Environment and Natural Resources Trust Fund (ENRTF)
2010 Work Program

Date of Report: 24 Nov 2009
Date of Next Progress Report:
Date of Work Program Approval:
Project Completion Date:

I. PROJECT TITLE: Quantifying Carbon Burial in Wetlands

Project Manager: James Cotner
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Location: This project is focused on the entire state, but we will sample lakes in the six shaded study areas shown in Figure 1, representing five of Minnesota's ecoregions. This will allow us to integrate our results over the entire state.

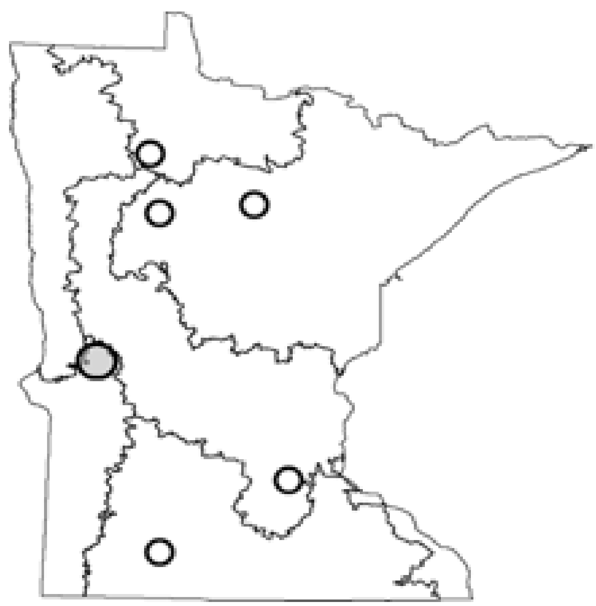

Figure 1. The location of the proposed project. The shaded grey circle shows the location of our NSF work on 13 lakes in western MN. Hollow circles show the location of additional lakes to be studied with LCCMR funds, as well as additional lakes in the western Minnesota study area. Lines represent boundaries of Minnesota's seven ecoregions. The scope of the project includes the entire state but efforts will be focused on lakes in various ecoregions.

Total ENRTF Project Budget:	**ENRTF Appropriation**	**$**	**144,000**
	Minus Amount Spent:	**$**	**0**
	Equal Balance:	**$**	**144,000**

Legal Citation: M.L. 2010, Chp. 362, Sec. 2, Subd. 3g

Appropriation Language:
$144,000 is from the trust fund to the Board of Regents of the University of Minnesota to determine the potential for carbon sequestration in Minnesota's shallow lakes and wetlands. This appropriation is available until June 30, 2013, by which time the project must be completed and final products delivered.

II. PROJECT SUMMARY AND RESULTS:

Shallow lakes can bury carbon very effectively and could be used to mitigate carbon dioxide release from fossil fuels. The state of Minnesota emits over 150 million metric tons of CO_2 annually due to fossil fuel burning and a stated goal is to stabilize releases at 1990 levels by 2010. Reaching this goal will require both minimizing sources and maximizing sinks such as lakes.

In this project, we will determine how much carbon is removed from the atmosphere by shallow lakes statewide and make recommendations to managers about how they can increase carbon burial in Minnesota's shallow lakes. Our goals are to estimate the amount of carbon sequestered by Minnesota shallow lakes, determine how carbon storage varies spatially across the state, estimate the quantity of shallow lake carbon storage for carbon credits, and determine if we can manage our shallow lakes to bury carbon more efficiently. This work will potentially provide economic incentives to land owners for wetland preservation through quantification of CO_2 removal and estimation of potential carbon credits statewide. This project will expand on our current work being done in 13 shallow lakes in western Minnesota funded by the National Science Foundation (NSF). The NSF project will determine whether lakes dominated by submerged macrophytes (lakes in a clear water state) bury more carbon than lakes dominated by algae (lakes in a turbid water state). It will also assess how carbon burial varies when lakes shift from the turbid to clear water states. LCCMR funds will be used to expand this work beyond western Minnesota, and will quantify carbon storage in shallow lakes in four other ecoregions of Minnesota. These results will be coupled with estimates of number of shallow lakes in each ecoregion via GIS to produce estimates of total carbon storage for each ecoregion, and we will identify the primary determinants of carbon storage capacity for lakes in each ecoregion. Finally, these results will be interpreted in light of carbon credits to evaluate the potential for Minnesota shallow lakes and wetlands to be a participant on the global carbon trading market.

