North Dakota Water Resources Research Institute

Annual Technical Report

FY 1999

Introduction

This report deals with the activities of the North Dakota Water Resources Research Institute (ND WRRI) during the period March 1999 to February 2000. The ND WRRI is one of 54 entities known collectively as the National Institutes for Water Resources. The Institutes were established by Congress (Water Resources Research Acts of 1964, 1972, 1984 and 1990) at the Land Grant University in each state, the District of Columbia, the Virgin Islands, Puerto Rico, and Guam/Federated States of Micronesia, and are administered by the United States Geological Survey. Each Institute conducts research, education, and information transfer on water resources. The bulk of the Institute's resources are allocated to the research and education functions through the mechanism of Graduate Research Fellowships. Information transfer is done through an annual newsletter initiated in 1992, a website initiated in 1999, and presentations and publications by grant and fellowship recipients. The ND WRRI has its offices at North Dakota's land grant institution, North Dakota State University (NDSU). The current director is also the Chair of the Department of Chemistry, and the Institute's administrative office is housed in that Department. Graduate Students are supported by Federal 104b funds at both NDSU and the state's other research university, the University of North Dakota (UND). During FY 2000, the Institute operated with a Federal allotment of $68,178 administered through the United States Geological Survey, plus co-funding from the two universities and other water resources agencies in the region. Graduate Research Fellowship Program For the past five years, the bulk of the Institute's modest Federal funds have been used to support research by a small grants program developed in consultation with the State Advisory Committee and the faculty of both universities. Competitive Graduate Research Fellowships (GRFs) are provided directly to water resources research graduate students. More discussion of this fellowship mechanism is given later under ND99-01. Regional, State and Local Collaborations In five of the seven GRF projects reported below, Federal and State agencies and a local watershed board provided co-funding, in-kind services such as water analyses, or actual collaboration in the research. ·North Dakota Department of Health, and USGS Northern Prairie Wildlife Research Center: DeKeyser/Kirby, A Vegetative Classification of Seasonal and Temporary Wetlands Across a Disturbance Gradient Using A Multimetric Approach. ·ND Department of Health: Jaskowiak/Fawley, Sheyenne River Periphyton Study. ·Pelican River (MN) Watershed District: Nustad/Lin, Determination of the Factors Causing Elevated Phosphorus Levels in a Natural Wetland and Methods for Remediation. ·ND Department of Health, and ND Water Commission: Skubinna/Korom, Modeling the Hydrogeochemistry of Denitrification in In-Situ Microcosms in the Elk Valley Aquifer. ·Minnesota Department of Natural Resources: Zimmer/Butler, Effects of Fathead Minnows on Wetlands Ecosystems Information Transfer The Institute has a newsletter which is issued in December of each year. Copies of past newsletters can be obtained by writing to the Director. A website was added during FY 2000. The address is www.nodak.edu/wrri. The institute continued its modest support of the Biotic Resources Seminar Series at North Dakota State University. State Advisory Committee The State Advisory Committee has participated in the periodic formulation of water resources research priorities for the Institute and state of North Dakota, and in the evaluation of research proposals and projects. The committee membership is as follows. Gregg Wiche, District Chief, U.S. Geological Survey, Water Resources Division, Bismarck, North Dakota Milton Lindvig, Director, Water Appropriation Division, ND State Water Commission,Bismarck, North Dakota Francis J. Schwindt, Chief, Environmental Health Section, ND State Health Department, Bismarck, North Dakota These members are senior

officials in the three entities in North Dakota responsible for much of the water resources research done outside of NDSU and UND. Program Management Dr. Gregory J. McCarthy, Distinguished Professor and Chair of the NDSU Department of Chemistry, continues as Institute Director. Various support personnel of the Department assist with Institute functions on a part-time basis. The offices of the Institute are located in Ladd Hall on the North Dakota State University campus. The director may be reached at ND Water Resources Research Institute, 104 Ladd Hall, North Dakota State University, Fargo, ND 58105-5516; phone: (701) 231-7193, fax: (701) 231-8831; Internet: gmccarth@prairie.nodak.edu

