous iron and associated aquifer reactions. This research complements the previous works by investigating the role of Fe(II) in the regional aquifer denitrification processes. Geochemical modeling, PHREEQC, is employed to gain insight into the in situ denitrification processes that take place via all major electron donors.

SUMMARY OF RESEARCH RESULTS

A better way to estimate groundwater denitrification reaction is to compute the mass balance of the redox sensitive species. The University of North Dakota (UND) denitrification team installed mesocosms (ISMs) to understand the fate of a contaminant nitrate in the actual field conditions. Many studies, including the works of the UND denitrification team, have shown evidently, using the mass balance method of estimation,

the significant role of sulfides (dominantly pyrite) and organic carbon in the denitrification processes of aquifers. However, the role of Fe(II) has largely been overlooked in the regional studies mainly because of two reasons: 1) the geochemical evidence for ferrous iron is more difficult to decipher due to the precipitation of Fe(III)-oxyhydroxides from the aqueous solution. 2) in the event when denitrification by both Fe(II) and organic carbon gave rise to precipitating reaction products, the role of Fe(II) is deceivably masked by that of the organic carbon. Therefore, two important measures were taken to tackle the problems.

First the abundance of Fe(II) and the minerals that host it were determined using multiple complementary analytical techniques: wet chemical extractions, x-ray diffraction and Mössbauer spectroscopy. The results of these analyses confirmed that the sites, where pyrite and organic carbon did not seem to be dominant, are found to be relatively rich in potential ferrous iron minerals. Then the use of a geochemical modeling resolved the intricacy between the two precipitating denitrification reaction products by figuring out the maximum amount of inorganic carbon that could be produced in the process. First, PHREEQC simulated the amount of inorganic carbon precipitated out from solution indirectly through the co-precipitating Ca 2+ and Mg 2+ that were released into solution by cation exchange reactions. In some of the sites, Ca 2+ and Mg 2+ mmoles/L were also decreased in solution. Therefore, computing the mass balance of Ca 2+ and Mg 2+ provided the maximum fraction of these cations lost from both the solid phase and solution. If all these cations were assumed to be co-precipitated together with the inorganic carbon, which is not likely, it provides the upper limit for the inorganic carbon that can possibly produced in the N-ISMs. By process of elimination the net nitrate lost due to denitrification but not accounted for by reactions with pyrite and organic carbon was attributed to Fe(II) and verified through the forward geochemical modeling.

During the verification work emphasis was given to the modeled and measured cations, anions and pH values. Cations of the Robinson N-ISM matches well (Fig. 1a). As expected Na+, the cation associated with the tracer Br-, shows some deviations. Measured and modeled anions, except some minor deviation in Robinson (Fig. 1b), are in agreement. Recalling the challenge of imitating the natural geochemical environment on one side and practicality of the modeling work on the other side, the above observations are satisfactory.

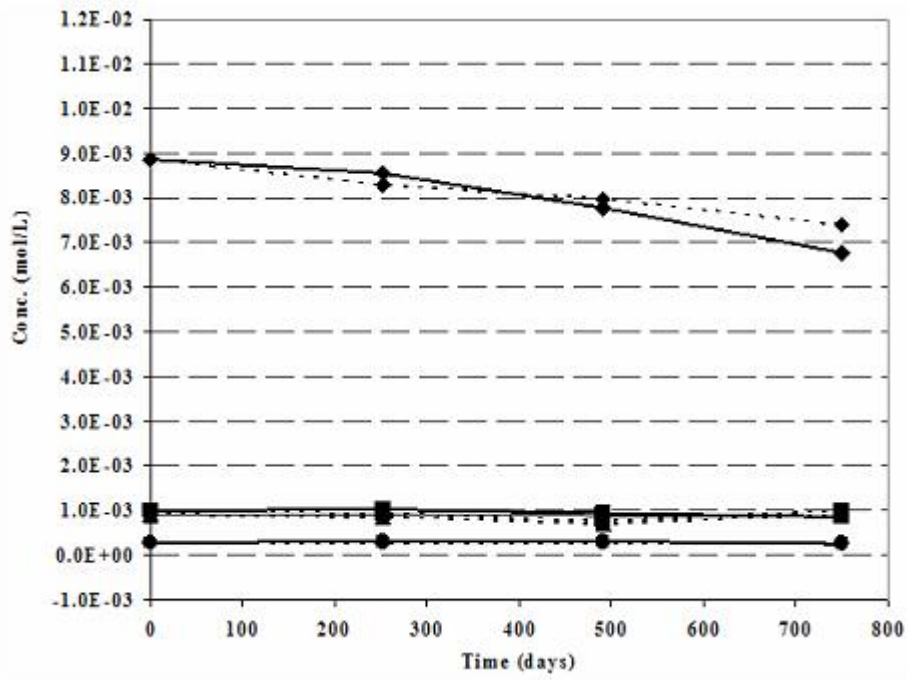

Figure 1a. Robinson (North Dakota) Nitrate mesocosm: Modeled (dashed lines) vs. Measured (solid lines) Cations-N-ISM.

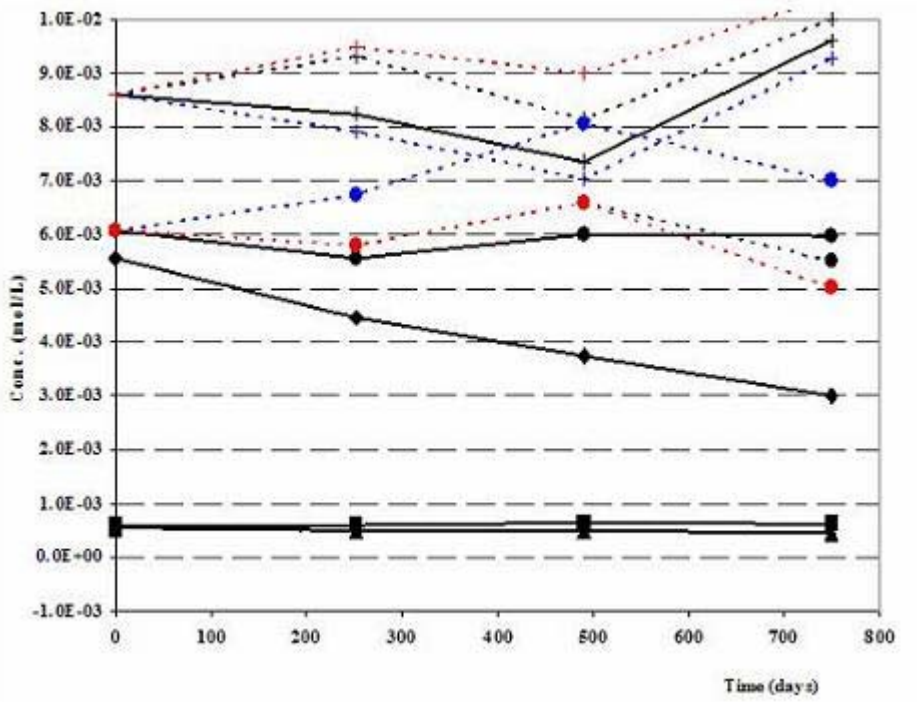

Figure 1b. Robinson (North Dakota) Nitrate mesocosm: Modeled (dashed lines) vs. Measured (solid lines) Anions-N-ISM (colored results for inorganic carbon and pH represent three different scenarios during the forward geochemical modeling: 1. when net nitrate forced to react with Pyrite, CH2O and Fe(II) (black). 2. When net nitrate forced to

react with Pyrite and Fe(II) only (red) 3. When net nitrate forced to react with Pyrite and CH2O only (blue))