III. PROGRESS SUMMARY AS OF *24 November 2009*

IV. OUTLINE OF PROJECT RESULTS*:*

RESULT/ACTIVITY 1: Estimate the statewide potential for shallow lakes to bury carbon in their sediments, and calculate the statewide potential for shallow lakes to serve as carbon credits.

Description: We will estimate both temporal and spatial variability in carbon storage in shallow lakes, scaling estimates of carbon storage in individual lakes to estimates for Minnesota’s ecoregions, and estimating the potential for Minnesota’s shallow lakes to remove carbon and develop estimates of carbon credits in the carbon trading market.

Summary Budget Information for Result/Activity 1: **ENRTF Budget: $144,000**
Amount Spent: $0
Balance: $144,000

Deliverable	**Completion Date**	**Budget**
1. *Identify variables driving carbon storage in each ecoregion and provide an estimate of carbon buried for individual lakes in each ecoregion, total burial for each ecoregion, as well as statewide burial of carbon in shallow lakes*	30 Jun 2012	$84,550
2. *Convert estimates of carbon burial by shallow lakes into estimates of potential carbon credits for each ecoregion and the entire state.*	30 Jun 2013	$59,450

Result Completion Date: *30 June 2013*

Result Status as of *31 December 2010*:

Result Status as of *30 June 2011***:**

Result Status as of *31 December 2011***:**

Result Status as of *30 June 2012***:**

Result Status as of *31 December 2012***:**

Result Status as of *30 June 2013***:**

Final Report Summary: 30 June 2013

V. TOTAL ENRTF PROJECT BUDGET:

Personnel: $ 115,425
Post-doctoral fellow will be paid 100% time to do the following: 1) Assess temporal variability in organic carbon burial rates in lake sediment cores taken thoughout the state of Minnesota; 2) Assess variation in different regions of the state in terms of organic carbon burial; and 3) Determine the potential for carbon credits to be traded via a cap and trade system using Minnesota's shallow lakes.
Contracts: $15,000
This funding will be used to support Dr. Kyle Zimmer's (University of St. Thomas) efforts on the project. Most of this funding will support travel and supply expenses.
Equipment/Tools/Supplies: $ 10,120
These funds will be used primarily for supplies used in collection and processing

of sample cores collected throughout the state of Minnesota. In addition to cores collected and processed for the NSF funded work, we will need to collect cores and surface sediment samples from lakes in the other ecoregions (Figure 1). These funds will enable the collection, processing and analyses associated with these other regions such as: total organic carbon estimates and some stable isotope measurements.

Acquisition (Fee Title or Permanent Easements): $

Travel: $3,455

These funds will be used to collect cores and surface sediment samples from shallow lakes throughout the state of Minnesota (Figure 1).

Additional Budget Items: $

TOTAL ENRTF PROJECT BUDGET: $144,000

Explanation of Capital Expenditures Greater Than $3,500:

VI. PROJECT STRATEGY:

A. Project Partners: Dr. Kyle Zimmer (University of St. Thomas: $15,000)

B. Project Impact and Long-term Strategy: This work needs to be done to (a) help Minnesota take advantage of remaining wetlands in future carbon trading, and (b) to leverage funds to help protect those wetlands.

C. Other Funds Proposed to be Spent during the Project Period: National Science Foundation

$443,474 to Cotner; Total award $1,212,103. Clarification: There are five scientists from two universities (University of St. Thomas [including Zimmer] and University of Minnesota-Twin Cities), and one research institute (Science Museum of Minnesota/St. Croix Watershed Research Station) funded through this NSF project. Of the >$1.2 million of total funding, Cotner is receiving $443,474 to fund research that is related to, but not overlapping, with the work program outlined here. Much of the remaining work that is being funded by NSF is focused on interactions between climate variability and organic matter burial in the past. This work should help in the present project in that it will help us project organic matter burial in shallow lakes into the future.

D. Spending HIstory: *None*

VII. DISSEMINATION: We will publish the results of this study in peer-reviewed scientific journals and explore other methods of making these results known including regional, national and international meetings, newspaper articles and other statewide publications.

VIII. REPORTING REQUIREMENTS: Periodic work program progress reports will be submitted not later than 31 Dec 2010, 30 Jun 2011, 31 Dec 2011, 30 Jun 2012, 31 Dec 2012, 30 Jun 2013. A final work program report and associated products will be submitted between June 30 and August 1, 2013 as requested by the LCCMR.

IX. RESEARCH PROJECTS: Research addendum attached

Research Addendum for Peer Review

Project Manager Name: James Cotner

Project Manager Email address: cotne002@umn.edu

Project Title: Quantifying Carbon Burial in Healthy Minnesota Wetlands

Project number: 220-G

Abstract - Summarize the research and its essential qualities including a clear statement on the purpose of the research.