Research Program

Basic Project Information

Basic Project Information	
Category	**Data**
Title	Graduate Research Fellowships
Project Number	ND99 - 01
Start Date	03/01/1999
End Date	02/29/2000
Research Category	Not Applicable
Focus Category #1	Water Quality
Focus Category #2	Wetlands
Focus Category #3	Ecology
Lead Institution	North Dakota State University

Principal Investigators

Problem and Research Objectives

One objective of the Section 104b Program is to ensure the future availability of water resources research professionals. Graduate education/training is currently the major activity of the ND WRRI through a competitive Graduate Research Fellowships (GRF) awarded to students in a degree program on a topic directly related to water resources. The research advisor is responsible for support of his/her own time on the project and for operating funds. For faculty with established and externally funded research programs, this fellowship allows the advisor to add another graduate student to the research group. With more junior faculty, NDSU and UND administrative offices provide faculty summer salary, and/or small matching grants to the advisor or student to cover operating costs. During FY 2000, the direct support of graduate student research through the GRF program accounted for 83% of the expenditures of funds provided by the Federal 104b allotment. Applications were solicited from both the University of North Dakota and North Dakota State University. Those applications were reviewed by State and Federal government water resources professionals. A panel consisting of the Institute Director, and the three members of the State Advisory Committee, selected the fellows. For FY 1999, all applications were judged to be strong, and sufficient funds were available to fund each of the student applicants. The Request for Applications and selection of fellows for the FY 2001 program were done during this fiscal year. Applications for renewal of existing fellowships were approved, and of two new fellowship applications, one was approved.

Methodology

The North Dakota Water Resources Research Institute expends the bulk of its Federal 104b allotment, and its matching funds for the host universities, local, state and regional entities, on research of graduate students through its Graduate Research Fellowship Program. In five of the seven fellowship projects, Federal and State agencies, and a local watershed board, are providing co-funding or in-kind services such as water analyses: · Moorhead Water Treatment Plant: Hurley/Lin, An Investigation of Ozone Consumption Rates and By-Product Formation at the Moorhead Water Treatment Plant · ND Department of Health: Jaskowiak/Fawley, Sheyenne River Periphyton Study. · Pelican River (MN) Watershed District: Nustad/Lin, Determination of the Factors Causing Elevated Phosphorus Levels in a Natural Wetland and Methods for Remediation. · ND Department of Health and ND State Water Commission: Skubinna/Korom, Modeling the Hydrogeochemistry of Denitrification in In-Situ Microcosms in the Elk Valley Aquifer. · Minnesota Department of Natural Resources: Zimmer/Butler, Effects of Fathead Minnows on Wetlands Ecosystems Summaries of the research objectives and progress from each of the FY 1999 fellows follow. Periodic updates of research progress are made to the web page of each GRF. See the Institute's website at www.nodak.edu/wrri and select the 1999 or 2000 Fellows link.