Table 1. Relative Roles of the Common Reductants in Aquifer Denitrification Reactions for Akeley (MN), Robinson (ND) and Karlsruhe-S (ND)

Research Site	Electron Donors	OC %	FeS_2 %	Fe(II) %
Akeley (MN)	Range/Average in %	46 – 60/51.2	3.0 – 14/7.47	27 – 50/41.3
Robinson (ND)	Range/Average in %	0.0 – 23/7.81	1.0 - 5.0/2.31	75 – 99/89.9
Karlsruhe-S (ND)	Range/Average in %	23 – 27/25.1	14 – 28/21.4	46 – 63/53.5

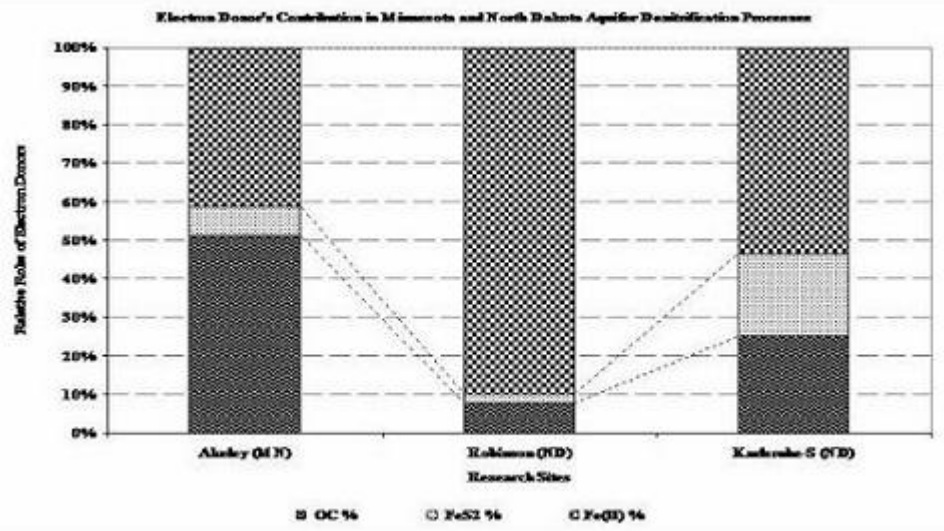

Figure 2. Average Contribution of Each Electron Donor in the Natural Denitrification Reactions of North Dakota and Minnesota Aquifers, as Computed via Advanced Geochemical Modeling, PHREEQC; Employing the Concept of Forward Geochemical Modeling (Akeley (MN), Robinson (ND) and Karlsruhe-S (ND)).

Conclusion

All aqueous analytical data, mineralogy and chemistry of sediments and geochemical modeling works are evidently showing the proportional role of the common electron donors (Fig. 2) and Fe(II)-supported denitrification has a significant role as a natural remediation process (Table 1). Validation of the modeling work by comparing output files with the target solutions of different time steps, chosen previously to verify the work, demonstrate that dilution, CEC and reversible reactions were responsible for the geochemical evolution observed in the C-ISM. Whereas for the nitrate chamber, in addition to dilution, CEC, and reversible reactions, denitrification reaction that involves CH2O, FeS2 and Fe(II) were the major processes that evolved the geochemical environment of the N-ISMs. Moreover, close observation of the hydrochemical data of the ISMs also demonstrate that denitrification rate was higher for those sites with high concentration of electron donors and vice versa.

EFFECTS OF WEST NILE VIRUS INFECTION, IMMUNE FUNCTION, AND AGE ON FEMALE YELLOW-HEADED BLACKBIRD (XANTHOCEPHALUS XANTHOCEPHALUS) REPRODUCTION

GRF Project 2004ND46B
Fellow: Jennifer Newbrey
Adviser: Wendy Reed
Department of Biological Sciences
North Dakota State University
Fargo, ND 58105

DESCRIPTION OF THE CRITICAL WATER PROBLEM

Recent high water levels and canalization of water resources (i.e., Garrison Diversion) in North Dakota have resulted in an increase of aquatic habitats for many wildlife species. Current water conditions correspond with increased numbers of wetland breeding birds and increased habitat for breeding mosquitoes. Because birds often serve as intermediate hosts for mosquito borne diseases, increased populations of birds and mosquitoes could impact the ecology, rate of emergence, and persistence of diseases in humans and wildlife. The recent spread of WNV into the state has produced a need for research to study the influence of the virus on wetland wildlife in North Dakota. The North Dakota Department of Health reported the first cases of WNV in the state in the summer of 2002. The first bird to test positive for WNV was an American crow (*Corvus brachyrhynchos*) found on July 14th , and the first positive human cases were reported on August 28th. There were 19 human cases of WNV and 2 deaths in the state in 2002. In 2003, the virus was much more widespread, with 422 human cases and 4 deaths. This year alone, 788 bird carcasses have been tested in the state and 189 were WNV positive.

Because stagnant water in wetlands is ideal breeding habitat for mosquitoes, wildlife associated with these habitats may suffer high rates of WNV infection. The recent arrival of WNV into the state necessitates a study of the prevalence and immunological impact of WNV on native North Dakota wetland species. Most research on the virus has focused on using carcasses of birds as a surveillance system for detecting the spread of WNV across North America. No published research has been conducted on a living population of free-ranging birds. Failure of biologists to adequately address disease emergence in free-ranging wildlife may lead to diminished geographic distributions and populations declines.

The Missouri Coteau of central North Dakota has many small prairie wetlands, which provide essential foraging and breeding habitat for many species of birds. Yellow-headed blackbirds are an ideal species to study WNV infection because they breed in high-density wetland colonies throughout the Coteau. Establishing rates of WNV infection in yellow-headed blackbirds is necessary to determine the vulnerability of this wetland dwelling species and the influence of WNV infection on reproduction. Information

gathered on WNV for this study can also be used to model and predict potential impacts of the virus on other species of wetland birds.

SCOPE AND OBJECTIVES

The overall objective of this project is to determine the effects of female age and infection with West Nile virus on yellow-headed blackbird (*Xanthocephalus xanthocephalus*) maternal investment into eggs. The specific objectives of this project are to identify the prevalence of WNV in a free-living population of yellow-headed blackbirds, to quantify variation in immune function of female blackbirds, and to measure the relationship between female immune function and age on carotenoid allocation to eggs. These objectives will allow us to evaluate potential relations between wetland bird WNV infection and increased aquatic habitat for breeding mosquitoes in North Dakota.