What role do small lakes and wetlands play in the global carbon cycle and can we manage them to bury organic matter efficiently? While it is recognized that the inorganic carbon dynamics of the ocean are critical to atmospheric CO_2 remediation, terrestrial and freshwater systems bury more organic carbon annually. Recently, burial of organic matter 'between the cracks' in freshwater systems has been recognized as important to the global carbon cycle. Despite their small surface area relative to terrestrial and marine systems, these systems bury more than 0.5 Pg of organic matter annually. Therefore, understanding the controls of organic matter fluxes to and within freshwater lakes and wetland sediments represents an important regulatory mechanism for increasing organic carbon removal through expeditious management practices. Many of these systems are already heavily managed for various goals, but not necessarily for carbon removal. If we knew more about the sources and controls of organic carbon burial in these systems, could we manage them specifically for carbon removal?

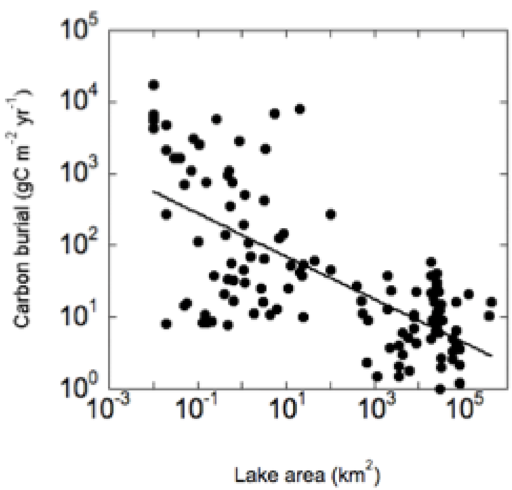

Figure 2. Lake area versus organic carbon burial rates. Note the tremendous variation in burial rates in the smallest lakes (figure based on Mulholland and Elwood 1982; Dean and Gorham 1998; Wetzel 2001; Einsele et al. 2001; Alin and Johnson 2007; Squires et al. 2006; Downing et al. 2008).

The research described in this proposal will build research we are currently conducting with funding from the National Science Foundation (NSF). The three-year NSF project will estimate carbon burial rates in 13 shallow lakes in western Minnesota (see map in Fig. 1), and will elucidate variables and particularly management practices that either increase or decrease burial rates. In addition, this project will provide statewide estimates for carbon credit offsets in shallow lakes.

Background Recent work by Einsele et al. (2001) indicated that lakes likely have stored over 820 Pg of organic carbon (OC) through the Holocene period. Most of that storage has occurred in small lakes, which in their study was anything smaller than 500 km^2. The lakes we will study are typically much smaller than this at less than 0.05 km^2 and therefore likely are depositing organic matter at some of the highest rates measured globally (Fig. 2). Of the 304 million lakes on the Earth, nearly 301 million are less than 0.01 km^2 (Downing et al. 2006) making these systems very relevant and a recent estimate indicated that there are 4.4 million of these small lakes in the state of Minnesota (John Downing, personal comm.)! Much of the ability of the oceans to remove carbon from the atmosphere comes from their ability to absorb inorganic carbon, but a comparison of **just** organic carbon burial in lakes to the much more extensive oceans reveals that lakes are currently burying about 30-60% as much of organic matter buried in oceans (Cole et al. 2007). Furthermore, one recent comparison indicated that lakes buried organic matter 4-10 times more intensively on a surface area basis than forests in SE Canada over the Holocene (Cole et al. 2007).

Small lakes bury OC efficiently due to their small size and proximity to terrestrial systems. Typically, terrestrially produced organic matter is more recalcitrant to remineralization through biogeochemical processes due to higher lignin content, lower N and P content and more hydrophobic and aromatic composition (Hedges et al. 1997; Burdige 2007). Furthermore, high nutrient content and high light levels make wetlands and shallow lakes extremely productive (Wetzel 2001), which paradoxically contributes further to preservation of organic matter by generating anaerobic conditions that can persist both in summer and in the winter under ice. Although anaerobic conditions do not guarantee high rates of organic matter preservation, one of the most important consequences is decreased bioturbation and lower dissolved oxygen levels in sediments (Fenchel et al. 1998; Burdige 2007).