Principal Findings and Significance

Solid-Liquid Extraction and Room-Temperature Phosphorimetry of Polychlorinated Biphenyls and Polychlorinated Dibenzofurans in Water Samples Fellow: Andrea F. Arruda, Department of Chemistry, NDSU Advisor: Andres D. Campiglia, Assistant Professor of Chemistry, NDSU Matching Support: NDSU central administration Degree Progress: Ph.D. completion expected by August 2001. The primary objective of this project was to provide rapid, simple and cost effective analytical approaches for the determination of organic pollutants in water sources. Our efforts were concentrated on polychlorinated biphenyls (PCB) and polychlorinated dibenzofurans (PCDF). The developed methodology is based on solid-liquid extraction (SLE) and room temperature phosphorimetry (RTP). Several optimization studies were performed to enhance maximum PCB and PCDF phosphorescence emission on the extraction membrane. These included judicious selection of extraction membranes, phosphorescence enhancers and their optimum concentrations, and substrate-drying conditions to avoid water and oxygen quenching of phosphorescence emission. The oven-drying step - often necessary to remove trapped water from the extraction membrane and improve analyte recovery in chromatographic analysis - was substituted by air sample drying. Syringe and stainless steel filter holders substituted the vacuum pump commonly used in SLE to process the sample. By processing 100mL of water through the extraction membrane, limits of detection at the parts-per-trillion level (10-12g.mL-1) were obtained for PCB and PCDF. Linear dynamic ranges varied from three to four orders of magnitude. Relative standard deviations were between 5 and 10%. The potential interference of several organic pollutants commonly encountered in water samples was evaluated. Synthetic mixtures containing polycyclic aromatic hydrocarbons (PAH), humic and fulvic acids, pesticides and chlorinated organic compounds were used to mimic the composition of heavily contaminated "real-world" water samples. Red River water samples (collected at several locations within the Fargo-Moorhead area) were spiked with PCB and PCDF mixtures and analyzed by SLE-RTP. No matrix interference was observed. In summary, we have developed a simple, rapid, and cost effective analytical procedure to determine total PCB and total PCDF content in water samples. Analysis time (water extraction and phosphorimetric detection) takes less than 10min per sample, which is important for screening numerous samples. A Vegetative Classification of Seasonal and Temporary Wetlands Across a Disturbance Gradient Using A Multimetric Approach Fellow: Edward S. DeKeyser, Department of Animal and Range Sciences, NDSU Advisor:

Don Kirby, Professor of Animal and Range Sciences, NDSU Matching Support: North Dakota State Department of Health, Bismarck; USGS Northern Prairie Wildlife Research Center, Jamestown, ND Degree Progress: Ph.D. completion expected by August 2000. An Index of Biological Integrity (IBI) was developed for quantitatively assessing the quality of seasonal and temporary wetlands. Between 1998 and 1999, vegetative composition was measured from 46 seasonal and 27 temporary wetlands mainly concentrated on the Missouri Coteau Vegetation Zone of central North Dakota. Wetlands were selected based on a range of disturbance from no disturbance (idle native prairie) to heavily disturbed (cropped). Vegetative data was delineated into metrics or characteristics of the data set (species richness, percentage of introduced and annual plants, etc.) and analyzed using principal components and cluster analyses. Five disturbance or quality classes, very good, good, fair, poor, and very poor, were determined. Based on these classes, ranges and scores were then assigned for each metric. By using this classification