METHODS

Female yellow-headed blackbirds were captured using nest traps to collect blood for WNV antibody detection and immunity quantification. Blood serum was tested for WNV antibodies using competitive enzyme-linked immunoabsorbent assay (ELISA) specifically designed to detect WNV antibodies in blood serum from avian species. To assess variation in immune function among females, I created blood smears and obtain ratios of immune system cells (heterophils to lymphocytes). Prior to release, each female was banded with a standard Fish and Wildlife Service aluminum band along with a unique color-band combination for individual field identification. I located and monitor nests of each banded female yellow-headed blackbird to determine nest success and nestling performance and how differences in carotenoid levels influences reproduction. Male yellow-headed blackbirds and other members of the Family Icteridae (red-winged blackbirds, common grackles, etc.) were also captured using live funnel traps for WNV antibody detection.

This study was conducted on several wetlands located within a five square mile area of the prairie coteau region of central North Dakota (Stutsman County). Central North Dakota has one of the highest concentrations of breeding yellow-headed blackbirds in North America. In addition, Stutsman County has one of the highest numbers of positive avian West Nile virus cases in central North Dakota.

KEY RESULTS

- In 2003, third-laid eggs were collected from 51 female yellow-headed blackbirds on 7 different wetlands**.** Twenty female yellow-headed blackbirds and blood and feather samples were collected for WNV antibody detection and carotenoid analysis. Also collected were blood samples from 9 male yellow-headed blackbirds, 19 grackles, 2 red-winged blackbirds, and 1 western meadowlark to use for WNV detection. The blood samples were tested for WNV antibodies.

Antibodies were detected in two individuals, one red-winged blackbird and one western meadowlark.

- In 2004, blood samples were collected from 91 yellow-headed blackbirds, 24 common grackles, three house sparrows, two brown-headed cowbirds, and one red-winged blackbird. All of the serum samples were tested for WNV antibodies and five positives were found for WNV antibodies, two female yellow-headed blackbirds, two house sparrows, and one common grackle. Also collected were 25,000 mosquitoes and a subset of the mosquitoes to the species level was identified. *Culex tarsalis,* a species known to transmit the virus in North Dakota, were present in all of my collections, but at low levels (5%). The mosquitoes were tested for WNV RNA using polymerase chain reaction, but all samples were negative for the virus.
- In 2005, eggs, feathers, and blood samples were collected from 69 female yellow-headed blackbirds. Also monitored were nest success of all study nests. Daily growth rates of 133 chicks from 55 nests were measured. In the lab, white blood cell ratios for each female to quantify differences in female immune function were obtained.
- Research is being continued beyond the Fellowship funding period.

SIGNIFICANCE OF RESEARCH

This study will provide essential information on the prevalence of WNV in a North American avian species. Infection with the virus can be lethal; however, the degree to which birds are adversely affected varies among species and even between individuals within a species. By testing for the presence of antibodies to WNV in yellow-headed blackbirds, I will be able to assess the vulnerability and degree of virus exposure in a free-living population of wetland dwelling birds. Many wildlife pathogens cause non-lethal physiological and reproductive effects that remain poorly understood. Because female birds allocate essential resources to eggs, exposure to pathogens can shift maternal resources away from reproduction. This seemingly small, non-lethal effect influences the survival of offspring and can therefore cause population level effects in the next generation.

ANALYSIS AND MODEL SIMULATION OF STORMWATER RUNOFF: A STUDY OF LAND USE AND SYSTEM DESIGN ON DISCHARGE FLOW RATES AND WATER QUALITY

GRF Project 2004ND49B
Fellow: Brajesh Gautam
Advisers: Wei Lin and G. Padmanabhan
Department of Civil Engineering
North Dakota State University
Fargo, ND 58105

DESCRIPTION OF THE CRITICAL WATER PROBLEM

The Red River of the North is an important resource for water supply and recreational purposes. However, the reach of Red River main stem covering Moorhead, MN and Fargo, ND areas has been identified as impaired for swimming designated use (primary contact recreation) under Section 303(d) of the Clean Water Act (CWA). The main causes contributing to impairment are excessive fecal coliform bacteria and high turbidity. High ammonia concentration in the river is another concern. An analysis of Red River quality data shows that urban runoff is a major source of fecal coliform and suspended solids. Fish kill in this reach of Red River occurred after a storm in August 2003. During the period of fish kill, low dissolved oxygen (DO) was observed in the river. Low flow rate in the river and high BOD concentration in the urban runoff were believed to be the reasons for the low DO and subsequent fish kill. The impact of urban runoff on the quality of a water body may vary significantly depending upon its existing water quality and the rates at which pollutants are introduced into the system. So we need to study flow of the runoff and major contaminant concentration. Loads of pollutants from runoff need to be calculated to accurately asses the effect of urban runoff and to propose control measures. The first step in the calculation of load is to estimate runoff. Runoff quantity is governed by the hydrological and physical characteristics of the of the drainage area. Simulation models are now days widely used in estimating stormwater flows in urban areas. More advanced models can simulate pollutants concentration in addition to flow and stages. So to find a broader picture of the affect of urban runoff on the Fargo Moorhead reach of Red River, sampling of the runoff and using this data to simulate a model is proposed.

The proposed research will be incorporated and synchronized with other related works going on with the view of analyzing the urban runoff of Fargo-Moorhead area. There is currently a study going on to estimate the Total Maximum Daily Load (TMDL) for the Fargo-Moorhead reach of the Red River. In this regard samples have been collected by River Keepers, the city of Moorhead and ND Department of Health. A number of samples from different location has been collected and analyzed for fecal coliform analysis and turbidity analysis. The analysis of 2002 data identified that fecal coliform is mainly being discharged from the urban area. The stormwater sampling and initial data show high BOD, fecal coliform and turbidity in storm runoff.

Following conclusions were drawn from that study.

- Fecal coliform impairment was present mainly in the urban section of the river.
- High fecal coliform counts were related with rain events and stormwater runoff from urban areas was identified as the main source of fecal coliform.
- Turbidity impairment was observed in both the urban and rural section of the river. Stormwater runoff might have caused increase of turbidity but the reach was impaired in both dry and wet seasons.