Research has shown that shallow lakes can exist in two alternative regimes (or alternative states): either a clear-water regime dominated by submerged macrophytes with low phytoplankton abundance, or a turbid-water regime dominated by phytoplankton with low macrophyte abundance (Scheffer 2004). Alternative regimes have been observed in shallow-water systems worldwide, including our study sites in Minnesota (Zimmer et al. 2003a; Zimmer et al. 2003b) (Fig. 3). Jackson (2003) found that macrophyte abundance was five-fold higher in clear Alberta lakes, while phytoplankton biomass was five-fold higher in turbid analogs. Lakes can switch back and forth between regimes due to changes in abundance of fish (Hanson and Butler 1994) and water depth (Blindow et al. 1993), and overall the resilience of each regime is influenced by nutrient levels (Scheffer et al. 2001). Benthivorous and planktivorous fish have strong influences on the alternative regime of shallow lakes by stabilizing the turbid regime, and can also induce shifts from clear to turbid regimes (Scheffer 2004). The clear regime is the usual management goal because of its positive influences on game fish and waterfowl abundance (Hanson and Butler 1994), biodiversity (Scheffer et al. 2006), and aesthetics. Thus, management agencies worldwide often use biomanipulation (intentional reduction of benthivore and planktivore abundance) to induce shifts from turbid to clear regimes.

In addition to differences in the dominant plants, there are other important biogeochemical differences between lake regimes. There is much greater turbulence and mixing in turbid lakes (Horppila and Nurminen 2005; Sondergaard et al. 2008) contributing to increased resuspension of particulate organic matter. Resuspension increases organic matter degradation rates (Koelmans and Prevo 2003) and microbial processes (Wainright 1987; Cotner 2000; Eiler et al. 2003) both by bringing freshly deposited organic matter back into typically warmer surface waters with high oxygen concentrations, but also by introducing dissolved oxygen back into the sediments (Gerhardt and Schink 2005). In Lake Michigan spring resuspension facilitates degradation of organic matter despite extremely low temperatures in late winter/early spring (Cotner et al. 2000). Another biogeochemical difference between systems dominated by rooted macrophytes vs. phytoplankton is that overall sediment decomposition processes are actually more anaerobic when macrophytes are present (Hines et al. 1994;Suplee and Cotner 2002) most likely due to the fact that oxygen excreted from plant roots is less than OC that is excreted.

<u>Hypotheses and Statement of Need</u>

Our long term goal is to understand how lakes regulate inorganic and organic matter dynamics on temporal scales from months to centuries. The goal of the NSF research project that complements our LCCMR project is to determine if differences in the dominant autotrophs in shallow lakes can significantly impact organic carbon storage in shallow lakes. In that project, we will explore these linkages in the modern functioning of shallow lakes as well as the paleo-record. Our central hypothesis is that carbon burial rates are highest in shallow lakes dominated by submerged macrophytes (hereafter macrophytes) rather than phytoplankton and that the two main mechanisms through which dominant plants can affect burial of organic matter are (a) production of large quantities of organic biomass that ultimately resides in the sediments and (b) altering the decomposition regime to enhance burial of organic matter.

In the work that will be performed for the LCCMR, we will apply the results of these hypotheses throughout the various ecoregions of the state of Minnesota. We recognize that the results of our work in western Minnesota will be ‘context specific’ and therefore we expect that we cannot directly extrapolate the carbon burial rates that we measure there to lakes in the remainder of the state. However, there is a great need to be able to estimate the carbon credits that landowners can acquire by managing lakes for this purpose. Furthermore, we anticipate that many of the management practices that will help contribute toward effective carbon removal from the atmosphere, could also have many other benefits to the state such as facilitating better water quality in wetlands and increasing waterfowl habitat. Specifically, we will apply the mechanistic results of the NSF study to the remainder of the state using a combination of available data and on-the-ground field observations.

Methodology

Our LCCMR work will include estimating both temporal and spatial variability in carbon storage in shallow lakes, scaling estimates of carbon storage in individual lakes to estimates for Minnesota’s ecoregions, and estimating the potential for Minnesota’s shallow lakes to remove carbon and develop estimates of carbon credits in the carbon trading market.

Temporal variability in carbon burial rates

Our NSF project is assessing long-term storage of carbon in shallow lake sediments in western Minnesota by analyzing sediment cores from lakes in this ecoregion. However, the LCCMR- sponsored postdocoral fellow will also utilize additional cores previously collected by the St Croix Watershed Research Station (a collaborator on our NSF project) to assess temporal variability of carbon storage in lakes in other ecoregion of the state. These data, when coupled with the data on spatial variability in carbon storage described below, will provide a comprehensive estimate of carbon storage in Minnesota shallow lakes through space and time, and identification of variables driving rates of carbon storage.