system, additional seasonal and temporary wetlands can now be assessed and placed in quality classes for mitigation or ecological purposes. An Assessment of the Periphyton Communities in the Sheyenne River, ND Fellow: Megan A. Jaskowiak, Department of Botany, NDSU Advisor: Marvin W. Fawley, Professor of Biology, NDSU Matching Support: North Dakota State Department of Health, Bismarck; NDSU central administration Degree Progress: Ph.D. completion anticipated in 2002. This research began as part of the environmental impact statement for the Army Corps of Engineers Devils Lake outlet project. In the first part of this study, periphytic algae was collected using artificial substrates at several sites along the Sheyenne River. The major goal of this study was to relate the periphyton communities to environmental factors that have the potential to be affected by a Devils Lake outlet. The relative abundance data for periphytic algae and environmental data were used for this assessment. This analysis was completed using canonical correspondence analysis (CCA). The environmental parameters which explained the most variance in the periphyton communities were pH, orthophosphate, hardness, arsenic, sulfate and nitrate+nitrite. For example, the diatoms Cymbella muellerii and Nitzschia sp. were primarily found at sites with low sulfate concentrations. Two other diatom species (Epithemia sorex, E. adnata) were only found at sites with low hardness. In contrast, the diatom, Nitzschia vermicularis was positively correlated with high hardness at downstream sites. Previous studies have indicated that levels of sulfate and harness will increase with the influx of Devils Lake water. Based on this study, these changes would likely impact the periphyton communities in the Sheyenne River. Additional research to be completed this year includes a comparison of natural substrates and artificial substrates and a comparison of the use of presence/absence data versus relative abundance data in CCA. Periphyton from natural substrates collected in the 1999 sampling season will be identified and enumerated. These new data will be compared with the artificial substrate data. This comparison will determine if the artificial substrate communities are a good representation of the natural periphytic communities. In addition, the artificial substrate samples will be examined using presence/absence data rather than relative abundance data. These presence/absence data will be compared to the previously collected relative abundance data. This comparison will provide evidence for the potential use of presence/absence data in periphyton studies. Determination of the Factors Causing Elevated Phosphorus Levels in a Natural Wetland and Methods for Remediation Fellow: Rochelle A. Nustad, Environmental Engineering Program, Department of Civil Engineering, NDSU Advisor: Wei Lin, Assistant Professor of Civil Engineering, NDSU Matching Support: Pelican River (MN) Watershed District; NDSU central administration; Detroit Lakes Water Treatment Plant Degree Progress: M.S. expected in August 2000 Natural peat wetlands in the area of Detroit Lakes, MN appear to be releasing phosphorus to nearby Ditch 14. Ditch 14 water eventually enters Lake Sallie, an important recreational lake. Elevated phosphorus levels in Lake Sallie have led to algal blooms. The objectives of this research are to: 1. study the transport and transformation mechanisms of phosphorus in a wetland environment; 2. determine the factors that cause the elevated phosphorus levels in the ditch; and 3. determine the feasibility of aeration within the ditch as a method to decrease phosphorus at the outlet of the ditch. In the summer of 1999 nine sampling wells were placed at three locations at three different depths in the Ditch 14 wetland complex. Over the course of the summer, the wells and