RESEARCH OBJECTIVES

Based on the observation from the summer 2002 sampling results, a study plan was developed. The purpose of the study was to get a better understanding of the broader aspect of urban runoff pollution in addition to aiding the source assessment and linkage analysis elements of the Red River TMDL development project. The approach adopted during the study was a combination of stormwater runoff sampling and computer modeling. The following are the objectives:

- Use water quality samples to determine the concentration of pollutant in storm runoff from different land use dominated areas within Fargo-Moorhead urban area
- Use flow measurement data to develop hydrograph for stormwater runoff
- Calibrate Stormwater Management Model (SWMM) for the Fargo-Moorhead urban runoff
- Calculate the Fecal Coliform and Total Suspended Solids (TSS) loads from Fargo- Moorhead urban areas
- Study the effects of land use and management practices on runoff flow and concentration of fecal coliform and TSS

RESULTS

Initial phase of the study consisted of review of literature pertaining to non-point source pollution, storm water runoff and urban runoff. During the summer of 2004, runoff flow and quality sampling was carried out in different landuse dominated sub drainage areas of cities of Fargo and Moorhead. The sampling results were used to generate flow hydrograph and fecal coliform and TSS pollutograph. The initial results showed a higher concentration of fecal coliform in commercial areas. With subsequent sampling, the effects of other major factors such as antecedent dry days, intensity and duration of the rainfall were also observed. The sampling work provided the base for modeling of the runoff. The sampling results were used to calibrate SWMM model. Matching the total volume was given priority during the hydrograph calibration process. As total load was the primary focus of the analysis, loadograph calibration was suggested instead of pollutograph calibration. The calibrated model was then simulated for calculation of total volume and total load of fecal coliform and TSS from all the Fargo Moorhead drainage areas. In addition, the SWMM model has been used as a tool to analyze the impact of Sanitary Sewer Bypass on the Red River fecal coliform concentration and to calculate the critical conditions for high fecal coliform concentration in the Red River.

BENTHIC MACROINVERTEBRATE STOICHIOMETRIC IMPLICATIONS FOR NORTH DAKOTA AND MINNESOTA FISHERIES

GRF Project 2005ND74B
Fellow: Dan McEwen
Adviser: Malcolm G. Butler
Department of Biological Sciences
North Dakota State University
Fargo, ND 58105

WATER PROBLEM

A primary motivation for managing many aquatic systems is fisheries production and community structure. Economic and recreation pressures prevail for creating and maintaining good fisheries. Millions of dollars have been appropriated by North Dakota for fisheries management. Successful implementation of management programs call for an understanding of the kinds of environmental characteristics that are amenable to the production of desired fish species. While many environmental factors contribute to the structuring of fish communities, the role of food quality in terms of benthic invertebrate stoichiometric constraints is not known but may be significant. The reason that little is known about these potential constraints is that high quality data on benthic invertebrate stoichiometry is not available. We propose to address questions relating benthic invertebrate food quality to fisheries community structuring by determining stoichiometric values for common North Dakota and Minnesota benthic invertebrates at a fine taxonomic resolution. We will explore how the structure of different macrobenthic communities may constrain fish communities or growth rates by relating our data to lake surveys of fishes.

OBJECTIVES AND METHODS

Objectives:

- Address taxonomy, stoichiometry, and benthic-pelagic coupling in the context of benthic constraints on fisheries in North Dakota and Minnesota lakes along a trophic gradient from oligotrophic to eutrophic.
- Stoichiometric analysis of benthic invertebrates, identified at high taxonomic resolution, will be assessed for variability in C, N, and P content, which will then be related to the nutritional needs of various fish species.
- Also address sediment and water composition in stoichiometric terms.

Methods:

- Nonquantitative sampling will be conducted on 4 lakes in North Dakota and 4 lakes in Minnesota, targeting species of Chironomidae, Ephemeridae, and Amphipoda.

- Macrobenthic invertebrate samples will be collected with an Ekman grab and preserved in 95% ethanol or dried for elemental analysis. Preserved benthos will be separated from lake sediments using a sucrose-floatation procedure.
- Organisms will be separated into course scale taxonomic categories using a stereoscope.
- Make head mounts or photographs of pertinent morphological characteristics of individual animals.
- Stoichiometric analyses will be made using mass spectrophotometry and standard methods will be used for phosphorus analysis.
- Stoichiometric relationships will be derived for invertebrate taxa at varying developmental stages to evaluate variation within species.
- These data will be used in bioenergetic and resource competition models to predict likely fish community structure.

RESULTS

Invertebrates were sampled during the summer of 2005 at 4 North Dakota lakes (Metigoshe, Warsing, Crooked, and Danzig) and 4 Minnesota lakes (Rainy, Namakan, Kabetogama, and Christina). Benthos have been sorted, dried, and weighed for stoichiometry analyses, and quantitative samples are being identified to determine community structure. Phosphorus analyses are currently being conducted and samples are being prepared for carbon and nitrogen analysis.

SIGNIFICANCE OF RESEARCH

The results have the potential for advancing our understanding and management of North Dakota's water resources. Many hypotheses related to materials cycling through aquatic communities cannot be tested because of limited knowledge of macroinvertebrate body stoichiometry at fine-scale taxonomic resolution. These data will be collected and published. Should significant stoichiometric relationships between fish and their prey be established, our results could have significant management implications for determining how much effort is put into the management of lakes for particular fish communities For example, stocking or habitat creation in lakes where nutrient regimes are not supportive of particular fish communities could be avoided, and resources could be directed toward more suitable environments.

EVALUATION AND VALIDATION OF AN INDEX OF PLANT COMMUNITY INTEGRITY FOR ASSESSING WETLAND PLANT COMMUNITIES IN THE PRAIRIE POTHOLE REGION

GRF Project 2005ND75B
Fellow: Christina Melaas (Hargiss)
Adviser: Donald Kirby
Department of Animal and Range Sciences
North Dakota State University
Fargo, ND 58105

WATER PROBLEM

Since the implementation of the Clean Water Act in 1972 (Public Law 92-500) there has been increased effort to restore and maintain our nation's wetlands. Legislation since this Act, accompanied with a wide range of land uses within the Prairie Pothole Region (PPR), has resulted in the EPA and other government agencies trying to answer the question of how to assess the health of a wetland. Efforts were made by the Natural Resources Conservation Service (NRCS) and the US Army Corps of Engineers (COE) to answer this question when they created the Hydrogeomorphic (HGM) Model for wetland functional assessment. Another attempt to answer this question was through the creation of the Index of Biological Integrity (IBI) for biological assessment. This was a joint venture of the EPA and several state agencies.

DeKeyser et al. developed an IBI for seasonal wetlands in the PPR that they termed the Index of Plant Community Integrity (IPCI). An IPCI has also been developed to quantitatively assess the condition of temporary and semi-permanent wetlands of the Northwestern Glaciated Plains (NWGP) ecoregion. The NWGP ecoregion is within the mixed grass prairie of North Dakota. Wetland assessment was based on disturbance level and multiple vegetative composition measurements. This classification allows for other temporary, seasonal, and semi-permanent wetlands in the NWGP to be classified and placed into quality classes for mitigation and ecological purposes. However, it is not known whether it is applicable to other ecoregions of the PPR, and whether it is reliable through major climatic disturbances such as droughts. In the current study, the research area was extended to include more of the PPR, specifically the entire NWGP and Northern Glaciated Plains (NGP) of South Dakota, the NGP of North Dakota, and the NWGP of Montana (Omernik 1987). In addition to ecoregion assessment, wetlands were chosen based on the level of disturbance in the wetland and surrounding area, and under a wider range of disturbances including drought. These measurements will help to evaluate the IPCI's effectiveness over a larger geographic area, and over a larger disturbance gradient.

OBJECTIVES

The specific objectives of this study include:

1. Evaluate the IPCI assessment technique over a larger spatial area within the PPR.
2. Evaluate the IPCI assessment method based on a wider variety of disturbances.
3. Validate the metrics, quality classes, and assessment methods used in the IPCI.
4. Determine if/how the HGM Model can be incorporated into the IPCI to evaluate wetland condition.

RESULTS

An evaluation of the Index of Plant Community Integrity (IPCI) was conducted for assessing wetland plant communities in the Prairie Pothole Region. The IPCI evaluates the condition of temporary, seasonal, and semi-permanent wetland plant communities based on disturbance level and multiple community attributes. During 2003 and 2004, vegetative composition was measured for temporary, seasonal, and semi-permanent wetlands located in South Dakota, North Dakota, and Montana concentrated in the Northern Glaciated Plains and Northwestern Glaciated Plains Ecoregions. Wetlands were selected based on classification and type of disturbance ranging from little disturbance (native rangeland) to heavily disturbed (cropland). Wetland data was analyzed using vegetation metrics and further analyzed using nonmetric multidimensional scaling and cluster analyses. All metrics tested were significant in indicating disturbance level in wetlands. Three classes were determined (Good, Fair, and Poor) for temporary and semi-permanent wetlands. Five classes were determined (Very Good, Good, Fair, Poor, and Very Poor) for seasonal wetlands. Based on these classes, score ranges were assigned to the metrics that better defined the ranges designated in the original IPCI. Using the modified IPCI, wetlands in the Northern and Northwestern Glaciated Plains of South Dakota, North Dakota, and Montana can be placed into disturbance classes for ecological purposes and mitigation needs.

Analyses of data showed that the IPCI proved to be an effective tool for evaluating the health of wetland plant communities in the NGP and NWGP of North Dakota, South Dakota, and Montana. Specific metric ranges were changed to better suite a larger data set when compared to the original IPCI. The HGM Model was not able to evaluate wetlands consistently with the IPCI.

SIGNIFICANCE

The IPCI can be used by private landowners, agencies, and land managers for providing baseline data by identifying and assessing wetland plant communities. Also, the IPCI can be used in restoration efforts to monitor change year to year. The IPCI can also be used in reclaimed areas and for mitigation purposes.

MOLECULAR PHYLOGEOGRAPHY OF *ETHEOSTOMA NIGRUM* (RAFINESQUE) IN THE UPPER MIDWEST

GRF Project 2005ND76B
Fellow: Ali Tackett
Adviser: Craig Stockwell
Department of Biological Sciences
North Dakota State University
Fargo, ND 58105

WATER PROBLEM AND OBJECTIVES

The geologic history and abundant potential study sites of the upper Midwest provide a unique opportunity for the assessment of spatial genetic diversity. The Johnny Darter, *Etheostoma nigrum* (Rafinesque), with its large range and abundant populations, is an excellent species to study to answer phylogeographic questions about North Dakota and Minnesota. In this study, the genetic diversity of *E. nigrum* will be examined by using microsatellite PCR primers designed initially for other species of *Etheostoma* and recently optimized for *E. nigrum*. This information will provide not only the inferred gene flow among the darters but will also provide a baseline against which to evaluate gene flow for other fish species located in the same water bodies. For instance, many game fish are stocked and transferred within and among watersheds with no genetic monitoring. By studying a benthic fish with a small home range, it will be possible to uncover the phylogeographic structure among the various watersheds of the upper Midwest. In turn, this information can be used by managers for conserving genetic diversity within and among watersheds.

This project uses molecular markers and their application in conservation ecology and as such the project spans the fields of ecology and genetics. More specifically, microsatellite markers will be used to examine the genetic relationships among Etheostoma nigrum (Johnny Dater) populations in the northern Midwest, specifically North Dakota and Minnesota.

Seining a Minnesota Stream Spring 2005

E. nigrum taken from Lake Ida, MN, Spring 2005

Sampling site on Upper Mississippi River Minnesota, Summer 2005

Sampling Site on Fish Hook River Minnesota, Summer 2005

PROJECT PROGRESS

During the spring, summer and fall of 2005, 408 individuals were captured from the Upper Missouri River, Red River of the North, and Upper Mississippi River watersheds. DNA was extracted from fin clips taken from each fish. This DNA is currently being used to optimize microsatellite makers to examine genetic diversity within and among the

sampled populations. To evaluate genetic structure, we are examineing 9 microsatellite loci using primers developed for congeners of *E. nigrum*. We have been able to consistently amplify eight microsatellites, but one requires further optimization for use with *E. nigrum*. Of the 4 loci most thoroughly examined, herterozygosities ranged from 0.0% to 84.7% with allelic richness between 1 and 28. Within the richest locus, individual populations (k=5, n=59) appear to differ in genetic structure and distribution of alleles.

SIGNIFICANCE OF RESEARCH

The genetic evaluation of E. nigrum populations may have management implications. Most of the fish populations in the upper Midwest have been isolated since the end of the Pleistocene. Managers often transfer and stock game fish from one water body to another with little to no regard for the genetic structure of the systems. This practice is occasionally based upon the idea that gene flow will occur in systems that are hydrologically connected; but in actuality, gene flow is largely influenced by the migratory habits of individual species. Species with small home ranges may have little gene flow between closely located populations. Over time, these populations develop a unique genetic identity, often adapting to local conditions. When fish transfers are planned without consideration of this diversity, populations become genetically homogenous. This results in a loss of genetic variation among populations and perhaps even outbreedig depression. This is especially important if populations are locally adapted. Understanding the current diversity and gene flow of E. nigrum in the watersheds of the upper Midwest will aide in the establishment of management and conservation units as well as help managers plan for the transfer and stocking of fishes. E. nigrum are particularly useful for evaluating phylogeographic structure because they are non-migratory and unlikely to be accidentally transferred due to their use of benthic habitats. The optimization of published primers for use on E. nigrum will provide an excellent opportunity for not only this study but for future molecular work on Johnny Darters throughout their range. This project will provide a baseline with which other species and populations may be compared. Once the genetic relationships among this species are better understood and the diversity is used to help managers and scientists in this area, the information could potentially be used to manage congeners throughout the range of Etheostoma nigrum.

THE IMPACT OF WETLANDS AND WETLAND EASEMENTS ON NORTH DAKOTA LAND VALUES

GRF Project 2005ND78B
Fellow: Kendall Goltz
Adviser: Jay Leitch
Department of Agricultural Economics
North Dakota State University
Fargo, ND 58105

STATE/REGIONAL WATER PROBLEM BEING INVESTIGATED

Wetlands are ubiquitous across the Prairie Pothole region of North and South Dakota and Minnesota and numerous Federal, State, and non-governmental agencies area actively involved in purchasing wetland conservation easements from private landowners. Common examples are the Small Wetland Acquisition Program of the United States Fish and Wildlife Service (USFWS), the Wetlands Reserve Program (WRP), and the Natural Resource Conservation Service (NRCS). To ensure that such programs are effective in encouraging landowners to place wetlands under easement while minimizing the expenditure of public funds, it is necessary that the impact of both wetlands and wetland easements on land values be fully understood.

In a previous study, impacts of Fish and Wildlife Service wetland easements on agricultural land values in North Dakota were estimated by regressing sale prices on physical and institutional characteristics of sold parcels. While easements on temporary wetlands did not influence prices, each additional acre of permanent wetland under easement decreased average prices by $321 (-79%). Because non-eased permanent wetlands were shown to reduce land prices by $161/ac., we can estimate the implicit price of a wetland easement per se to be $160/acre—6% below historical easement payment levels in the study area. Alternative model specifications further demonstrate the importance of separating eased and non-eased wetlands and of accounting for their hydrologic condition.

SCOPE AND OBJECTIVES

In this study, the previous research will be expanded to include the 25 counties of the Prairie Pothole Region of North Dakota. The impact of temporary, seasonal, and semi-permanent wetlands and wetland easements on land values within these counties during the 2000-2004 time period will be quantified. Since there has recently been an increasing trend in the sale of land for outdoor recreation purposes, the impact of wetlands and wetland easements on the sale prices of land parcels sold for hunting/recreation purposes will also be estimated.

RESULTS

4,332 agricultural land sales from the years 2000 to 2004 have been collected from county courthouse public records in all 53 North Dakota counties. 775 of the 4,332 total land sales were found to contain wetland easements. The boundaries of all sales tracts have been digitized into a GIS database by identifying and selecting field boundaries in the common land unit (CLU) database of the NRCS based on the legal descriptions of the database. Land uses (acres of cropland vs. pastureland) have been calculated through spatial overlay of the year 2003 or 2004 NASS CDL coverages. The relative productivity of the sale parcels is represented by spring wheat yields for cropland, and pounds of forage per acre for pastureland. These soil productivity measures were calculated through spatial overlays of tracts and the SSURGO soils database. The type of wetlands found within the sale tracts has been quantified using spatial overlays of the NWI Basin. Conservation easement acres within sale tracts were determined by overlaying USFWS easement boundaries with the sale tract and NWI wetland coverages. The hydrologic (wetness) condition of all wetlands and easements has been determined using spatial overlays of water classifications of the NASS CDL, and visual inspections of overlaid NAIP color aerial photography.

In addition, 210 land purchasers that reside either in one of the larger North Dakota cities or outside the state were identified as potential recreational land buyers. Survey information about the nature of the sale was obtained from 152 of the 210.

SIGNIFICANCE

It is anticipated that a methodology for agricultural land appraisals upon which to base the value of easement to offer a landowner and the ranking of potential wetland sites for restoration, conservation, or acquisition will emerge from this research. It is important to understand the implicit prices of wetlands and wetland easements to landowners so that a better prediction can be made of landowner willingness to restore, conserve, or degrade specific wetlands; and fair market levels of compensation to landowners can be calculated. GIS techniques for specifying sale parcel attributes is expected to improve.

State policy makers will benefit from knowing the impact of out of state buyers of recreational land on land values in North Dakota.

EFFECT OF FLOW PATH PROCESSES ON THE GEOCHEMISTRY AND QUALITY OF WATER DISCHARGED ALONG THE SEEPAGE FACE AT PIGEON POINT, SHEYENNE DELTA AQUIFER, RANSOM COUNTY, ND

GRF Project 2005ND79B
Fellow: William Lenarz
Adviser: Philip Gerla
Department of Geology and Geological Engineering
University of North Dakota
Grand Forks, ND 58202

WATER PROBLEM AND OBJECTIVES

The large seepage face at Pigeon Point, Ransom County, North Dakota, provides an opportunity to trace the evolution of groundwater geochemistry back to its source as infiltrating precipitation. Previous work delineated pathlines and the capture zone in the groundwater flow system, which extends several kilometers upgradient. The contrasting land cover within the spring and seep capture zone consists of dunes, native grass pasture, wetland, and irrigated cropland that lie above the phreatic Sheyenne delta aquifer. Previous work revealed that the seepage face shows a wide variation in mineralization and oxidation-reduction conditions, with strikingly more reduced and mineralized water discharging from higher areas indicating a shorter groundwater pathline. We hypothesize that the groundwater quality relates to vadose and shallow phreatic geochemical processes, which are largely controlled by differences in soils and land cover, and that water composition remains generally unchanged along deeper path lines.

METHODS

1. Install monitoring/sampling equipment along a groundwater pathline and select six springs to sample to represent best the varied water quality found within the discharge zone.
2. Collect samples of water during different seasons (Fall, Spring, and Summer) to determine if groundwater quality and chemical transport vary temporally across the study area.
3. Sample and analyze pH, conductivity, and dissolved oxygen in the field. Analyze major anions, cations, and total and organic carbon content at UND's Environmental Analytical Research Laboratory using flame atomic absorption spectrometry (FAAS), total organic carbon analysis (TOC), and ion chromatography (IC).
4. In conjunction with soil water and groundwater sampling and analysis, work to better understand the physical conditions of infiltration and recharge will be completed during the project. At and near the instrumentation sites, matric potential, moisture content, and soil permeability will be estimated using transducer tensiometers, portable time-domain reflectometry surveys, and a disk infiltrometer.

PROGRESS TO DATE

Installation of the monitoring/sampling stations along the selected groundwater flow pathline has been completed. Further site development was conducted to ensure successful water collection during the first and subsequent sampling events.. During the month of September, soil samples were collected from the three monitoring/sampling sites for further analysis (type of analysis yet to be determined). At the beginning of October, the first water samples were collected and analysis completed. Currently, the FAAS and TOC analysis has been finished. In addition to the fieldwork completed, a literature review of spring/fen/seep hydrogeochemistry and related groundwater/surface water interaction topics is continuing.

RESULTS

Upon initial observations and comparisons of the results from the sample collections, our initial hypothesis is holding true. The springs that are discharging at higher elevations (indicating shorter travel times and pathlines) are producing results indicating a much more reduced environment. The springs that are discharging at lower elevations (indicating longer travel times and longer pathlines) on the other hand are producing results indicating higher levels of oxidation. The common processes would lead to the idea that groundwater traveling over a shorter distance and shorter time span should discharge with a higher level of oxidation, while the groundwater traveling over the longer distance and taking more time should discharge more reduced. As our first two sample collections are indicating, the spring and fens at Pigeon Point are unique in that the groundwater discharging is reversed from what would commonly be expected.

SIGNIFICANCE

Although the variation of geochemical composition of groundwater on a regional basis is generally understood, much less is known about the detailed, local processes that lead to the spatial variation of groundwater chemistry along a flowline. The groundwater flow system at Pigeon Point is well constrained physically, and shows remarkable variation across the seepage face. Results will provide a conceptual model on how groundwater composition evolves within this shallow aquifer flow system. The model will be used to explain the unusual variation of water quality at the seepage face and help predict changes in water quality following alteration of land cover. The groundwater flow system maintains wetlands that host rare and unusual flora found only in boreal region hundreds of kilometers to the northeast. The north-facing slope, shaded by some of the only remaining old-growth riparian forest in North Dakota, creates a unique environment where continuously moist and cool hardwood forest borders an extensive xeric plant community developed in nearby dunes. This valuable natural resource exhibiting an unusually large biodiversity, however, is threatened by the growing demand for fresh water in the region. The Sheyenne delta aquifer constitutes an important source of high quality groundwater in southeast North Dakota and may provide water for Fargo in the future.

ASSESSING THE EFFECTIVENESS OF LOCAL WATER INSTITUTIONS IN WATER MANAGEMENT

GRF Project 2005ND86G (104-G)
PI: Robert Hearne
Department of Agricultural Economics
North Dakota State University
Fargo, ND 58105

Abstract

There are a variety of formal and informal local institutions that are involved with water resources management in rural areas. These governmental and non-governmental institutions have different objectives, different legal statuses, and different affiliations with state and local governments. Research is needed to assess the roles and effectiveness of local water institutions. As new initiatives to improve water quality are being proposed, it is important to assess the capacity of existing institutions to meet new and evolving needs. The objective of this research is to improve local management of water resources by providing policy makers and agencies with an improved understanding of the characteristics of successful local institutions. This research will focus on the Red River of the North basin in Minnesota and North Dakota although some assessment of Manitobas institutions will be included. The basin is fairly homogeneous in terms of land use and geographic features, but features three completely different sets of water law, which makes it an excellent case study of institutions. The overall objective of this research is to strengthen local water management institutions so that they may better meet evolving local and basin wide needs, especially the maintenance of water quality. Specific objectives of the research include: 1) Develop a set of objective and subjective criteria and indicators to evaluate local water management institutions; 2) Provide a review of the different governmental and nongovernmental institutions in the basin, classify their goals, activities and chartered purposes, and identify overlaps and functions that are not being addressed; 3) Identify and evaluate the characteristics of local water institutions that have a demonstrated capability to meet local goals and wider goals of the greater river basin; 4) Assess the use of: scientific and technical information; extension education and training programs; and other support provided by governmental and non-governmental agencies; 5) Analyze institutions and agencies likely behavior in a decision-making situation and further develop decision-making support tools; 6) Identify the characteristics of institutions that successfully evolve to meet new challenges; 7) Analyze preferences of a sample of residents and stakeholders toward watershed management issues and the types of institutions that they trust; and 8) Disseminate results to various forums including local workshops and scientific journals. Objective and subjective criteria and indicators for local water institutions will be refined for local circumstances by interviewing and surveying assorted State and Federal agencies who work on water management issues. A survey of local water institutions will be used to: identify goals, activities, and accomplishments; assess their understanding and use of technical information and extension training; and provide an understanding of how these institutions have evolved to meet changing needs. This survey will be supported by another survey of local leaders, county commissioners, and mayors. The Legal-Institutional Analysis Model will be used to assess negotiation strategies. And choice experiments, a stated preference technique that can estimate the non-market value for environmental goods and services, will be used to analyze residents and leaders preferences towards water management programs and institutional frameworks.

The Problem

A variety of formal and informal local institutions are involved with water resources management in rural areas. These include governmental institutions such as county water resources boards, watershed districts, soil and water conservation districts, and nongovernmental environmental and recreational interest groups. These institutions have different objectives, legal status, and affiliations with state and local governments. Many were established to meet priority needs of previous decades, and may or may not have evolved to meet current priority needs. The scope of their efforts and expertise may to too restricted to effectively plan and implement initiatives to deal with current and future challenges. These institutions may serve to incorporate rural areas into the larger basin wide initiatives to improve water quality, flood control, recreation, ecological services, and water supply security. They may effectively collaborate with neighboring and regional organizations to form successful partnerships. The importance of these rural watershed management institutions in water quality protection has increased in the last few years due to: 1) public participation in the process of establishing Total Maximum Daily Loads (TMDLs) for criteria pollutants in impaired waters; 2) the introduction of point source nonpoint source trading in pollution reduction credits for surface water, and 3) with new court rulings that have designated agricultural drainage ditches as point sources, and thus subject to a stricter enforcement standards.

Research is needed to assess the roles and effectiveness of local water institutions. As new initiatives to monitor and maintain water quality and reduce non-point source pollution are proposed, it is important to assess the capacity of existing institutions to meet new and evolving needs. The objective of this research is to improve local management of water resources by providing policy makers and agencies at the federal, state, and local level, including the water institutions themselves, with an improved understanding of the characteristics of successful local institutions and successful collaborations. This research will also identify the types of institutions that are able to accept increased responsibilities, such as contributing to the USGS' water quantity and quality monitoring system. The research will contribute to a better understanding of the processes of public participation in natural resource management by identifying the types of institutions that are truly representative of local constituencies, well-funded, and have low institutional costs. The potential for collaboration among these assorted institutions will be enhanced by the identification of likely allies among assorted institutional actors. Often these institutions were formed to meet local needs, such as landowners' needs to implement effective drainage systems, a community's need to protect it's own drinking water sources, and a rural area's need to develop its own flood mitigation strategies. These institutions should also serve to incorporate rural areas into the larger basin wide initiatives aimed at improving water quality, flood control, recreation, ecological services, and water supply security. Water quality impairments and flood events flow downstream to often more populated areas, therefore water and watershed management in upstream rural areas is crucial to the entire basin. Local initiatives to protect water quality and reduce flood and drought risk should be incorporated into broader initiatives to manage large river basins. Since state and federal institutions do not have the capacity to monitor water quantity and quality in all upstream areas, these efforts would be greatly facilitated with local cooperation.

The importance of rural watershed management institutions in water quality protection has increased in the last few years due to the goal of increasing public participation within the process of establishing TMDLs and introduction of point source-nonpoint source trading in pollution reduction credits for surface water (Fang and Easter, 2003; Taff and Senjem, 1996; Randall and Taylor, 2000; Taylor et al., 2003). These emerging markets allow point sources which are required to reduce emissions to purchase emissions reductions and contract for emissions reducing management practices from nonpoint sources. Savings occur when the unit cost of pollution reduction in the contracted nonpoint sources are less than the unit cost of abatement from the point sources. These savings are often possible with biochemical oxygen demand and organic pollutants. Rural watershed districts can facilitate these arrangements when they act as an intermediary between point and nonpoint sources (Taff and Senjem, 1996) or when they facilitate enforcement (Taylor et al, 2003). The US EPA's 2003 Water Quality Trading Policy promotes point-nonpoint trading within a watershed with approved TMDLs, especially in cases where water quality is impaired with excess nutrients or sediment. The EPA predicts that water quality trading will significantly reduce total Clean Water Act compliance costs. This policy does not specify trading rules and regulations, but does establish the goal of promoting cost-effective pollution reduction through trading.

The Red River of the North Basin is particularly well suited to research on water management issues. The basin is relatively small with 30,000 square miles in Minnesota, North Dakota, and South Dakota and another 15,000 square miles in Manitoba (excluding the large Assiniboine Basin which flows into the Red River south of Lake Winnipeg). The neighboring Devil's Lake basin which has a natural outflow to the Red River has another 3800 square miles. The population in the US sector of the basin was approximately 497,000 in 2000 with 40% in the Fargo/Moorhead and Grand Forks/East Grand Forks urban areas (Fritz, 2003; Stoner et al., 1998). One key feature of water management in the Red River Basin is the presence of three completely different sets of water appropriation law. Minnesota's water law is based upon riparian rights. North Dakota's water law is based upon prior appropriation. Manitoba has a system of water allocation that features provincial control. Because the basin is fairly homogeneous in terms of land use and geographic features, its existing institutional diversity make this an excellent case study for the analysis of local water institutions. Another feature is its multinational and multijurisdictional nature with the potential for international conflict. A series of overlapping local institutions, supported by different governmental partners, can be identified. These include:

1. *Soil and Water Conservation Districts* in Minnesota and *Soil Conservations Districts* in North Dakota are governmental subdivisions of the state, which generally coincide with county boundaries. They implement soil conservation projects, such as tree planting, and conduct planning and education activities. They are supported by the US Department of Agriculture's (USDA) Natural Resource Conservation Service (NRCS) and may with the consent of the counties make special assessments. In Minnesota, these Districts assist in the development of the county water management plan.

2. *Resource Conservation and Development Councils* in North Dakota and Minnesota are voluntary councils supported by a full-time NRCS coordinator. They are public/private partnerships designed to promote community and economic development and sustainable use of natural resources.

3. *Watershed Districts* in Minnesota are special purpose units of local government designed to conserve natural resources through land use planning, flood control, and other conservation projects. They have the power to tax, acquire property, construct and operate infrastructure, and adopt rules with the power of law. These Watershed Districts are guided by a county-appointed Board of Managers and assisted by volunteer Citizen Advisory Committees.

4. *Water Resource Districts* in North Dakota are units of local government that ideally emphasize hydrological boundaries, but in practice follow county boundaries. These Districts are governed by Water Resource Boards that are appointed by County Commissioners. These Boards have the authority to develop and operate water infrastructure, borrow funds and finance projects through special assessments, invoke the power of eminent domain, and regulate sewage discharges. Although local resource boards are generally drawn along county lines, North Dakota law does allow for multijurisdictional Joint Water Resource Boards to be formed through joint powers agreements. Some of these have been formed along watershed lines and provide planning and programs for watershed areas.

5. *Conservation Districts* in Manitoba are corporate bodies that can levy taxes and are designed to deal with all natural resources. Provincial water policy encourages input from local authorities, interest groups, and individuals into planning. Local authorities are encouraged to use land-use planning to support water quality, drainage, and conservation goals.

6. *Tribal Department of Natural Resources* of the White Earth Band of the Ojibwe and the Red Lake Band of the Chippewa have Departments of Natural Resources which are responsible for water quality and fisheries maintenance. Both of the reservations are located in the Minnesota side of the Red River Basin. The Spirit Lake Dakotah Nation, located in North Dakota, has a Environmental Protection office with water quality staff. These agencies are dedicated to fisheries, surface and groundwater quality, and planning.

In addition, there are a number of local nongovernmental environmental groups such as People to Save Sheyenne and River Keepers. Broader based environmental groups such as Ducks Unlimited, the Audubon Society, The Nature Conservancy, The Sierra Club, Manitoba Naturalists Society, the Rivers Council of Minnesota, and The Izaak Walton League all have initiatives in the Red River Basin. There are a number of basin institutions such as The Red River Basin Commission, Basinwide, River Watch, Red River Basin Decision Information Network, and The Red River Basin Institute. The International Joint Commission (IJC) is the international institution that overseas US Canadian international waters. Because there are so many organizations, with limited

geographical and functional scope and often without legal authority or political will, the effort directed at water management might not produce the desired results.
The effectiveness of local institutions in supporting both local and regional water management needs is a function of a variety of institutional attributes including: 1) legal status and affiliation with local governments; 2) affiliation with larger basin management initiatives; 3) primary purpose, such as water quality protection, flood control, environmental management, erosion control, and potable water maintenance; 4) financial support; 5) physical environment; 6) the institutional rules which these local entities employ; 7) the degree to which they have been politicized; 8) technical capacity of board members and staff to achieve consensus, conduct or commission needed analysis, and understand pertinent information; and 9) the influence and initiative of individual members and managers. These factors, and others, need to be assessed in order to improve institutional rules and capacity building programs.

Benefits of the Research

By identifying the attributes of local institutions that effectively achieve their own goals and/or further goals of water quality maintenance, this research will:1) ascertain whether existing institutional frameworks should be adapted to meet evolving needs or new institutions should be developed to address emerging issues such as water quality monitoring and enforcement; 2) support local institutions by identifying key characteristics that facilitate effectiveness; 3) assess the benefits and costs associated with having water resource institutions defined along county lines as opposed to watershed lines; 4) support the development of extension and education programs that strengthen local institutions by specifically addressing key characteristics of effectiveness; and 5) help policy makers in the design strategies to monitor and enforce nonpoint source pollution abatement initiatives. Based upon this research and subsequent reviews and comments, recommendations will be made to political leaders and lawmakers, agency officials, and local stakeholders.

This project will collaborate with the North Dakota State University's (NDSU) M.S. programs in Agribusiness and Applied Economics, and Natural Resources Management and is expected to support at least two M.S. students. It should produce at least two M.S. theses, a number of extension reports, at least two peer-reviewed scientific journal articles, and at least one workshop to present results to regional and local water management leaders.

Planned First-Year Goals

During the first year period of September 2005 – August 2006 planned goals were to
1) Develop a set of objective and subjective criteria and indicators to evaluate the effectiveness of local water management institutions;

2) Review the different governmental and nongovernmental institutions in the basin, classify their current goals and activities as well as their chartered purposes, and identify overlaps as well as functions that are not being addressed;
3) Identify and evaluate the characteristics of local water institutions that have a demonstrated capability to meet local goals and wider goals of the greater river basin, including water quality monitoring and participation in the establishing TMDLs.

Progress Towards Goals

A review of water management organizations and institutions has been conducted. A population of watershed and water districts and conservation districts has been identified. Current activities are focused on developing a set of criteria and indicators for effective public water management organizations. These criteria and indicators will be used to develop a survey instrument by August 2006. Surveys of organization managers, local informed stakeholders, and board members will be conducted in August of 2006. A preliminary draft of the survey instrument has been developed.

Craig Kritsky an MS student in NDSU's Agribusiness and Applied Economics program has been recruited and funded. He has finished required coursework and drafted the initial chapters of his thesis.