Cores collected by the St Croix Research Station have been ^{210}Pb-dated, providing a paleo-record for lake sediments in the recent past (2-300 years) and quantifying the organic carbon burial rate. Previously-collected cores will be sectioned and both the organic and inorganic carbon content will be determined by combusting sediment at 500ºC; inorganic carbon content will be estimated by further combustion at 900ºC. Coupled with age estimates from ^{210}Pb dating and cores collected from our NSF study, these data will provide estimates of carbon burial over the last several hundred years at many shallow lakes throughout the state. From these results, we will be able to assess impacts of European settlement on carbon burial, and make a first approximation as to the degree to which long-term carbon burial differs across Minnesota’s ecoregions.

Spatial variability in carbon storage

We will assess carbon storage in approximately 15 shallow lakes in each of the six study areas shown in Figure 1. These six areas represent five of the six ecoregions containing extensive numbers of shallow lakes, and capture the range of variability in land use and ambient nutrient levels observed for shallow lakes across Minnesota. The five ecoregions to be sampled include Northern Minnesota Wetlands (NMW), Northern Lakes and Forests (NLF), Northern Glaciated Plains (NGP), Western Corn Belt Plains (WCP), and North Central Hardwood Forests (CHF). A core hypothesis of this project is that climate, land use, and ambient nutrient levels are major determinants of carbon storage, and all three factors vary sharply across our study areas. Climate clearly varies across these sites, and Heiskary et al. (2004) found median phosphorus concentrations of 23 ppb (NLF), 50 ppb (CHF), 121 ppb (WCP), and 177 ppb (NGP) in lakes of each region. Land use varies from boreal mixed forest in NLF, to hardwoods in CHF, to predominately agriculture in WCP. Moreover, lakes in our CHF region fall along a gradient of increasing human development from Carver through Hennepin counties, allowing us to elucidate the effect of urbanization on carbon storage. Co-PI Zimmer has previously estimated the lake and watershed features in all of these study sites (described below), which will allow us to identify variables driving carbon storage in each ecoregion. Moreover, these lakes were randomly selected from a pool of candidate sites within each ecoregion, allowing us to extrapolate our results to all lakes in each region.

Present-day carbon storage will be assessed in July of both 2010 and 2011 by sampling the surface sediments (0 – 5 cm) of each lake. The amount of inorganic and OC permanently buried in lake sediments differs from the amount deposited at the sediment – water interface, due to post-depositional mineralization (Galman et al. 2008). We will analyze five (5) samples within the upper 5 cm sediment for total OC and inorganic carbon (mg g^{-1}) to establish the concentration of permanently buried carbon. In addition we will assess the spatial heterogeneity of carbon burial within the lake basin across a selection of lakes representing each ecoregion. Sediments will be dried to determine the bulk density and pre-treated with HCl to remove inorganic C, the loss of which will be used to calculate total inorganic C in sediments. Carbon abundance will then be estimated through pyrolysis of the sample in a Perkin-Elmer CHN analyzer.

Estimates of carbon storage in each lake will be coupled with previously collected data on lake and watershed features to identify variables driving carbon storage rates in each ecoregion. Co-PI Zimmer and collaborators sampled each of our LCCMR study sites once during July of 2009. Abundance and community composition of fish in each lake was estimated with 1 gill net and three trap nets set for 24 hrs (sensu Jackson and Harvey 1989 and Robinson and Tonn 1989). Results were expressed as the total biomass of each fish species captured and total biomass of piscivores, benthivores, and planktivores. Abundance of submerged aquatic macrophytes was estimated with a weighted plant rake at 20 stations located along transects in each lake, and results expressed as total plant biomass m^2 as well as species diversity and richness for each lake. Zooplankton were sampled using an integrated column sampler (Swanson 1978) at five locations in each wetland, while benthic macroinvertebrates were collected with sweep nets (Murkin et al. 1983) at five littoral locations in 0.75m of water. Abundance and carbon:nitrogen:phosphorus ratios of phytoplankton were estimated from three open water samples, while water clarity and specific conductance were measured at the same locations using a nephelometer and conductivity meter, respectfully. Additional water collected from the same three locations in each lake were analyzed for total phosphorus, total nitrogen, total dissolved phosphorus, and dissolved inorganic nitrogen. Lake morphometry (maximum and average depth) were determined from depth measurements taken at the GPS-referenced locations used to sample macrophytes.