surface water at each site were sampled weekly. Oxidation-reduction potential (ORP), pH, dissolved oxygen (DO), and temperature were measured on site. Well and surface water samples were brought to the Detroit Lakes Water Treatment Plant Laboratory and the NDSU Environmental Engineering Laboratory for total phosphorus, orthophosphate, chemical oxygen demand (COD), calcium, aluminum, and iron analyses. Results of field sampling showed that phosphorus concentrations are inversely related to ORP. Low ORP measurements for pore water samples indicate anaerobic conditions in the wetland. Phosphorus concentrations varied with depth and at different locations throughout the wetland. These variations are thought to be related to location, water depth, and vegetation. Seasonal variations of phosphorus concentrations were also observed. Pore water pH was typically found to be lower than surface water pH. The average pH range of the wetland pore water was determined to be 6.4 to 6.7. In this pH range metal phosphates usually have higher solubility. Batch reactor tests using Ditch 14 water were carried in the Fall of 1999 and the Spring of 2000 at the NDSU Environmental Engineering Laboratory to determine the effectiveness of aeration on phosphorus removal through precipitation. During both periods that the batch tests were performed DO was high indicating oxidizing conditions in the ditch. No significant phosphorus reduction was observed during the batch tests. It is possible that aeration would be effective during summer months when periods of reducing conditions occur. Modeling the Hydrogeochemistry of Denitrification in In-Situ Microcosms in the Elk Valley Aquifer Fellow: Paul A. Skubinna, Department of Geology and Geological Engineering, UND Advisor: Scott F. Korom, Assistant Professor of Geology and Geological Engineering, UND Matching Support: North Dakota Department of Health, Bismarck; North Dakota State Water Commission, Bismarck Degree Progress: M.S. completion anticipated in December 2000. Nitrate is one of the most common groundwater contaminants observed in aquifers. In areas where agricultural activity is prominent, nitrate from fertilization may infiltrate and contaminate aquifers like the Elk Valley Aquifer (EVA) in eastern North Dakota. The objective of this study is to gain a better understanding of the geochemical processes associated with the denitrification observed in the EVA. The research is being concentrated on reaction paths, products, denitrification capacities, and prediction of potential undesirable secondary products associated with the denitrification. The methodology of this study has been to replicate the experiment done by Schlag and Korom using in-situ microcosms (ISMs) located near Larimore, ND, and to add geochemical modeling. This approach incorporates fieldwork, analytical lab work, and computer modeling. The fieldwork has consisted of amending groundwater contained within the ISMs with potassium nitrate and potassium bromide on October 8, 1998, followed by monthly sampling of the amended water using the protocol outlined by Standard Methods. Analysis of the samples is performed in the UND Water Quality Lab using the Total Organic Carbon Analyzer and the Ion Chromatograph, for concentrations of carbon species and anions, respectively. The North Dakota State Health Department performs additional analysis on each sample for general anions and cations. Since October 8, 1998 the ISMs have been sampled fourteen times on a monthly schedule. Sample analysis has shown a decrease of approximately 5-10 ppm NO3-– N per month. As of February 19, 2000 nitrate-nitrogen concentration in the R-ISM has been totally degraded to an effective concentration of 0 ppm. The initial nitrate value was approximately 105mg/L. Bromide concentration in the R-ISM remains approximately 45 mg/L. In the ISM spike with KBr only (referred to as the C-ISM), the Br- concentration, which began the study at approximately 720mg/L, is approximately 600mg/L. This observation indicates that the Br- has effectively served its purpose as a relatively conservative tracer. Sulfate concentrations in the R-ISM have increased to seven times the initial concentration, while the sulfate concentration in the C-ISM has remained constant. Comparatively, bicarbonate concentrations have shown little fluctuation in either the C-ISM or the R-ISM. This suggests that denitrification by sulfide minerals is energetically favored over denitrification by organic carbon in this groundwater system. PHREEQ, an ion-association aqueous geochemical computer modeling program developed by the United States Geologic Survey, is being employed to model the water quality data observed in the ISMs. The research has moved into the modeling stage. It is expected that the analysis of the water quality data using PHREEQ will result in a

better understanding of the synthesis of geochemical processes associated with the denitrification observed in the EVA. An Analysis of Mercury in Mallards from Kellys Slough National Wildlife Refuge in Grand Forks County, North Dakota Fellow: Melani L. Tescher, Department of Biology, UND Advisor: Sally Pyle, Assistant Professor of Biology, UND Matching Support: UND central administration Degree Progress: M.S. August 2000 Although, methylmercury contributes only a small fraction to the total mercury pool in aquatic ecosystems, it is an increasingly common pollutant around the world. It is believed that contaminants like methylmercury are responsible for declines many avian populations through the reduction in habitat, food quality and quantity, reproductive impairment and low nesting success. Kellys Slough is a National Wildlife Refuge with a main purpose of waterfowl production and therefore makes a prime test system because it surrounded by land that has been cultivated for generations. The purpose of this study was to examine methylmercury bioaccumulation in waterfowl raised on Kellys Slough National Wildlife Refuge in Grand Forks County, North Dakota. To better understand the dynamics of bioaccumulation, baseline total mercury concentrations were assessed in the sediments. Environmental variables such as pH, dissolved oxygen, microorganisms and sediment clay content was also assessed. These variables aid or hinder the transformation of mercury to methylmercury. The food sources for the ducklings (macroinvertebrates and vegetation) for the young mallards were also studied. Sediment analysis showed total mercury concentration ranged from 24.70 ng/g-86.50 ng/g with a mean concentration of 42.12 ng/g ± SD 25.44. These levels are below the EPA standard (0.1-0.2 mg/g) for freshwater systems. Vegetation and macroinvertebrates were analyzed for total mercury content. The levels ranged form 4.94 ng/g to 86.50 ng/g (x = 45.65 ± 20.034s) in the vegetation and 4.16 ng/g-10.50 ng/g (x = 7.59 ± 2.702) for the invertebrates. Liver tissue was analyzed for inorganic and methylmercury. The reason behind the dual analysis was to determine the amount of inorganic mercury crossing the gut and the body. Due to the assumption that inorganic mercury does not cross the gut, the muscle tissue was analyzed only for methylmercury. Levels for each tissue showed ranged form 88.90 ng/g to 238.0 ng/g methylmercury (x = 138.79 ng/g ± 40.573) and 10.00 ng/g to 24.91ng/g inorganic mercury (x = 24.91 ng/g ± 16.682) in the liver and 44.40 ng/g to 107.0 ng/g (x = 73.05 ng/g ± 22.629) in muscle tissue. Regression analysis showed a positive correlation between total mercury concentration of sediment and vegetation. However, a negative correlation was seen between sediment and invertebrates, and vegetation and invertebrates. No significant difference was measured between the means of any of the groups. Methylmercury concentrations found from liver and muscle tissue were analyzed with a Paired t-test. There was a significance difference between the means for these to tissues (<0.001). We also saw a correlation factor 0.780. Paired differences showed a mean of 65.74 + SE 8.524 (t-value = 7.712, df = 9, sig. 0.000). The data collected were conclusive in determining differences in the bioaccumulation of methylmercury concentrations between the liver and muscle tissue. Effects of Fathead Minnows on Wetland Ecosystems Fellow: Kyle D. Zimmer, Department of Zoology, NDSU Advisor: Malcolm Butler, Professor of Zoology, NDSU Matching Support: Minnesota Department of Natural Resources; North Dakota State Department of Health, Bismarck; USGS Northern Prairie Wildlife Research Center, Jamestown, ND Degree Progress: Ph.D. completion anticipated in 2001 Fathead minnows are found in some wetlands of the Prairie Pothole Region, where they are often the dominant fish species. Many studies have shown that fish influence lake ecosystems, including impacts on invertebrate communities, nutrient cycling, and food-web structure. However, the effects of fish on wetland ecosystems are largely unknown. Additionally, extensive loss of prairie wetlands has necessitated restoration of these unique ecosystems. At present, little biological information is available regarding the success of these efforts in restoring natural communities. My objectives are to 1) identify effects of fathead minnows on restored and natural (nondrained) wetlands, 2) determine if influences of fathead minnows are more pronounced in restored wetlands than in natural wetlands, and 3) evaluate the ecological success of wetland restoration. I am studying 20 wetlands equally partitioned among four types of wetlands: natural with minnows, natural without minnows, restored with minnows, and restored without minnows. I am testing for effects of fathead minnows (presence/absence), wetland history (restored/natural), and fish-history interactions on