Lake size was estimated from digital air photos, lake volume estimated based on lake size and our GPS referenced depth measurements, and watershed size and boundaries for each lake are being estimated by the Minnesota Department of Natural Resources Division of Waters. Land use (including agriculture, development, natural grasslands, natural woodlands, and wetlands) within each watershed will be estimated at scales of 50 m, 200 m, and the entire watershed using MN GAP GIS data layers. Results will be expressed as the total proportion of the watershed represented by each land use, total area of each land use in each watershed, and lake area divided by the total area of each land use in the watershed. Delineation of watersheds and surface water flow by DNR Waters will also be used to classify each lake as a closed, flow through, or outlet only system.

The lake and watershed data will be used to identify key drivers of carbon storage in lakes. Inorganic carbon and organic carbon content of lake sediments (g per kg of sediment) will be our response variables, and some of our key predictor variables include watershed size, agriculture in watershed, ecoregion, turbid versus clear water state, and abundance of benthivorous and detritivorous fish such as fathead minnows and common carp. We will use an information theoretic approach (Anderson et al. 2000) to assess the relative importance of these and other variables as drivers of carbon storage in shallow lakes, and determine whether important variables differ among ecoregions. Our core hypothesis is that ecoregion, land use in watershed, and state (turbid versus clear) are the primary factors driving carbon burial. These results will provide managers, policy makers, and citizens with information regarding the best management strategies for maximizing carbon storage in shallow lakes, as well as the geographic areas of Minnesota where shallow lakes have the highest potential for carbon storage.

Carbon credit calculation

Following the estimation of temporal and spatial carbon burial in Minnesota wetlands and shallow lakes (this project) and the more detailed assessment of C cycling shallow lakes (NSF project), the potential for Minnesota lakes to be classified as carbon sinks will be assessed. The calculation of carbon burial in shallow lakes across Minnesota will allow us to estimate the amount of carbon per year these ecosystems sequester and archive. The effective rate of carbon burial (g C yr^{-1}) can then be used to calculate the carbon credits of a particular ecoregion or at a larger scale, the carbon credits a specific lake might represent. Along the same lines the carbon burial value of a lake can be used to calculate the monetary loss in carbon credits should the lake ecosystem be altered to a point where carbon burial is not taking place as efficiently.

Under a cap and trade system for greenhouse gases (GHG) the annual burial of carbon (as CO_2 equivalents) could be applied towards an ‘offset program’ wherein the conservation of an effective C burial shallow lake or region would be purchased by those emitting GHG above their reduction targets. In order to clearly establish the potential for Minnesota wetlands and shallow lakes to participate in a carbon trading system, we will liaise with members of the Nature Conservancy and Voluntary Carbon Standard for guidance on the incorporation as an accepted offset program.

Its worth noting that this project could be highly integrated with the LCCMR proposal submitted by PI Hanson (LCCMR #020-A3, Sustainable, Cost Effective Approaches to Management of Shallow Lakes) if the Hanson proposal is funded. If both projects are funded, we will be able to expand our sample size of lakes from 15 to 24 per ecoregion due to logistical collaboration between the two studies. However, the work described here is not dependent on the Hanson project being funded, as we will be able to proceed on sampling the 15 lakes in each ecoregion without any collaborative assistance.

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Curriculum Vitae: James Bryan Cotner

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Current position: Professor, Department of Ecology, Evolution and Behavior, University of Minnesota

Education:

B.A., Wittenberg University, Springfield, Ohio, 1981, Biology.
M.Sc., Kent State University, Kent, Ohio, 1984. Biology.
Ph.D., University of Michigan, Ann Arbor, 1990 Biology.
Post-doctoral research fellow, Great Lakes Environmental Research Laboratory and University of Michigan, Biological Limnology and Oceanography, 1990-1992.

Research Experience: The goal of my research program is to understand how bacteria and humans affect biogeochemical processes in aquatic systems. Microbes are incredibly important to ecosystem processes because of the great magnitude of their biomass and their diverse modes of heterotrophy and autotrophy. Because of this diversity of function, bacteria have significant impacts on the geochemistry of lakes, rivers and oceans. Humans have important effects on lakes and rivers through landscape and species alterations.Current research projects are focused on the Laurentian Great Lakes carbon and phosphorus cycling and the role of shallow lakes and wetlands in the global carbon cycle. Current funded projects:

2007-09 NSF REU ($224,000) for “Field Studies in Global Change at the Headwaters of the Mississippi” , PI: J. Cotner, co-PI: S. Cotner.
2009-2012 NSF Ecosystems RUI for “Burial of organic carbon in temperate, shallow lakes. (K. Theissen, J. Cotner, and M. Edlund co PIs).

Publications relevant to this proposal:

Cotner, J.B., J. Kenning and J.T. Scott. 2009. The microbial role in littoral zone biogeochemical processes: Why Wetzel was right. Verh. Internat. Verein. Limnol. 30 (6): 981-984.
Cotner, J.B., and B.A. Biddanda. 2002. Small players, large role: Microbial influence on auto-heterotrophic coupling and biogeochemical processes in aquatic ecosystems. Ecosystems 5, 105-121.
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Biddanda, B., M. Ogdahl and J.B. Cotner. 2001. Dominance of bacterial metabolism in oligotrophic relative to eutrophic waters. Limnology and Oceanography 46: 730-739.
Cotner, J.B., T.H. Johengen, and B.A. Biddanda. 2000. Intense winter heterotrophic production stimulated by benthic resuspension. Limnology and Oceanography 45: 1672-1676.
Stets, E.G. and J.B. Cotner. 2008. Biodegradable dissolved organic carbon in lake ecosystems: Sources and effects on planktonic respiration. Canadian Journal of Fisheries and Aquatic Sciences 65: 2454-2460.

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Associate Professor, Department of Biology, University of St. Thomas

Education
B.A. (Biology), 1992, Luther College, Decorah, IA.
M.A. (Biology, Fisheries Emphasis), 1994, St. Cloud State University, St. Cloud, MN.
Ph.D. (Zoology), 2001, North Dakota State University, Fargo, ND.
Postdoctoral Associate, 2001-2003, University of Minnesota, St Paul, MN.

Research experience
Dr. Zimmer's research focuses on community and ecosystem ecology of shallow lakes and wetlands. He is particularly interested in food-web interactions involving fish, and the subsequent effect of these interactions at the ecosystem scale. Current and recent research projects include:

2009 – 2012. Collaborative Research (RUI): Burial of organic carbon in temperate, shallow lakes. Funded by the National Science Foundation (K. Theissen, J. Cotner, and M. Edlund co PIs).

2005 – 2008 Carbon Sequestration in Minnesota's Wetlands: An Important Sink with Management Implications. Funded by the Initiative for Renewable Energy and the Environment (K. Theissen, J. Cotner, and S. Sugita co PIs).

2004-2007. Evaluating functional linkages among landscapes and wetland attributes: assessing the roles of geomorphic setting, land use, and fish on wetland community characteristics. Funded by MN DNR (M. Hanson and B. Herwig co PIs).

Publications Relevant to this Proposal:

Zimmer, K.D., M.A. Hanson, B.R. Herwig, and M.L. Konsti. 2009. Thresholds and stability of alternative regimes in shallow prairie-parkland lakes of central North America. Ecosystems 12:843-852.

Potthoff, A.J., B.R. Herwig, M.A. Hanson, **K.D. Zimmer**, M.G. Butler, J.R. Reed, B.G. Parson, M.C. Ward, and D.W. Willis. 2008. Cascading food web effects of piscivore introductions in shallow lakes. Journal of Applied Ecology 45:1170-1179.

Verant, M.L., M.L. Konsti, **K.D. Zimmer**, and C.A. Deans. 2007. Factors influencing nitrogen and phosphorus excretion rates by fish in a shallow lake. Freshwater Biology 52:1968-1981.

Herwig, B.R., and **K.D. Zimmer**. 2007. Population dynamics and prey consumption by fathead minnows in prairie wetlands: importance of detritus and larval fish. Ecology of Freshwater Fish 16:282-294.

Scheffer, M., G.J. van Geest, **K.D. Zimmer**, E. Jeppesen, M.G. Butler, M.A. Hanson, M. Søndergaard, S. Declerck, and L. De Meester. 2006. Small habitat size and isolation can promote species richness: second-order effects on biodiversity in shallow lakes and ponds. Oikos 112:227-231.

Attachment A: Budget Detail for 2010 Projects - Summary and a Budget page for each partner (if applicable)

Project Title: *Quantifying Carbon Burial in Healthy Minnesota Wetlands*

Project Manager Name: *James Cotner*

Trust Fund Appropriation: $ *144,000*

2010 Trust Fund Budget	Result 1 Budget:	Amount Spent (24 Nov 2009)	Balance (24 Nov 2009)	TOTAL BUDGET	TOTAL BALANCE
	Estimate the statewide potential for shallow lakes to bury carbon in their sediments, and calculate the statewide potential for shallow lakes to serve as carbon credits.	*0*	*144,000*		
BUDGET ITEM					
PERSONNEL: wages and benefits					
Post-doctoral fellow (100% time for 2 years; 19% fringe benefits)	84,550			84,550	
Technician (17% time for 3 years; 37% fringe benefits)	30,876			30,876	
Contracts	15,000			15,000	
Professional/technical Kyle Zimmer for travel and supply expenses					
Supplies *(filters, lab chemicals for analyses and other supplies)*	10,120			10,120	
Travel expenses in Minnesota	3,454			3,454	
COLUMN TOTAL	**$144,000**	**$0**	**$144,000**	**$144,000**	**$0**

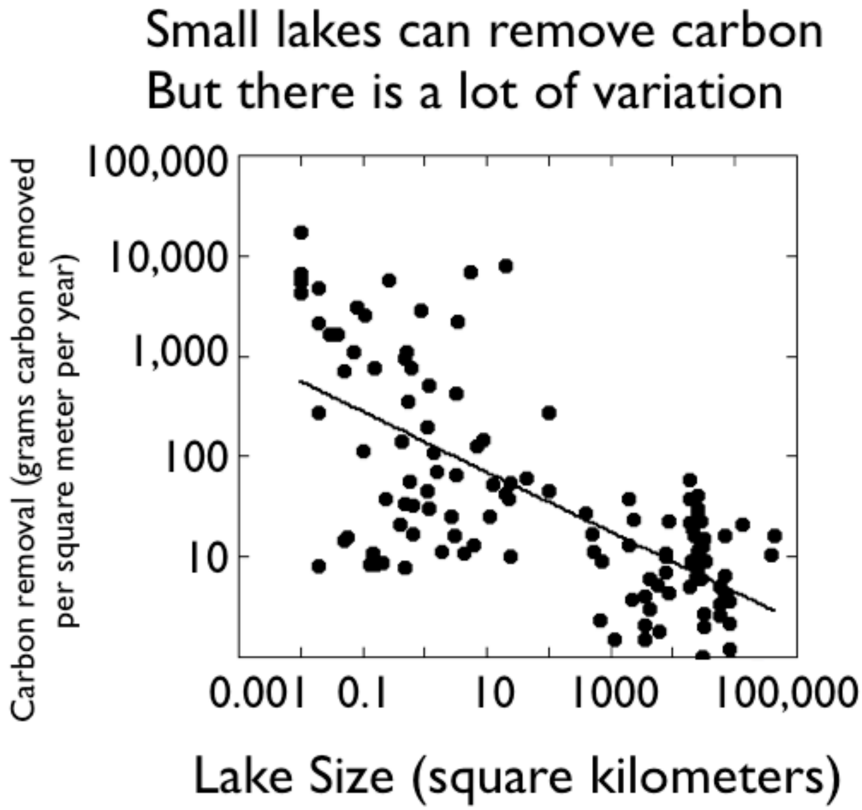

Figure 1. Variation in carbon burial with lake size. The lakes we will study are about 0.01 km^2 (far left of scale).

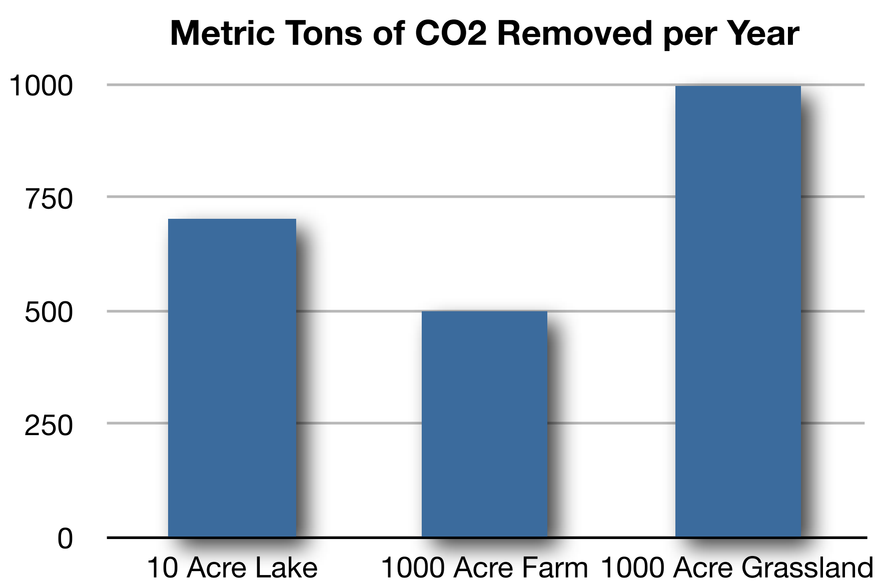

Figure 2. Burial of carbon in lakes vs. farms. A 10-acre lake can bury as much CO_2 as a 1000 acre farm using conservation tillage methods and about two-thirds of what is removed by a 1000 acre permanent grassland (based on data from Chicago Climate Exchange).