ecological characteristics of wetlands. Characteristics measured include abundances of aquatic invertebrates, aquatic macrophytes, and amphibians, as well as water-column levels of chlorophyll a, total phosphorus and nitrogen, and turbidity. Results from the first four years (1996-1999) of this five-year study indicate that fathead minnows have strong influences on prairie wetlands. Wetlands with fathead minnows had fewer aquatic insects, large cladocerans, ostracods, adult and larval tiger salamanders, and higher levels of turbidity, chlorophyll a, and total phosphorus. Additionally, a more detailed analysis indicated that presence of fathead minnows had a greater influence on the structure of aquatic invertebrate communities relative to several other environmental factors. In contrast, very few differences were found between natural and restored wetlands, suggesting restorations are successful in reestablishing natural wetland communities. Finally, few differences have been detected between natural and restored wetlands with minnows, indicating that both types of wetlands respond similarly to the influences of minnows. Dr. Butler and I are also working with several undergraduate students conducting related research. These include studies on the influence of fathead minnows on amphipod behavior, dispersal and distribution of marked fathead minnows, impacts of rotenone on aquatic invertebrates, selectivity of prey by fathead minnows, relative performance of vertical and horizontal invertebrate traps, and influence of diet on phosphorus concentrations in fathead minnows.

Descriptors

bioindicators, birds, denitrification, ecosystems, fish ecology, ground-water quality, heavy metals, lakes, nutrients, organic compounds, phosphorus, pollutants, rivers, suspended sediments, trace elements, urban water systems, water quality, water treatment wetlands

Articles in Refereed Scientific Journals

Arruda, A. F. and A. D. Campiglia, 1999, Determination of trace levels of polychlorinated biphenyls on reversed phase octadecyl bonded silica phases, Anal. Chim. Acta, 386, 271-280. Arruda, A. F. and A. D. Campiglia, 2000 (in press), Determination of polychlorinated dibenzofurans by Solid-Liquid Extraction and Room Temperature Phosphorimetry, Environ. Sci. Technol. (in press). Hagestuen, E.D., A. F. Arruda and A. D. Campiglia, 2000 (in press), On the improvement of by Solid-Phase Extraction Room-Temperature Phosphorimetry for the analysis of polycyclic aromatic hydrocarbons in water samples, Talanta (in press). Hanson, M.A., C.C. Roy, N.H. Euliss, K.D. Zimmer, M.R. Riggs, and M.G. Butler, 2000, A surface activity trap to capture water surface and aquatic invertebrates in wetlands, Wetlands 20, 205-211. Noraker, T.D., K.D. Zimmer, M.G. Butler, and M.A. Hanson, 1999, Distribution and dispersal of marked fathead minnows (Pimephales promelas) in prairie wetlands, Journal of Freshwater Ecology 14: 287-292. Schlag A. J., and S.F. Korom, 1998, In-Situ Tracer Test of Denitrification by Sulfide in the Elk Valley Aquifer, Eastern North Dakota (abstract), Eos Trans. AGU, 79, 45. Zimmer, K.D., M.A. Hanson, and M.G. Butler, 2000, Factors influencing invertebrate communities in prairie wetlands: a multivariate approach, Canadian Journal of Fisheries and Aquatic Sciences 57, 76-85.

Book Chapters

Hanson, M.A. and K.D. Zimmer, 2000, Effects of fathead minnows on prairie wetland ecosystems: summary of results from 1996-1999, In B. Joselyn (ed.), Summaries of research findings 2000, MN DNR Wildl. Pops. Res. Unit, St. Paul, MN. Zimmer, K.D., M.G. Butler, M.A. Hanson, and W.G. Duffy, 1999, Influences of fathead minnows on phosphorus and nitrogen cycling in prairie wetlands, In B. Joselyn (ed.), Summaries of research findings 1999, MN DNR Wildl. Pops. Res. Unit, St. Paul, MN. Hanson, M.A. and K.D. Zimmer, 1999, Effects of bait fish on ecological characteristics of restored and

nondrained prairie wetlands: a pre-treatment summary, In B. Joselyn (ed.). Summaries of research findings 1999, MN DNR Wildl. Pops. Res. Unit, St. Paul, MN.

Dissertations

Jones, Jon Paul, Determining Capture Zones for Three-Dimensional, Heterogeneous, Anisotropic Aquifers by Monte Carlo Analysis, 1999, "M.S. Thesis," Department of Geology and Geological Engineering, University of North Dakota, Grand Forks, ND.

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Hanson, M.A. and K.D. Zimmer, 1999, Fish in waterfowl marshes: cause for concern? Minnesota Waterfowler 12, 7-9.

Information Transfer Program

USGS Internship Program

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	N/A	N/A	N/A	2
Masters	2	N/A	N/A	N/A	2
Ph.D.	5	N/A	N/A	N/A	2
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	9	N/A	N/A	N/A	9

Awards & Achievements

Publications from Prior Projects

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications