Ecosystems: Organic carbon burial in shallow lakes

I. Response to previous reviews

This proposal is a resubmission of a previously reviewed proposal (July 2008). There was a consensus that we are addressing an important and timely issue, yet there were concerns about our approach. Criticisms focused on using a correlative rather than experimental approach and research questions that were too broad. We agree with these concerns and have cut back on the number of lakes that we will study from ca. 50 lakes throughout Minnesota to 15 lakes in the western region of the state. This means that we will not address the relevance of climate gradients to present-day carbon deposition. Our focus is entirely on the role that dominant plants and dissolved oxygen play in organic carbon (OC) burial. By limiting the number and geographic distribution of lakes, it will enable experimental manipulation of five of the study lakes from a phytoplankton- to a macrophyte-dominated state while we make observations of annual and inter-annual variation among 10 unmanipulated lakes. Furthermore, we will also conduct *in situ* decomposition experiments to examine how each stable state affects decomposition rates of multiple types of plants.

II. Overview

What role do small lakes and wetlands play in the global carbon cycle and can we manage them to bury OC efficiently? While we recognize that the inorganic carbon dynamics of the ocean are critical to remediation of anthropogenically produced CO_2, terrestrial and freshwater systems produce **and bury** the largest proportion of primary production annually. Recently, burial of organic matter ‘between the cracks’ in freshwater systems such as wetlands and shallow lakes 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 on organic matter fluxes to and within freshwater lakes is likely an important regulatory mechanism for increasing OC removal through expeditious management. Many of these systems are already heavily managed for various goals, but not necessarily for OC removal. If we knew more about the sources and controls of OC burial in these systems, could we manage them specifically for carbon removal?

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 research proposed here is to determine if differences in the dominant autotrophs in shallow lakes can significantly impact OC storage. We will explore these linkages in the modern functioning of shallow lakes, and use the paleo-record to determine how carbon burial rates have changed over time. ***Our central hypothesis is that carbon burial rates are highest in shallow lakes dominated by submerged macrophytes (hereafter macrophytes) rather than phytoplankton.*** 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. A key aspect of the work proposed here is that macrophytes facilitate both of these processes by producing recalcitrant, i.e., lignified, organic matter and restricting decomposition by (1) reducing sediment resuspension, and (2) restricting mixing of atmospheric O_2 into the lake. The rationale for this hypothesis is that previous work indicates that decomposition processes are likely more important to carbon storage in shallow lakes than is primary production and that macrophyte dominated systems have high organic matter concentrations in sediments, low resuspension rates, as well as highly stratified and anaerobic conditions in both the summer and winter.

The specific aims of our proposed project are the following:

1. Determine the sources of organic matter to short-term and long-term burial in shallow lakes. Although the watershed areas of many of the shallow lakes that we will study are small, we have measured substantial quantities of terrestrial organic matter in the sediments of some systems. Our approach will be to use modern proxies of both terrestrial and aquatic vegetation to make inferences of both present day burial sources as well as burial in the past several hundred years. We hypothesize autochthonous sources (macrophytes and phytoplankton) are most important to deposition, but that there should be selective preservation of both macrophyte and terrestrial vegetation due to high lignin content and increased anaerobic conditions in macrophyte-dominated lakes.

2. Determine organic carbon burial rates in macrophyte vs. phytoplankton-dominated systems. We will study production, decomposition and burial in five turbid (phytoplankton-dominated), five clear (macrophyte-dominated), and five experimentally manipulated (from turbid to clear) shallow lakes. We hypothesize that turbid lakes will have less organic matter in surface sediments, higher resuspension rates, and less stratification than clear lakes. We will also examine the paleo-record for evidence of dominant plants and correlations with OC burial.

2.1 Determine how plants affect dissolved oxygen availability. We hypothesize that increased stratification and higher plant biomass in clear lakes will increase the extent of anaerobic conditions in the clear lakes. We will make observations and conduct experiments to determine if macrophyte lakes are more stratified and have overall lower dissolved oxygen availability annually. By experimentally manipulating five lakes from the turbid to clear state we will be able to determine how plants affect stratification, dissolved oxygen, sediment resuspension, decomposition, and burial. Lastly, we will examine sediment cores for indicators of past anaerobic conditions and correlate that with dominant plants in the lake.

2.2 Determine how dissolved oxygen availability affects plant decomposition. We hypothesize that decreased oxygen availability should contribute to selective preservation of more lignified materials such as is found in macrophytes and terrestrial material. This hypothesis will be examined both experimentally in the laboratory under aerobic and anaerobic conditions and in turbid, clear and switching lakes. This hypothesis will also be examined in the past by examining proxies of dominant plant types and correlating it with the type of organic matter preserved in the sediments (terrestrial, macrophyte, phytoplankton).

At the completion of this work, we will know (a) whether the dominant plant in shallow lakes has a strong influence on OC storage in the Upper Midwest, (b) whether anaerobic conditions are an important mechanism that facilitates organic matter burial, (c) whether turbid and clear lakes have behaved similarly in the past few hundred years as they do today in terms of OC burial, and (d) how much OC is presently buried in shallow prairie lakes via collaboration with the Minnesota Department of Natural Resources (DNR). Furthermore, the paleo-studies will provide additional understanding of how human settlement and modern land-use practices have affected OC burial in lakes over the past ca. 300 years (Fig. 1).

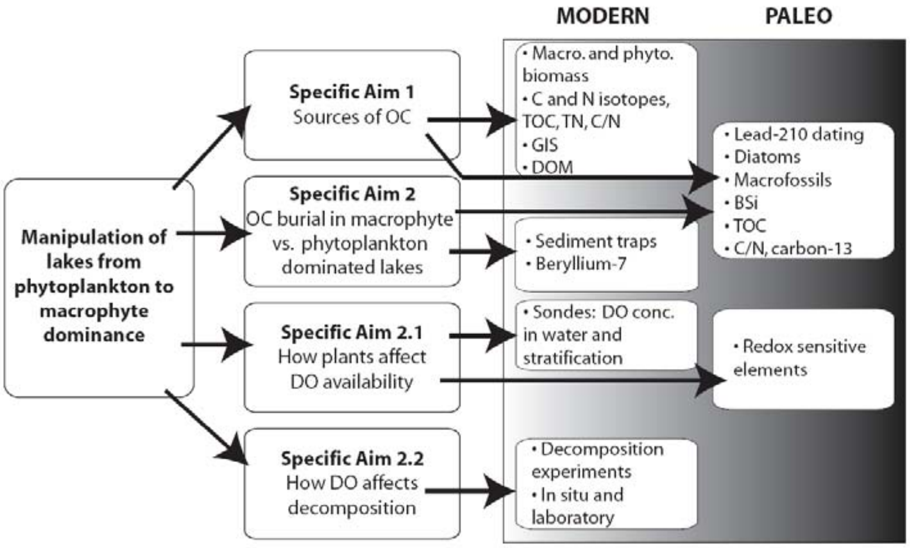


Figure 1. Project summary illustrating the relationships and integration among the specific aims of the project.

We know that freshwater systems store a disproportionately high amount of carbon relative to their size and that most of this carbon originates from both aquatic and terrestrial primary production

(Dean and Gorham 1998; Einsele et al. 2001; Cole et al. 2007). We also know that primary production and autotroph biomass in shallow-water systems are dominated by either macrophytes or phytoplankton (Jackson 2003) and that anaerobic conditions can inhibit organic matter decomposition rates (Twilley et al. 1986; Hamilton et al. 1995; Burdige 2007). But we do not know the degree to which the dominant autotroph in a system can influence both anoxia and decomposition rates. The work proposed here will make important connections among these processes and make much needed measurements of the role of shallow freshwater systems in the global carbon cycle.

Significance of the proposed work. Global analysis of carbon flux and storage has traditionally focused on terrestrial and marine habitats, yet recent work has shown that freshwater systems are a critical part of the global carbon cycle, serving as active sites for carbon transformation and storage (Einsele et al. 2001; Cole et al. 2007). Lentic systems play an especially important role as OC sinks, burying even more **organic** carbon than the oceans, despite their much smaller surface area (Dean and Gorham 1998). Among lentic systems, small, shallow lakes may be especially important for carbon burial given their high accumulation rates of sediment, proximity to terrestrial carbon sources and large numbers of these lakes (Cole et al. 2007). For example, lakes and wetland systems in the Prairie Pothole Region of North America could bury nearly 3% of current CO_2 emissions in North America over a 10-year period (Euliss et al. 2006) if properly managed.

Thus, shallow lakes in the Upper Midwest have high potential for mitigation of atmospheric CO_2 emissions from fossil fuels. But one of the biggest problems is that there is a nearly 4 orders of magnitude variation in OC burial rates in small lakes and wetlands (Fig. 2). One of the most important goals of the proposed work is to help resolve the factors that contribute to such high variability in OC burial, specifically the importance of different source materials as well as the plant-mediated oxygen regime. Furthermore, the connections we will make between biogeochemistry, terrestrial watersheds, and dominant plants will further our understanding of carbon storage and management of many aquatic ecosystems.

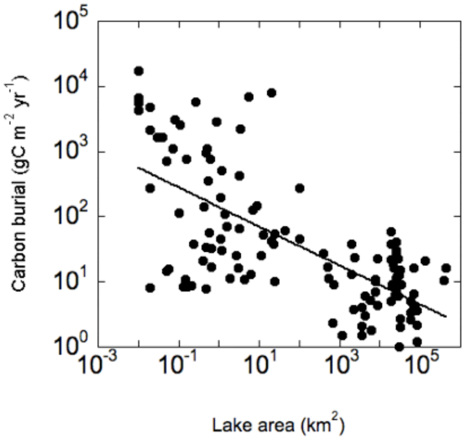


Figure 2. Lake area versus OC burial rates. Note the tremendous variation in burial rates in the smallest lakes (figure based on Mulholland and Elwood 1982; Dean & Gorham 1998; Wetzel 2001; Einsele et al. 2001; Alin and Johnson 2007; Squires et al. 2006; Downing et al. 2008).

III. Background

Recent work by Einsele et al. (2001) indicated that lakes likely have stored over 820 Pg of 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 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) 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 carbon sink in the oceans comes from their ability to absorb inorganic carbon, but if we compare organic carbon burial in lakes to the much more extensive oceans, amazingly we find that they are currently burying about 30-60% of organic matter buried in oceans (Cole et al. 2007). Furthermore, one recent comparison indicated that lakes bury 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 demonstrated 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 1994a) 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 1994b), biodiversity (Scheffer et al. 2006), and aesthetics (Moss et al. 1997). Thus, management agencies worldwide often use biomanipulation (intentional reduction of benthivore and planktivore abundance) to induce shifts from turbid to clear regimes.

Figure 3. Minnesota shallow lakes in turbid and clear-water 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; Søndergaard 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 et al. 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.

IV. Plan of work: Overview of study area and planned activities

This work will be conducted in shallow lakes classified as Class V wetlands (Stewart and Kantrud 1971) in the prairie ecoregion of western Minnesota. These lakes have extensive open water and permanent hydroperiods. Submerged macrophytes are the dominant vascular plants, with emergent macrophytes restricted to narrow fringes along the perimeter. Average maximum depths are around 2 m, and submerged macrophytes can potentially grow throughout the entire basin. All PIs have multiple years of experience working in these systems.

We will build on previous work among the PIs with personnel at state agencies. Having strong management connections will enable us to transcend the academic-management barrier and facilitate on-the-ground implementation. Zimmer and Cotner are collaborating with the Minnesota Department of

Natural Resources (DNR) to study shallow lakes across five ecoregions in the state. Ramstack and Edlund have been working extensively with the Minnesota Pollution Control Agency (PCA) to use sediment diatoms to reconstruct historical total phosphorus concentrations and ecological condition of shallow lakes (Ramstack et al. 2003; Heiskary et al. 2004).

This project will extend a three-year study that the MN DNR is initiating to examine interactions of landscape features and fish in 150 shallow lakes in Minnesota. Their study is already a massive collaboration, involving scientists from the DNR Divisions of Wildlife Research, Fisheries Research, and Waters, as well as the Red Lake Band of Chippewa Indians. The timeline of the DNR study matches ours, and they will study the same lakes proposed here along with many others allowing interpretation of our work in a broader spatial context. Moreover, our collaboration with the DNR will enable estimation of annual rates of carbon burial for all shallow lakes in the prairie region of Minnesota. The DNR Research and the Shallow Lakes Program both have strong interests in our work, and have pledged support via assistance with site selection, geographic information systems (GIS) to analyze lake watersheds, and application of rotenone. Moreover, the DNR will also share data they collect on nutrient levels, aquatic invertebrate communities, and fish populations in our study sites. We are confident this will be a successful collaboration, as one of the PIs (Zimmer) has successfully worked with our DNR collaborators for 13 years. Pleased see attached letters of support from the DNR.

Study approach. We will study 15 lakes evenly distributed among three groups: turbid, clear, and experimental lakes. Individual lakes will serve as our unit of replication. The experimental lakes will be initially turbid, but will be treated with the fish toxicant rotenone to induce a shift to the clear regime for years two and three. Lakes will be selected in a stratified-random procedure based on regime and proportion of watershed used for agriculture versus planted with native grasses. Watershed features of each lake (size, slope, proportion used for agriculture, native grasses, etc.) will be determined from GIS. Selecting lakes for each group that fall along a continuum of native grasses in the watershed will allow us to assess relationships between watersheds and sources of carbon (terrestrial, macrophytes, or phytoplankton) in short-term burial. Our previous work on these systems found no relationship between probability of lakes being turbid and amount of agriculture in the watershed (Zimmer et al. unpublished data). Based on our past experience, we suspect our study sites will average 8 ha in size, 2 m maximum depth, and have 347 ha watersheds (range of 8 to 2,650 ha). Phytoplankton abundance will average 9 μg/L in clear lakes and 81 μg/L in turbid lakes, while macrophytes average 1.5 kg m^2 in clear lakes and 0.09 kg m^2 in turbid lakes.

Lake regimes shift quickly after rotenone treatment with pronounced increases in macrophyte abundance usually observed in the summer after the fall application (Hanson and Butler 1994; Noonan 1998) (Fig. 4). Data collections described below will be conducted year-round from mid-summer 2009 through mid-summer of 2012. Rotenone will be applied at 3 mg L^{-1} to experimental lakes in late fall of 2010 by DNR collaborators, giving us two summers of data before and after the lakes shift from turbid to clear regimes. This experimental shift between regimes will facilitate our ability to demonstrate cause-effect relationships between macrophytes and dissolved O_2, sediment resuspension, decomposition, and OC burial. Large-scale biomanipulations may be thought of as "sledgehammer manipulations" with limited

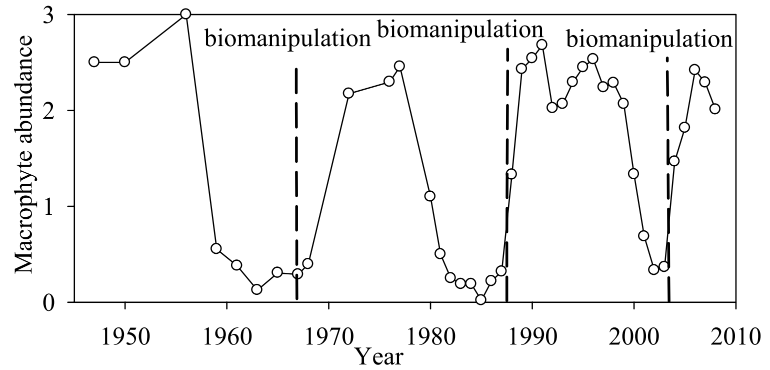


Figure 4. Macrophyte abundance in Lake Christina (a shallow MN lake) from 1947 through 2008. Data are abundance values used by the Minnesota DNR, and show three shifts from phytoplankton dominance to macrophyte dominance in response to three biomanipulations.

application to natural systems (Sarnelle 2003). However, our biomanipulation mimics winterkill of fish, a natural, common process in shallow lakes (Carlson and Berry 1990; Danylchuk and Tonn 2003) and Zimmer et al. (submitted) found that 14% of shallow Minnesota lakes shifted regimes between years. It is possible that lakes in clear and turbid groups may also switch regimes during the course of this study. However, we see these "serendipitous" experiments as only strengthening our ability to demonstrate cause-effect relationships. Our use of multiple lakes, field and lab experiments, and spatially coupled estimates of macrophytes, dissolved O_2, sediment resuspension, decomposition, and carbon burial in individual lakes will allow us to separate influences of macrophytes from other variables such as benthivorous fish.

Specific Aim 1: Determine the sources of organic matter to short-term and long-term burial in shallow lakes.

Critical to understanding how management and natural processes contribute to OC burial in aquatic systems is that we know the sources of the material that is buried. We will examine this specific aim both in the modern environment using plants and organic matter in the watershed and paleo-environments via lake cores. Organic C:N ratios, $\delta^{13}C$ and $\delta^{15}N$ will be measured in terrestrial and aquatic plants from the study lakes and plants in the watersheds and compared with the isotopic signatures that we observe downcore in lake sediments. ***We hypothesize that both terrestrial and aquatic OC are important sources to shallow lakes and that dissolved organic matter (DOM) is an important vector for delivery of terrestrial organic matter for burial in shallow lake sediments.***

Our previous work has demonstrated that organic matter that is buried in the sediments of a couple of these shallow lakes is a mixture all of these materials (Fig. 5). Perhaps most surprising was the fact that a significant fraction of the buried material has a terrestrial signature. One source that will be further examined here is DOM. A recent study concluded that DOM is an important source of buried organic matter in boreal lakes (von Wachenfeldt and Tranvik 2008). The organic carbon burial was strongly correlated with dissolved OC levels and they argued that DOM was directly precipitating. This could be an important source of organic matter in western Minnesota lakes because these lakes have both high inorganic carbon concentrations (50-100 mg C L^{-1}) as well as high DOC concentrations (10->100 mg L^{-1}). At such high concentrations, it is likely that DOC may co-precipitate with carbonates during common whiting events (Otsuki and Wetzel 1973; Kufel and Kufel 2002).

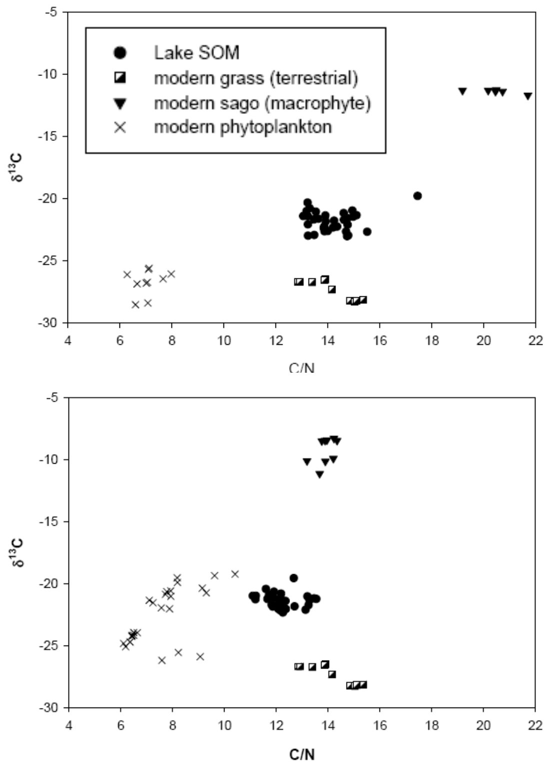


Figure 5. $\delta^{13}C$ plotted against C/N for lakes Mavis East (top) and Mavis West (bottom). Note that sediment organic matter (SOM) seems to be influenced most by macrophyte and terrestrial plant biomass.

In addition to examining the sources of OC to shallow lakes, we will also try to understand what factors have the strongest effects on terrestrial delivery to shallow lakes. We will test for relationships among the proportion of terrestrial carbon in sediment traps and watershed size, slope, and proportion of watershed represented by row-crop agriculture versus native grasses.

Planned studies. We will make measurements of all autotroph biomass components and their elemental and isotopic composition. Macrophyte biomass per unit area and volume will be determined at 20 stations located equidistant along four transects in each lake. Depth will be recorded and macrophytes collected using a PVC quadrant sampler (Schriver et al. 1995). Macrophytes within the sampler will be harvested and weighed, giving both areal and volumetric estimates of macrophyte biomass. Proportion of the total sample represented by each macrophyte species will also be determined. Phytoplankton biomass will be estimated monthly by collecting water samples and measuring chlorophyll *a* concentrations and carbon content. Periphyton will be measured at peak biomass in July by scraping macrophyte leaves and stems, and collecting surface sediments. Biomass will be estimated using chlorophyll *a* concentrations and carbon content (Wetzel and Likens 1991). Terrestrial plant biomass will be estimated in the watershed using GIS in collaboration with our DNR colleagues. We will collect samples from the dominant plants to estimate the elemental and isotopic composition of terrestrial plants. Stable isotope ratio and elemental measurements of terrestrial and aquatic plant carbon and nitrogen ($\delta^{13}C$, $\delta^{15}N$, TOC, TN, C/N) are the geochemical tools that will be used to help uniquely identify different plant sources to the sediments (see Specific Aim 2 below for sediment coring methods).

Watershed and ambient lake features (lake depth, nutrients, watershed size, and land use within watersheds) will be coupled with observations of terrestrial plants and their elemental and isotopic composition to understand terrigenous inputs to lakes. Average lake depth will be estimated from depths at the 20 stations. As part of their 150 lake study, our DNR collaborators will use GIS to analyze the watershed and landscape features of our study sites, and provide data on lake nutrient levels. Variables to be measured include lake elevation, watershed size, slope, and land use (row crops, pasture, etc.) at multiple scales. These watershed features will also be used in our regression models to estimate terrestrial inputs to lakes.

As discussed above, DOM can be an important terrestrial source of organic matter to these lakes, especially in late winter and early spring. We will collect monthly samples for measuring DOM concentration, fluorescence excitation-emission spectra (EEMs; Cory and McKnight 2005) and isotopic composition in the surface waters but we will also extract DOM from surface sediments using both a basic (0.5 N NaOH) and an acidic ($Na_4P_2O_7$) extraction technique (Wolfe et al. 2002), and examine their fluorescence, absorbance, and elemental stoichiometric (C, N and P) properties.

Expected outcomes. Our null hypothesis is that the organic matter that gets buried in the sediments only reflects the biomass composition of the lake and watershed. However, we expect that a higher proportion of macrophyte biomass will reside in the sediments relative to phytoplankton because of higher lignin content (Sun et al. 1997; Filley et al. 2001). Under anaerobic conditions macrophyte tissue should be selectively preserved in these lakes (Specific Aim 2) (Burdige 2007). We also expect that a higher proportion of lake biomass (macrophytes, periphyton, and phytoplankton) will be buried in the sediments than expected based on watershed to lake surface areas. Most of the lakes that we will make measurements in have watersheds that are about 10x larger than the lake surface area. However, high in-lake production rates increase the importance of autochthonous sources of carbon in sediments.

Anticipated problems/alternative strategies. The role of DOM in OC burial has not been examined directly in previous studies. We will try to make connections between the fluorescence, absorbance, and isotopic composition of fulvic and humic acids that we extract from the sediments and the properties of DOM that we measure coming into the lakes seasonally, however, we expect that there will be other types of OC that are extracted that may not have come into the lakes as DOM. Nonetheless, we think this is an important question that needs to be specifically addressed because DOM is typically the largest pool of organic matter in aquatic systems (Wetzel 2001; Cotner and Biddanda 2002). If we find that dissolved OC can be buried at a significant rate in lakes, it could have profound effects on our understanding of mechanisms involved in the global carbon cycle.

Specific Aim 2: Determine organic carbon burial rates in macrophyte vs. phytoplankton dominated systems.

There are a number of reasons why we think that macrophyte systems should bury OC more effectively than phytoplankton. First, they should degrade slower than other autochthonous primary producers; second, they 'engineer' the physical environment to inhibit decomposition (Caraco et al. 2006). Specifically, related to the latter, we hypothesize that macrophyte-dominated systems should have much lower rates of sediment resuspension with two important consequences, one being that resuspended materials are likely to be physically broken down at faster rates and the second being that less oxygen is advected from the surface waters into the sediments. The latter consequence means that buried organic matter is exposed to dissolved O_2 for a shorter period of time in macrophyte-dominated systems than in phytoplankton systems. Lastly, again related to changes in the physical environment, it is likely that macrophyte-dominated systems should be more strongly stratified than are phytoplankton-dominated systems.

We have broken this specific aim into three parts. In the first part, we will examine modern and paleo-OC burial and tie this to the dominant plant type. In the second part, we will examine the hypothesis that the dominant plant type influences the dissolved oxygen regime of shallow lakes (modern and paleo) and in the third portion of this specific aim, we examine how dissolved O_2 availability affects OC decomposition in modern and paleo-environments in clear and turbid systems. We are aware that considerable work has been done in the past looking at dissolved O_2 and decomposition (Bastviken et al. 2004; Van Mooy et al. 2002; Bastviken et al. 2004), but to our knowledge, none of this work has been done in the context of clear and turbid shallow lakes.

Modern burial (short-term deposition). We will use a combination of sediment traps and sediment inventory of the natural isotope ^{7}Be to measure OC deposition at the month to annual scale of time (Fitzgerald et al. 2001). ^{7}Be is produced cosmogenically and has a half-life of ca. 53 days. It sorbs strongly to particles in aqueous systems and its activity is largely independent of particle type (Fitzgerald et al. 2001) making it an excellent tracer of particle deposition. ^{7}Be activity will be measured monthly in multiple sediment traps (3) deployed in each lake as well as in cores taken at the same sites. The sediment resuspension rate in each lake will be calculated by separating residual and 'new' inventories between sampling dates assuming that all delivery to sediment traps and surface sediments is via particle deposition (Canuel et al. 1990).

Planned modern studies. Cylindrical sediment traps will be used that have a height to diameter ratio of 6:1 to reduce resuspension of materials within the trap (Bloesch and Burns 1980). Three sediment traps will be deployed in each lake; one in the center (2-4 m depth), another in the littoral zone (0.5 m depth), and a third trap will be located between the center and littoral zone traps (1 m depth). The sediment traps will be sampled monthly from May-August. Collected material will be subsampled for ^{7}Be, particulate carbon, and δ^{13}C. Sedimentation rates ($mg \cdot m^{-2} \cdot d^{-1}$) of OC are determined by dividing the mass in traps by the duration of deployment and by the area of the trap opening. Subsamples for carbon content and δ^{13}C will be acidified to remove inorganic carbon. Sediment traps will be deployed in all three study years.

Long-term burial. We will use the paleo-record as a tool to understand the relationship between short-term deposition and long-term burial of OC and to understand historical patterns of OC burial in shallow lakes. We will use multiple proxies in sediment cores to determine when the lakes were in macrophyte versus phytoplankton-dominated states and a direct measure of OC in the sediments during those time periods to estimate long-term burial. We will focus on changes occurring over the past 200-300 years, which will provide information both pre- and post-European settlement. Our goals are to 1) understand the historical timing of regime shifts in shallow lakes, 2) understand the ecological conditions associated with regime shifts, 3) understand the historical pattern of carbon burial associated with regime shifts, and 4) determine the relationship between short-term deposition and long-term burial of OC.

Biological proxies will inform us on the timing and nature of historical ecological shifts and regime changes in these systems. Diatom-based paleolimnological techniques have been used throughout

Minnesota to quantitatively reconstruct historical environmental conditions, and develop statewide nutrient criteria (Ramstack et al. 2003; Edlund and Kingston 2004; Edlund 2005; Heiskary and Wilson 2008). Recent paleolimnological work on shallow MN and WI lakes has shown that the diatom communities in sediment cores provide information on the timing of stable regime shifts in these lakes (Kramer 2006; Edlund and Ramstack 2007). However, taken alone, diatom community changes can be subtle. Therefore, additional proxies must be examined in sediment cores from shallow lakes. Preliminary data from Horse Lake in Polk County, WI indicates that shifts in the diatom communities are correlated with macrophyte community shifts, and that when this lake was in the macrophyte-dominated state there is a higher percentage of OC in the sediments (Fig. 6).

Therefore, to characterize regime shifts, we will identify (in addition to diatoms) zooplankton, macrophyte remains, and other macrofossils in ^{210}Pb-dated sediment cores. Changes in the zooplankton species assemblage in cores reflect changing ecological conditions in a lake, and especially respond to changes in fish communities (McGowan et al. 2005). Macrophyte remains in sediment cores give direct evidence of changes in the macrophyte species present over time and information on the ecological state of the system (Ayres et al. 2007). To supplement diatom community data, biogenic silica (BSi) content and accumulation rate will be measured in the cores, which are proxies for historical diatom productivity.

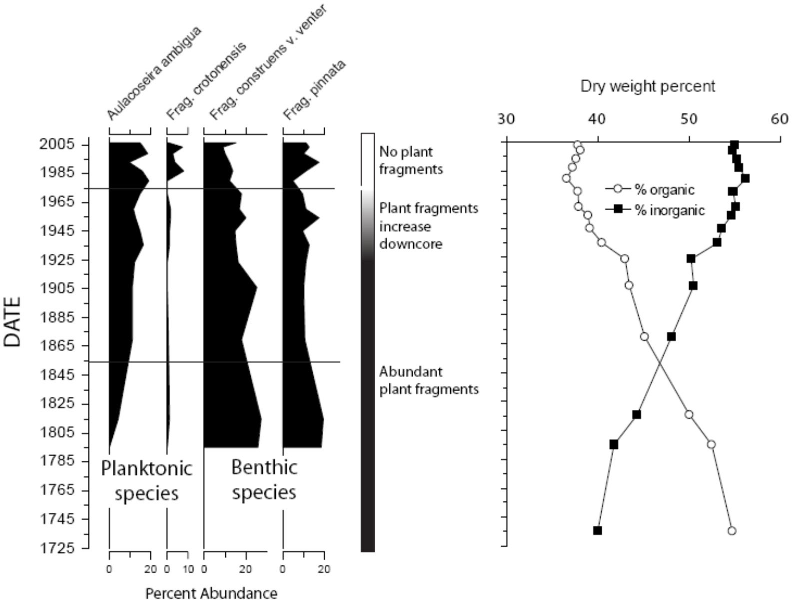


Figure 6. Downcore results of predominant benthic and planktonic diatoms, observations of macrophyte remains, and loss-on-ignition data from Horse Lake, WI (3.4 m maximum depth). Horizontal lines in the diatom stratigraphy indicate the predominant changes in diatom community based on a constrained cluster analysis. Increases in OC coincide with increases in macrophyte remains and greater abundance of benthic diatoms.

In addition to biological proxies, we will analyze OC in sediment cores, as well as historical changes in the sources of carbon and nitrogen. Organic matter is a small but important portion of lake sediment that is made up of a complex mixture of biochemicals that originate from the remains of organisms that once lived in a lake and its watershed (Meyers and Ishiwatari 1993). Downcore investigations of the stable isotopic, elemental, and molecular characteristics of lacustrine organic matter provide evidence that can be used to reconstruct past environmental conditions, climate histories, and human influences (Meyers 2003). In particular, stable isotope ratio and elemental measurements of carbon and nitrogen (δ^{13}C, δ^{15}N, TOC, TN, C/N) are geochemical tools that are widely used in paleoclimate and paleoenvironmental studies involving lake sediments (e.g. Talbot and Johannessen 1992; Hodell and Schelske 1998; Theissen et al. 2005, 2008).

When used together, the stable isotopic and elemental values recorded in sedimentary organic matter can also provide important source information (for Specific Aim 1). C/N ratios can be of further use in distinguishing sources of organic matter. C3 terrestrial plants and lacustrine algae cannot be distinguished on the basis of their δ^{13}C values which fall in a similar range, but their C/N values (Terrestrial plants: 22 to 46; algae: 6-9) are distinct and can be used for this purpose (Meyers and Ishiwatari 1993). Although they are less widely used, the δ^{15}N values of organic matter can be used to identify the source of organic matter as well. The $\delta^{15}N$ values of algae (8.5‰) are often distinct from land plants (0.5‰) because the $\delta^{15}N$ value of dissolved NO_3 used by algae is typically 7-10‰ more enriched than atmospheric N_2 made available to plants by N fixers in the soil (e.g. Peterson and Howarth 1987). Interpretation of $\delta^{15}N$ values can be influenced by the input of isotopically heavy NO_3 ($\delta^{15}N$: 10-25‰) from farm runoff and human sewage (Teranes and Bernasconi 2000) as well.

Planned paleo studies. Multiple piston cores (up to five cores per lake, 1-2 m in length) will be collected from each lake; this technique recovers the very loose uncompacted sediment surface without disturbance. The coring locations will represent a transect across the depositional zone of each lake. One "primary" core from each lake will be ^{210}Pb dated and analyzed for biological proxies. The additional cores will be stratigraphically aligned to the primary core by matching up profiles of magnetic susceptibility and other geochemical markers, as well as biomarkers if necessary (Anderson 1990; Triplett et al. 2009). Organic matter will be analyzed in all cores from each basin. Use of multiple cores will allow us to account for spatial variability in deposition across each lake basin and obtain a historic measure of basin-wide OC burial for each study lake.

Cores will be logged for magnetic susceptibility on a Geotek Standard MSCL with an automated trackfeed at the Limnological Research Center (see attached letter of support). Dry-density (dry mass per volume of fresh sediment), water content, organic content, and carbonate content of sediments will be determined in up to 40 core increments by standard loss-on-ignition techniques.

Sediment cores will be analyzed for ^{210}Pb activity to determine age and sediment accumulation rates for the past 150 years. ^{210}Pb will be measured at 16-20 depth intervals by ^{210}Po distillation and alpha spectrometry methods, and dates determined according to the c.r.s. (constant rate of supply) model. If necessary, secondary dating to determine the 1963-1964 peak in deposition of ^{137}Cs will also be run. Freeze-dried samples are measured for ^{137}Cs at 667 keV using a high-resolution germanium diode gamma detector and multichannel analyzer. Results of the ^{210}Pb analysis will be used in conjunction with loss-on-ignition analysis to determine background and historical sedimentation rates on the cores.

Approximately 15-20 core increments will be analyzed for diatom microfossils in each core; the intervals analyzed will be chosen on a per-lake basis, depending on the land use history of each watershed. Diatoms will be identified to species level, and a minimum of 400 valves will be counted in each sample (chrysophyte cysts will also be included in the counts).

Zooplankton, macrophytes, and other macrofossils will be identified in the same core sections chosen for the diatom analysis. From 1-5 cm^3 of wet sediment will be sieved and material from each fraction will be quantitatively transferred to gridded counting dishes and macrofossils quantified using random fields or scanning the entirety of the sample. Macrophyte seeds, propagules, distinguishable anatomical remains and oocysts (*Chara*) will be identified to the lowest taxonomic unit and indistinguishable plant matter will be quantified using image analysis software (we will modify the techniques of Rasmussen and Anderson (2005) and Ayers (2007)).

Approximately 20 increments per core will be analyzed for BSi following the methods in DeMaster (1979) and Conley and Schelske (2001). Dissolved silica will be measured colorimetrically on a Lachat QuikChem 8000 flow injection autoanalyzer as molybdate reactive silica (McKnight 1991).

Cores will be subsampled for bulk sedimentary organic matter (SOM) at 2 cm intervals to find the primary contributors to buried organic matter, whether it is phytoplankton, macrophytes, or terrestrial plants. Based on our previous ^{210}Pb age-dating work on shallow lakes, this gives a resolution of approximately 5 – 10 years per sample, but intervals may be shortened if dating and other details of sediments warrant higher resolution. Samples for TOC, C/N, and $\delta^{13}C$ are dried at 60° C, ground, weighed, and treated with 6% sulfurous acid to remove all carbonate phases (Verardo et al. 1990). Samples for TN and $\delta^{15}N$ analysis are prepared in nearly the same fashion but are not be reacted with acid, because forms of inorganic N are generally of minimal significance in lake sediments and acid treatment has been shown to significantly influence $\delta^{15}N$ values. All samples will be analyzed using a Carlo Erba NA1500 elemental analyzer/Conflo II device coupled with a Finnigan Delta Plus mass spectrometer in the Stable Isotope Laboratory at Stanford University. Organic C:N (atomic) values are calculated based on TOC and TN results. All $\delta^{13}C$ values are expressed relative to the Pee Dee Belemnite (PDB) standard and all $\delta^{15}N$ values are expressed relative to atmospheric N_2.

Age data are used to determine linear sedimentation rates (LSR) for shallow lakes. Mass Accmulation Rates (MAR) and TOC Mass Accumulation Rates (TOC MAR) will be calculated using the following equations:

MAR ($g\ cm^{-2}\ yr^{-1}$) = Linear sedimentation rate ($cm\ yr^{-1}$) x dry bulk density ($g\ cm^{-3}$)

TOC MAR = MAR x TOC concentration x 1000 ($mg\ cm^{-2}\ yr^{-1}$).

Multi-proxy data will be summarized with multivariate ordinations and stratigraphic diagrams, and temporally correlated with changes in OC in the sediments.

Expected outcomes. Using this approach will allow us to determine how modern carbon burial rates differ in macrophyte versus phytoplankton dominated systems; the use of biomanipulated lakes will strengthen our ability to demonstrate cause-effect relationships between lake state and OC burial. The paleolimnological record will allow us to determine the historical pattern of OC burial associated with regime shifts, and to determine the relationship between short-term deposition and long-term burial of OC. By measuring OC in multiple cores and sediment traps per lake, we will obtain a measure of historic and modern basin-wide OC burial for each study lake.

Anticipated problems/alternative strategies. These techniques will not be successful on shallow lakes that have dried out in the past because ^{210}Pb dating, and the resulting measure of sedimentation rate, is not reliable if the sediment record is not continuous. We will use historic records, in combination with old aerial photos, to target lakes that should have continuous sediment records. With careful site selection, Edlund and Ramstack have had success coring, ^{210}Pb dating, and analyzing the paleo-record of shallow lakes throughout MN.

Specific Aim 2.1: Determine how plants affect dissolved oxygen availability.

Planned studies- Modern redox conditions. To examine how plants affect dissolved oxygen (DO) availability in the modern environment, we will monitor DO levels continuously for short periods of time (biweekly to monthly). We think it is most critical to our hypotheses to have multiple spatial measurements in clear and turbid lakes rather than having a continuous record of DO from each lake. We have requested funds for the purchase of 9 sondes that, together with 3 other sondes already available will be deployed in the lakes. During the growing season, two clear and two turbid lakes will be monitored with DO optical sensor sondes. Sondes will deployed at the surface and near the sediments both in the open water and in the littoral area of the lakes. Sondes will be serviced, re-calibrated and moved to different lakes at monthly intervals. With 12 sondes and moving sondes monthly, each of the 15 lakes will be monitored for a minimum of one month during the summer and we will insure that both turbid and clear lakes are constantly monitored. We will also deploy sondes in the fall until several weeks after ice cover to assess whether and how long they experience hypoxia in the winter.

Previous work in similar lakes indicated that there can be strong horizontal and temporal DO gradients in these productive lakes especially macrophyte-dominated ones (Rose and Crumpton 2006; Van de Bogert et al. 2007). Time series DO will also be analyzed to estimate gross primary production (GPP) and respiration rates (R) and infer net primary production (NPP) (Van de Bogert et al. 2007). The change in DO (ΔO_2) can be related to epilimnetic NEP after accounting for atmospheric O_2 exchange (AtmOX) using the relationship NEP = ΔO2 + AtmOX (Cole et al. 2000). Other parameters needed to calculate AtmOX, temperature and wind speed, are monitored continuously at meteorological stations. These measurements will enable determining if differences in burial are merely a function of NEP, i.e., more autochthonous production equals more burial.

In addition to logging sondes, we will make multiple profiles of DO, temperature and pH at six sites during monthly lake sampling in the growing season and at least three times in the winter. These profiles will also enable estimation of the degree of lake mixing occurring in clear and turbid regimes.

Paleo-redox conditions. There are four commonly used classifications to identify the redox status of natural waters: oxic, suboxic, anoxic, and euxinic. Oxic waters and sediments contain oxygen, while suboxic and anoxic environments are sufficiently reducing to reduce Fe(III) and sulfate respectively. The fourth classification of redox status euxinic, meaning anoxic sediments with sulfide persisting in the water column, also may be observed in some basins with limited circulation.

A number of redox-sensitive elements (RSEs) that exist in recent sediments and organic-rich rocks have been used as indicators of the redox conditions of the natural waters in which they formed (e.g. Wignall and Twitchett 1996; Kimura and Watanabe 2001; Algeo and Maynard 2004; Bostick et al. 2005). Redox-sensitive trace elements are useful because they have multiple oxidation states and depending upon the redox conditions of the depositional environment, they may either remain in solution or form insoluble compounds that are retained in the sediment record. Oxidized conditions tend to favor metal solubility while reducing conditions favor insolubility of trace elements. U, V, and Mo have been particularly useful because when coupled with TOC data, their concentrations help to more specifically distinguish between the four common classifications (oxic, suboxic, anoxic, and euxinic) used to identify the redox status of natural waters (Tribovillard et al., 2006). Biological proxies of paleoanoxia such as chironomids, respond more strongly to productivity and habitat gradients in shallow lakes than oxygen regime (Brodersen et al., 2001).

We will combine our measurement of several RSEs in the sediment with Principal Components Analysis (PCA) to accurately capture past redox conditions. Analyses will be done at UST with an Inductively Coupled Plasma Atomic Emission Spectrometer. We will measure both major (Fe, S) and trace (Co, Cr, Mo, Ni, Pb, Th, U, V, Zn) RSEs in water and sediment samples for each of our study lakes. As these lakes are seasonally anoxic, we will measure water trace element concentrations twice in each year of this study following methods outlined in Hamilton-Taylor et al. (2005) to explore changes in the concentration of RSEs under anoxic and oxic conditions. Sediment samples will be taken at 2 cm intervals from the primary core in each lake and prepared for analysis using a digestion method which uses strong acids (HF, HNO_3) and microwaving of samples to extract RSEs which are often strongly bound (i.e. method outlined in Morford and Emerson 1999). With the large data set that will result, PCA of RSEs concentration data will be useful in determining which of these redox conditions may have been present during sediment deposition.

Expected outcomes. We expect that profiles and monitoring of DO in macrophyte and phytoplankton lakes will show that a higher proportion of the volume in macrophyte lakes becomes anoxic annually. In winter, we expect that these lakes should become anoxic sooner and remain that way under the ice. In summer, we expect that macrophyte lakes may experience anoxia particularly at night in the densest plant beds. We also expect that sediments should reflect plant mediated differences in redox conditions, with more frequent and persistent anoxia when macrophyte remains are found in the sediments.

The use of RSEs is a good test of our hypothesis that the redox status of shallow lake waters is greatly influenced by the dominant plant community (macrophyte vs. phytoplankton). We suspect that oxic (anoxic) lake waters will have higher (lower) concentrations of RSEs. We also suspect that past intervals with higher (lower) concentrations of RSEs in the sediment record will also be those with greater (lower) abundances of macrophyte fragments and/or stable isotopic and elemental signatures that indicate an increased (decreased) presence of macrophytes.

Anticipated Problems/alternative strategies: There are a number of potential problems that could complicate our results. In modern measurements of DO, although we know that macrophyte beds go anoxic even in the daytime (Rose and Crumpton 1996), we do not know if the phytoplankton lakes also experience a similar degree of anoxia. Profiles in some of these lakes indicate that even phytoplankton lakes are often not well-mixed and can be anoxic at the bottom. This is one of the main reasons why we need to make measurements at long temporal and intensive spatial scales, to gain understanding of how great the differences in the DO regimes are between these lake types. For paleo-redox work, it could be that both lake types have nearly to completely anoxic sediments, so finding differences in these regimes may be difficult. Another possible approach that we could take if we do not find sufficient redox differences in the sediment is to make measurements of DO profiles in the sediments using microprobes and use these data along with burial rates to calculate the degree of oxygen exposure in the sediments before final burial (Hartnett et al. 1998). Cotner's lab is currently set up to make these measurements.

Specific Aim 2.2: Determine how dissolved oxygen affects plant decomposition rates.

In situ decomposition rates of macrophytes (*Stuckenia pectinata*), filamentous algae (*Cladophora* spp.), and terrestrial grass (*Andropogon gerardii*) will be estimated on an annual basis. Macrophytes and grasses will be collected from one lake and one watershed to control for potential differences in nutrient content of plants among different lakes, and *Cladophora* will be cultured in the laboratory. In July, samples of each autotroph will be rinsed, weighed, placed in separate 1 mm mesh nylon liter bags (Bayley et al. 1985) and deployed at 3 stations in each lake at multiple depths (0.5 m, 1 m, and 2 m). Seven bags of each type of autotroph will be deployed and one bag retrieved at two weeks, one month, 2 months, 6 months, one year, two years, and three years. In years two and three, 5 bags of each autotroph will be deployed at each station in early July to examine inter-annual variability. We will also examine the rates of decomposition for different types of macrophytes and phytoplankton in the laboratory. The advantage of this approach is that we can control the oxygen regime (aerobic or anaerobic) the plants experience. We will use a factorial design to examine loss of organic matter from these same species at high and no oxygen at constant temperatures (10ºC; near mean annual temperature). Anoxic conditions will be generated by bubbling N_2 gas initially and aerobic conditions maintained by bubbling air continuously. Decomposition rates of the plants and algae in both field and lab experiments will be estimated from observed changes in dry weight and tissue chemical composition over time for each treatment (Enriquez et al. 1993). We will also estimate concentrations of hemicellulose, cellulose, lignin, and cell solubles using a sequential digestion and a fiber analyzer (Ankom Technology, New York, USA); the final acid-insoluble fraction is ashed to determine lignin content on an ash-free dry mass basis (Kay et al. 2008).

Expected outcomes. Previous work has demonstrated that OC decomposition under aerobic and anaerobic conditions are similar initially (Burdige 2007). So we expect that the biggest differences in decomposition rates between aerobic and anaerobic treatments should occur after the first month or two when anaerobic rates should slow relative to aerobic rates. We expect these differences in rates to be most pronounced for the most lignified plants (macrophytes and grasses) rather than algae (Kristensen et al. 1995). We also expect the in situ decomposition rates to be highest in the turbid lakes due to more physical degradation and more oxygenated water columns.

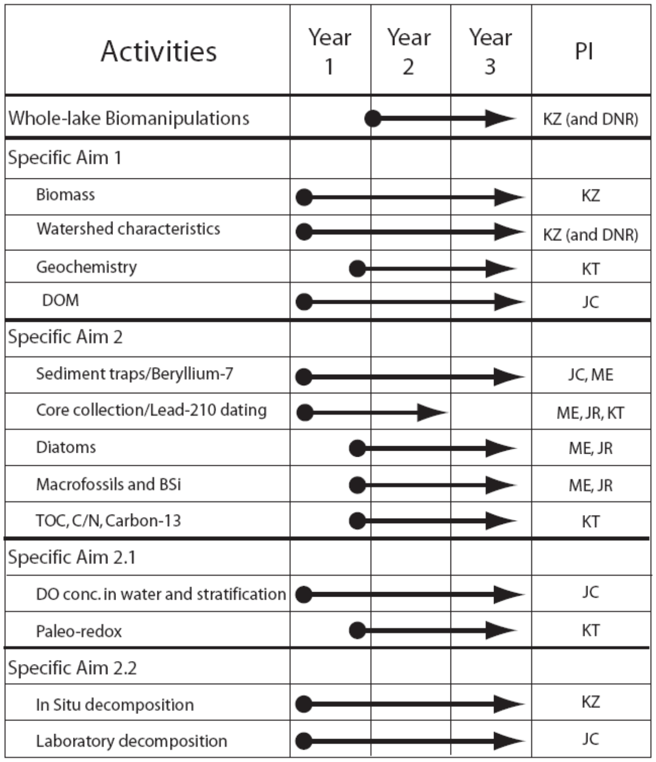
Anticipated problems/alternative strategies. Our choice of 1 mm mesh bags for decomposition represents a balance between biases of larger mesh (loss of smaller pieces from bag) versus smaller mesh (creation of anoxic conditions, excluding macroinvertebrate shredders) (Brinson et al. 1981; Webster and Benfield 1986). We will address this issue by deploying bags with smaller (0.25 mm) and larger (4 mm) mesh sizes in a subset of lakes during the first year and comparing results to the 1 mm bags. One problem with using loss of plant biomass is that it assumes that OC that is no longer part of the plant has decomposed when in fact it may have only been converted to dissolved OC. We will not be able to observe DOM losses in the field experiments but we make these measurements in the laboratory to see if there are big differences in the importance of this loss among plants and in different oxygen regimes.

Overall timetable. This project will have three years of data collection (Fig. 7). Sites will be selected in summer 2009, and sampled from summer 2009 through early summer of 2012. This will provide three years of data collection during the open-water growing season, and three years of data during the time the lakes are frozen over.

V. Broader impacts/ Synergistic interactions

Collaborations. Our research involves collaborators from an undergraduate institution (St Thomas), a research-intensive university (University of Minnesota), an independent research organization (St Croix), and state management and research agencies (MN DNR). These collaborations will bridge the historical boundary between academia and management organizations, increasing the impact of both the basic and applied aspects of our research. Additionally, these collaborations will broaden the education of undergraduates, graduate students, and postdoctoral associates involved with this work.

Management implications. This work has profound management implications. If we find that a significant amount of production is buried, and a positive relationship between macrophytes and burial rates, it would suggest another important reason for managing shallow lakes for these plants. Given the negative relationship between macrophytes and both planktivorous and benthivorous fish (Scheffer 2004), lakes could be actively managed for the removal of atmospheric C by managing fish. Management plans for some lakes consist of maintaining low fish abundance and clear-water regimes due to positive influences on waterfowl abundance (Hanson and Butler 1994b), biodiversity (Scheffer et al. 2006), and aesthetic values (Moss et al. 1997). Adding positive influences on C sequestration to this list may create powerful partners among management agencies and interest groups, facilitating more effective management of greater numbers of ecosystems**.** Another management implication has to do with how macrophyte biomass and composition affects fish kills mediated through DO concentrations.



Activities	Year 1	Year 2	Year 3	PI
Whole-lake Biomanipulations		●——	——→	KZ (and DNR)
Specific Aim 1				
Biomass	●——	——	——→	KZ
Watershed characteristics	●——	——	——→	KZ (and DNR)
Geochemistry	●	——	——→	KT
DOM	●——	——	——→	JC
Specific Aim 2				
Sediment traps/Beryllium-7	●——	——	——→	JC, ME
Core collection/Lead-210 dating	●——	——→		ME, JR, KT
Diatoms	●	——	——→	ME, JR
Macrofossils and BSi	●	——	——→	ME, JR
TOC, C/N, Carbon-13	●	——	——→	KT
Specific Aim 2.1				
DO conc. in water and stratification	●——	——	——→	JC
Paleo-redox	●	——	——→	KT
Specific Aim 2.2				
In Situ decomposition	●——	——	——→	KZ
Laboratory decomposition	●——	——	——→	JC

Figure 7. Timeline and lead PIs for specific activities.

Classic management options for fish include reducing water levels, piscivore stocking, or application of pesticides (Moss et al. 1997). However, numerous studies have shown that landscape features (isolation, ditches, etc.) influence the distribution and abundance of fish in lakes (Magnuson et al. 1998; Hershey et al. 1999), and preliminary data of our DNR collaborators suggests similar relationships in our study areas (B. Herwig unpublished data). GIS data collected by our DNR collaborators will include estimates of distance between shallow lakes and other water bodies, and natural and anthropogenic connections among lakes. If we find strong relationships between C burial and plant dominance, state and federal management agencies may be able to manage C burial in shallow lakes by managing landscapes for fish distributions. This is important, as current management of shallow prairie lakes and wetlands is often focused on water-level management via ditches and culverts, resulting in increased connectivity that facilitates fish dispersion among basins (Hanson et al. 2005). Thus, current management likely increases the abundance and distribution of benthivores and planktivores in shallow lakes at the landscape scale.

Outreach. The Science Museum of Minnesota (SMM) annually invites up to a million learners of all ages to experience their changing world through science, and this research group will seek supplemental funding (e.g. NSF-ISE) to bring the results of this project to a broad audience through exhibit programming and educational outreach. In addition, we have budgeted for website development through the SMM, to explain the relevance of this work to the general public. Edlund has had success working with the SMM web-development staff to make the results of previous NSF-funded work available to the public through the SMM website **(**www.smm.org/mongolia).

Lakes in the global carbon cycle. The importance of small lakes and wetlands in the global carbon cycle is currently not well-studied, and we need to know how effectively these systems impact carbon burial. We do not know how carbon burial scales with lake size and we know even less about how different management practices might interact with these processes. This work will make important contributions to both assessing how organic carbon is stored in these systems in the past as well as understanding how humans have changed their function.

Mentoring Activities for Postdocs. Zimmer will serve as the primary mentor for our requested postdoc, and he has experience mentoring postdocs (Dr. Adam Kay) in the undergraduate environment of UST. However, the postdoc will play a key role for integrating research activities among the three institutions, and will spend extensive time working at both UMM and SMM. Overall, the postdoc will have a unique chance to work in three different types of institutions (UST, UMN, St. Croix), increasing his/her breadth of skills and experience. This will serve as a “hands-on” learning experience for effectively collaborating with people from diverse institutions with diverse research interests, and it will help the postdoc decide on a long-term career path. As the primary mentor, Zimmer will make sure the postdoc does not fall “between the cracks” of the three institutions, and will mentor them on preparing publications and presentations, supervising undergraduate research projects, and supervising field and lab work. If the postdoc’s goal is a faculty position, mentoring will be expanded to include discussions on teaching in a classroom setting, effective teaching methods, and course preparation and design.

VI. Results of prior support:

Cotner: NSF DEB-0519041 (Sep 2005-Aug 2009): Ecological stoichiometry and the relevance of prokaryotic heterotroph biodiversity. The work proposed here will build on ongoing NSF-supported work in Cotner’s laboratory centered on lakes in Minnesota. Important developments and findings from this current project are: (a) development of a repeatable method for characterizing microbial diversity in lakes using PCR coupled with automatic ribosomal intergenic spacer analysis (ARISA); (b) there is considerable evidence of great variation in the elemental composition of the microbial flora (Stets and Cotner in prep.; Cotner et al. 2008; Hall et al. 2008) which has important implications for microbial growth and respiration (Hall et al. 2008). For instance, we have observed that bacteria isolated from Minnesota lakes have extremely variable stoichiometry with C:P ratios varying from 15-207:1 and N:P from 3.3-42: 1 (mol: mol). If this variation is representative of the bacteria in these lakes, stochastic community assembly could have profound effects on the regeneration of N and P. Examination of individual taxa in chemostats indicates that there is also great variation in taxa isolated from Minnesota lakes (Scott et al. in prep.). This project has supported the research of eight undergraduates, three graduate students and a post-doc. Results have been presented at 10 national meetings, three international meetings, and three regional meetings.

Edlund*:* The diatoms, ostracodes, and chironomids of western Mongolia's saline lakes: Biodiversity, ecology, and research applications," (Award# DEB-0316503, ROA supplement DEB-0431529 to M.B. Edlund; Period: 2003-2007). An international partnership (Mongolia, USA, Belgium) surveyed the diatoms, ostracodes, and chironomids of western Mongolia. During the course of two field seasons (2004, 2005), a biotic inventory was conducted on 60 lakes that range from fresh to saline, vary in brine types, and cross major ecotones between the Altai Mountains, the Valley of the Great Lakes, and the western Khangai steppe. This inventory targeted the most useful biota for developing paleoclimate reconstruction models (diatoms, ostracodes) and water-quality indicators (aquatic insects, diatoms). Physico-chemical data taken in concert with biological collections identified unexpected but widespread degraded water quality in this region, which is dominated by nomadic pastoralism. Furthermore, these data have allowed calculation of species-specific environmental optima and tolerances, critical for construction of water-quality and paleolimnologic inference models. An ROA supplement furthered our sampling strategy to include collection of ten sediment cores to test links between grazing intensity, climate, primary productivity, and fire. To date this project has contributed four undergraduate research projects, two doctoral dissertations, fifteen national and international presentations (one plenary), four websites (project site, www.smm.org/mongolia), and seventeen refereed publications**.**

Zimmer and Theissen: No prior NSF support.

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Zimmer, K. D., M. A. Hanson, and M. G. Butler. 2003a. Interspecies relationships, community structure, and factors influencing abundance of submerged macrophytes in prairie wetlands. Wetlands 23: 717-728.

---. 2003b. Relationships among nutrients, phytoplankton, macrophytes, and fish in prairie wetlands. Can. J. Fish. Aquat. Sci. 60: 721-730.

Kyle D. Zimmer

i. Professional Preparation

Luther College	Biology	B.A.	1992
St. Cloud State University	Biology	M.A.	1994
North Dakota State University	Zoology	Ph.D.	2001
University of Minnesota	Aquatic Ecology	Postdoctoral	2001-2003

ii. Appointments

2003- Present	Assistant Professor, Biology Department, University of St Thomas, St. Paul, MN.
2001-2003	Postdoctoral Fellow, Department of Ecology, Evolution, and Behavior, University of Minnesota, St. Paul, MN.
2000-2001	Graduate Research Fellow, Department of Biological Sciences, North Dakota State University, Fargo, ND.
1997	Instructor, Department of Biological Sciences, North Dakota State University, Fargo, ND.
1995-2000	Graduate Research Assistant, Department of Biological Sciences, North Dakota State University, Fargo, ND.

iii. Publications

Five closely related publications (undergraduate authors underlined)

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.

Zimmer, K.D., B.H. Herwig, and L.M. Laurich. 2006. Nutrient excretion by fish in wetland ecosystems and its potential to support algal production. Limnology and Oceanography 51:197-207.

Angeler, D.G., P. Chow-Fraser, M.A. Hanson, S. Sánchez-Carillo, and **K.D. Zimmer**. 2003. Biomanipulation: a useful tool for freshwater wetland mitigation? Freshwater Biology 48:2203-2213.

Zimmer, K.D., M.A. Hanson, and M.G. Butler. 2003. Relationships among nutrients, phytoplankton, macrophytes, and fish in prairie wetlands. Canadian Journal of Fisheries and Aquatic Sciences 60:721-730.

Zimmer, K.D., M.A. Hanson, and M.G. Butler. 2001. Effects of fathead minnow colonization and removal on a prairie wetland ecosystem. Ecosystems 4:346-357.

Five other publications

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 16:282-5 294.

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

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.

Hanson, M.A., **K.D. Zimmer**, M.G. Butler, B.A. Tangen, B.H. Herwig, and N.H. Euliss. 2005. Biotic interactions as determinants of ecosystem structure in prairie wetlands: an example using fish. Wetlands 25:764-775.

Zimmer, K.D., M.A. Hanson, and M.G. Butler. 2003. Interspecies relationships, community structure, and factors influencing the abundance of submerged macrophytes in prairie wetlands. Wetlands:717-728.

iv. Synergistic Activities

Reviewer

- *Archiv für Hydrobiologie*, *Canadian Journal of Fisheries and Aquatic Sciences*, *Ecology*, *Hydrobiologia*, *Journal of the North American Benthological Society*, *Transactions of the American Fisheries Society*, W*etlands*, the Army Corps of Engineers, the Biological Resources Division of the US Geological Survey, the National Science Foundation, and the Natural Sciences and Engineering Research Council of Canada.

Undergraduate Research Advisor

- Advised 28 undergraduate research projects, to-date results of five are published in peer-reviewed journals with an undergraduate as first author (1998-present).

Moderator

- Moderated *Wetlands Ecology* session at the 2003 American Society of Limnology and Oceanography meeting in Salt Lake City, UT.

Committee Member

- Member of the Minnesota Department of Natural Resources' (DNR) Wetland and Fish Rearing Advisory Committee (1999-2001), the Fish Rearing Ad Hoc Committee of the Minnesota DNR (2005-2007), and the academic representative on the Executive Committee of the Minnesota Chapter of the American Fisheries Society (2006-2007).

v. Collaborators and Other Affiliations

a. Collaborators

David Angeler (University of Castilla, Spain); Patricia Chow-Fraser (McMaster University, Canada); Walter Duffy (Humboldt State University); Ned Euliss (Northern Prairie Wildlife Research Center); Rob Grift (Netherlands Fisheries Research); Mark Hanson and Brian Herwig (Minnesota Department of Natural Resources); Jens Peder Jensen and Erik Jeppesen (National Environmental Research Institute, Denmark); Martin Scheffer, Gerben van Geest, and Frank Roozen (Wageningen University, The Netherlands); Salvador Sánchez-Carillo (Instituto Tecnologico de Sonora, Mexico).

b. Graduate and Postdoctoral Advisors

Steven Williams (St. Cloud State University)
Malcolm Butler (North Dakota State University)
Robert Sterner (University of Minnesota)

c. Thesis Advisor and Postgraduate-Scholar Sponsor

Postgraduate sponsor for Adam Kay at the University of St Thomas.

Biographical Sketch
Kevin M. Theissen

i.) Professional Preparation

Carleton College Geology B.A. (high honors) 1996
Stanford University Geological and Environmental Sciences Ph.D. 2003

ii.) Appointments

2006 – Present	Assistant Professor of Geology, University of St. Thomas, St. Paul, MN
2003 – 2006	Assistant Professor of Geology (Limited-term), University of St. Thomas
2002 – 2003	Physical Scientist, U. S. Geological Survey, Menlo Park, CA
2001	Instructor, Stanford University Continuing Studies, Stanford, CA
1997 – 2002	Teaching Assistant and Research Assistant, Stanford University
1996 –1997	Teaching Assistant, Biosphere 2 Center, Oracle, AZ
1994 – 1996	Physical Science Aide, U. S. Geological Survey, Denver, CO

iii.) Publications
Five most relevant to proposed work:

Theissen, K. M., Dunbar, R. B., Rowe, H. D., and Mucciarone, D. A., 2008. Multidecadal- to Century-scale Arid Episodes on the Northern Altiplano During the Middle Holocene, Palaeogeography, Palaeoclimatology, Palaeoecology, 257, 361-376.

Theissen, K. M., Zinniker, D. A., Moldowan, J. M., Dunbar, R. B., and Rowe, H. D., 2005. Pronounced Occurrence of Long-chain Alkenones and Dinosterol in a 25,000 year Lipid Molecular Fossil Record from Lake Titicaca, South America. Geochimica et Cosmochimica Acta, 69, 623-636.

Bostick, B. C., **Theissen, K. M.,** Fendorf, S., and Vairavamurthy, M. A., 2004. Record of Sulfur Redox Status in Sediment Laminations from Lake Titicaca: a Sulfur K-edge X-ray Absorption Near Edge Structure (XANES) Study, Chemical Geology, 219, 163-174.

Theissen, K. M., Dunbar, R. B., Cooper, A. K., Mucciarone, D. A., and Hoffmann, D., 2003. The Pleistocene History of the East Antarctic Ice Sheet In the Prydz Bay Region: Stable Isotopic Results from ODP Site 1167, Global and Planetary Change 39, 227-256.

Theissen, K.M., Dunbar, R.B., and Cooper, A.K., 2003. Data Report: Stable Isotopic Measurements of Sedimentary Organic Matter and N. Pachyderma (s.) from Site 1166, Prydz Bay Continental Shelf In Cooper, A.K., O'Brien, P.E., and Richter, C. (Eds.), Proc. ODP, Sci. Res., 188 [CD-ROM]. Available from: Ocean Drilling Program, College Station, TX.

Five Other Publications: (student authors underlined)

Warnke, D. A., Richter, C., Florindo, F., Damuth, J. E., Balsam, W. L., Strand, K., Ruikka, M., Juntila J., **Theissen, K.**, and Quilty, P., 2004. The Plio-Pleistocene section of ODP Site 188 1165, Prydz Bay, Antarctic continental margin: a high-resolution integrated-stratigraphy committee (HIRISC) report. In: Cooper, A.K. and O'Brien, P.E., (Eds.) Proc.

ODP, Sci. Res., 188 [CD-ROM]. Available from: Ocean Drilling Program, College Station, TX.

O'Brien, P. E., Cooper, A. K., Erwin, P., Florindo, F., Handwerger, D., Lavelle, M., Passchier, S., Pospichal, J. J., Quilty, P. G., Richter, C., **Theissen, K. M.**, Whitehead, J. M, 2004. Prydz Channel Fan and the history of extreme ice advances in Prydz Bay. In: Cooper, A.K. and O'Brien, P.E., (Eds.) Proc. ODP, Sci. Res., 188 [CD-ROM]. Available from: Ocean Drilling Program, College Station, TX.

Rowley, P.D., Cunningham, C.G., Steven, T.A., Workman, J.B., Anderson, J.J., and **Theissen, K.M.** 2002. Geologic map of the Central Marysvale Volcanic Field, southwestern Utah. U.S. Geological Survey, Geologic Investigations Series I-2645-A. [Geologic map]

Theissen, K.M., 2008. The Earth's Record of Climate: A focused-topic introductory course in paleoclimatology. Journal of Geoscience Education, 56, 342-353.

<u>Meyer, E.E.</u>, <u>Quicksall, A.N.</u>, Bostick, B.C., Landis, J.D., and **Theissen, K.M.**, Reduced depositional environments of a Neoproterozoic synglacial carbonate in the Kingston Peak Formation, southern Death Valley region, CA., Accepted pending revisions, Chemical Geology special issue.

iv.) Synergistic Activities

Reviewer:

Journals: Palaeogeography, Palaeoclimatology, Palaeoecology, Science of the Total Environment,Proceedings of the Ocean Drilling Program. Scientific proposals: National Science Foundation (as both mail-in reviewer and panelist), Research Council of Norway.

Faculty contributor and mentor to UST Summer Academy program:

Developed and led field and laboratory activities for 38 underrepresented students over the past three summers. Continued mentorship of students during the academic year. This is part of a proposal "Expanding Our Nation's STEM Talent Base: A strategic Plan at the University of St. Thomas" that was funded for 5 years by the NSF STEP program (Proposal # 0431544) in 2004.

Professional committee member:

Antarctic Drilling Program (ANDRILL) Scientific Measurements Advisory Panel, 2004-present

v.) Collaborators and Other Affiliations

a) Collaborators

Benjamin Bostick (Dartmouth College), Scott Fendorf (Stanford University)
Blas Valero Garces (Consejo Superior de Investigaciones Cientificas, Spain)
J. Michael Moldowan (Stanford University), David A. Mucciarone (Stanford University)
Amy Myrbo (University of Minnesota), Harold Rowe (University of Kentucky)
Kelly MacGregor (Macalester College), Patricio Moreno (Universidad de Chile)
Murthy Vairavamurthy (Brookhaven National Laboratory), David Zinniker (Yale University)

b) Graduate Advisor

Robert B. Dunbar (Stanford University)

Curriculum Vitae: James Bryan Cotner

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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.

Professional Experience:

2008 to present	Professor, Department of Ecology, Evolution and Behavior, University of Minnesota
2001 to 2008	Associate professor, Department of Ecology, Evolution and Behavior, University of Minnesota
1998 to 2001	Assistant professor, Department of Ecology, Evolution and Behavior, University of Minnesota
1992 to 1998	Assistant professor, Department of Wildlife and Fisheries Sciences and Department of Oceanography, Texas A&M University.

Publications (5 most relevant):

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.

Biddanda, B.A., and J.B. Cotner. 2002. Love handles in aquatic ecosystems: Role of dissolved organic carbon drawdown, resuspended sediments and terrigenous inputs in the carbon balance of a Great Lake (Michigan). Ecosystems 5: 431-445**.**

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.

Publications (5 others):

Cotner, J.B., J.W. Ammerman, E.R. Peele, and E. Bentzen. 1997. Nutrient-limited bacterioplankton growth in the Sargasso Sea. Aquatic Microbial Ecology 13:141-149.

Cotner, J.B., B.A. Biddanda, W. Makino, E. Stets. 2004. Organic carbon biogeochemistry of Lake Superior. Aquatic Ecosystem Health and Management 7: 451-464.

Makino, W., J.B. Cotner, R.W. Sterner, and J.J. Elser. 2003. Are bacteria more like plants or animals? Growth rate and substrate dependence of bacterial C:N:P stoichiometry, Functional Ecology 17: 121-130.

Cotner, J.B., W. Makino, B.A. Biddanda. 2005. Temperature affects stoichiometry and biochemical composition of *Escherichia coli*. Microbial Ecology 52:26-33.

Cotner, J. B., Jr. and R. G. Wetzel. 1992. Uptake of dissolved inorganic and organic phosphorus compounds by phytoplankton and bacterioplankton. Limnology and Oceanography 37: 232-243.

Synergistic Activities

- PI for REU Site (2008-present; Itasca Biological Station and Laboratories, ‘Global change at the headwaters of the Mississippi’).
- Director of Undergraduate Studies for Dept. EEB, University of Minnesota (2008-)
- PI for Global Change Ecology, NSF-REU Site, Itasca Biological Station and Laboratories (2008-)
- Co-Chair (with Samantha Joye) of the American Society of Limnology and Oceanography’s Aquatic Sciences Meeting in Feb 2003, Salt Lake City.
- Mentor for American Society for Limnology and Oceanography Committee for Under-represented Minorities in Limnology and Oceanography. (1995)

Collaborators (in the past 48 months)

James W. Ammerman, Texas A&M University, Bopiah Biddanda, University of Minnesota, Pat Brezonik, University of Minnesota, Brian Eadie, NOAA/GLERL, James Elser, Arizona State University, Dan Engstrom, Minnesota Science Museum, W. Fagen, Arizona State University, Wayne Gardner, University of Texas, Jon Harrison, Arizona State University, Sarah Hobbie, University of Minnesota, Jeff Jerremiason, Minnesota Pollution Control Agency, Thomas Johengen, University of Michigan, Peter Lavrentyev, Akron University, Terri Markow, University of Arizona, Ed Nater, University of Minnesota, Robert Sterner, University of Minnesota, Deborah Swackhamer, University of Minnesota, Ed Swain, Minnesota Pollution Control Agency, Larry Wieder, University of Oklahoma, Kirk O. Winemiller, Texas A&M University.

Advisors and advisees

Robert T. Heath, Kent State University, M.Sc.; Robert G. Wetzel (deceased), Ph.D.; Wayne Gardner, Univ. Texas, Postdoctoral research supervisor.

Advisees and Related Experience:

Advisees: Casey Moore, M.Sc., Kelly Gloger, M.Sc., Michael Suplee, M.Sc., Ph.D., David E. Shormann, Ph.D., Yesim Buyukates, M.Sc., Edward Hall, Ph.D., Edward Stets, Ph.D.

BIOGRAPHICAL SKETCH

MARK B. EDLUND

Science Museum of Minnesota-St. Croix Watershed Research Station
16910 152nd St. N., Marine on St. Croix, MN 55047
Phone 651-433-5953 email mbedlund@smm.org

Professional Preparation

University of Minnesota, Twin Cities Campus, Biochemistry, B.S. (1987)
University of Michigan, Ann Arbor, Natural Resources, M.S. (1992)
University of Michigan, Ann Arbor, Natural Resources, Ph.D. (1998)
University of Michigan, Science Museum of Minnesota, Post-doc (1998-2001)

Appointments

2007-present, Senior Scientist, Science Museum of Minnesota, St. Croix Watershed Research Station
2002-2006, Associate Scientist, Science Museum of Minnesota, St. Croix Watershed Research Station
2001-present, Adjunct Faculty, Univerisity of Minnesota, Geology and Geophysics, Water Resources Science
2001-present, Adjunct Faculty, National University of Mongolia, Biology Faculty
2000-2002, Assistant Scientist, St. Croix Watershed Research Station, Science Museum of Minnesota
1998-2001, Postdoctoral Research Fellow, Center for Great Lakes and Aquatic Sciences, University of Michigan
1998-1999, International Research Fellow, National Science Foundation, Mongolian State University and University of Michigan
1997-1998, Rackham Predoctoral Fellow, University of Michigan
1987-1997, Research Assistant I, Center for Great Lakes and Aquatic Sciences, University of Michigan

Five Publications Relevant to Proposed Activity

Edlund, M. B., Engstrom, D. R., Triplett, L., Lafrancois, B. M. and Leavitt, P. R. 2009. Twentieth-century eutrophication of the St. Croix River (Minnesota-Wisconsin, USA) reconstructed from the sediments of its natural impoundment. Journal of Paleolimnology. DOI:10.1007/s10933-008-9296-1

Triplett, L. D., Engstrom, D. R. and **Edlund, M. B.** 2009. A whole-basin stratigraphic record of sediment and phosphorus loading to the St. Croix River, USA. Journal of Paleolimnology DOI:10.1007/s10933-008-9290-7

Shinneman, A. L. C., **Edlund, M. B.**, Almendinger, J. E. and Soninkhishig, N. 2009. Diatoms as indicators of water quality in Western Mongolian lakes: a 54-site calibration set. Journal of Paleolimnology DOI:10.1007/s10933-008-9282-7

Heiskary, S. A., Swain, E. M. and **Edlund, M. B.** 2004. Reconstructing Historical Water Quality in Minnesota Lakes from Fossil Diatoms. Environmental Bulletin No. 4: 1-8.

Edlund, M. B. and Stoermer, E. F. 2000. A 200,000-year, high-resolution record of diatom productivity and community makeup from Lake Baikal shows high correspondence to the marine oxygen-isotope record of climate change. Limnology and Oceanography 45:948-962.

Five Other Significant Publications

Edlund, M. B., Triplett, L. D., Tomasek, M. and Bartilson, K. 2009. From paleo to policy: partitioning of historical point and nonpoint phosphorus loads to the St. Croix River, Minnesota-Wisconsin, USA. Journal of Paleolimnology DOI: 10.1007/s10933-008-9288-1

Serieyssol, C. A., **Edlund, M. B.** and Kallemeyn, L.W. 2009. Impact of logging, damming, and hydromanagement on two boreal lakes: a paleolimnological before—after, control—impact study. Journal of Paleolimnology DOI:10.1007/s10933-008-9300-9

Edlund, M. B., Taylor, C. M., Schelske, C. L. and Stoermer, E. F. 2000. *Thalassiosira baltica* (Bacillariophyta), a new exotic species in the Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences 57:610-615.

Edlund, M. B. and Stoermer, E. F. 1997. Review: Ecological, evolutionary, and systematic significance of diatom life histories. Journal of Phycology 33:897-918.

Edlund, M. B., Stoermer, E. F. and Pilskaln, C. H. 1995. Siliceous microfossil succession in the recent history of two basins in Lake Baikal Siberia. J. Paleolimnol. 14:165-184.

Synergistic Activities

1. Visiting Professor, 2003-present, Iowa State University, Iowa Lakeside Laboratory, co-teach Ecology and Systematics of Diatoms, the only North American summer diatom course offered offered continuously for 46 years
2. Participation of nine undergraduates (three UROP, four supported by NSF-ROA) in previous NSF-funded projects
3. Council, International Society for Diatom Research, 2002-2006
4. Associate Editor, 2006-present, *Phycologia*, International Phycological Society
5. Participation in NAWQA Diatom Taxonomy Workshops at Academy of Natural Sciences of Philadelphia (2004-2007)

Collaborators and Other Affiliations (last five years)

Collaborators and Co-Editors:

Andresen, N. A., University of Michigan; Bixby, R. J., University of New Mexico; Brant, L. A., Northern Iowa University, Earth Sciences, Engstrom, D. R., Science Museum of Minnesota; Jahn, R., Botanic Garden and Botanical Museum Berlin-Dahlem, Free University Berlin; Jamsran, Ts., National University of Mongolia, Biology; Kim, Y. H., Chungbuk National University, Korea; Levkov, Z., Krstic, S. and Nakov, T., St. Cyril and Methodius University (Macedonia), Biology; Morales, E. A., Academy of Natural Sciences Philadelphia; Peck, J., University of Akron, Geology; Schelske, C. L., University of Florida, Fisheries and Aquaculture; Soninkhishig, N., National University of Mongolia, Biology; Spaulding, S. A., University of Colorado, INSTAAR; Stoermer, E. F., University of Michigan (retired); Triplett, L. D., Gustavus Adolphus College; Williams, R. M., University of Michigan, Natural Resources; Wolfe, A. P., University of Alberta, Earth & Atmos. Sciences

Proposal Collaborators

Dr. Kyle Zimmer, University of St. Thomas, Dr. Jim Cotner, University of Minnesota, Dr. Kevin Theissen, University of St. Thomas

Graduate and Postdoctoral Advisors

Stoermer, E. F., University of Michigan, M.S. (1992), Ph.D. (1998), Post-doc (1998-2001)

Thesis Advisor and Postgraduate-Scholar Sponsor

Dr. N. Soninkhishig, Biology Faculty, National University of Mongolia
Dr. Avery Cook Shinneman, Postdoc, University of Nebraska
Sara Mueller, MSc, Minnesota Pollution Control Agency
Kristina Brady, MSc, University of Minnesota, Limnological Research Center
(two current students)

SUMMARY PROPOSAL BUDGET

YEAR 1

	FOR NSF USE ONLY		
ORGANIZATION **University of St. Thomas**	PROPOSAL NO.	DURATION (months)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kyle D Zimmer**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months			Funds Requested By proposer	Funds granted by NSF (if different)
	CAL	ACAD	SUMR		
1. **Kyle D Zimmer - Assistant Professor**	0.00	0.00	1.00	$ **6,016**	$
2. **Kevin M Theissen - Assistant Professor**	0.00	0.00	0.50	**3,154**	
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**2**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.50	**9,170**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**35,000**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**4**) UNDERGRADUATE STUDENTS				**18,658**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**62,828**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**13,046**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**75,874**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
Electronic dessicator			**$ 800**		
Square-back canoe			**1,400**		
TOTAL EQUIPMENT				**2,200**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**3,700**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**10,890**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**10,890**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**92,664**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs (Rate: 37.0000, Base: 90464)**					
TOTAL INDIRECT COSTS (F&A)				**33,472**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**126,136**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **126,136**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME **Kyle D Zimmer**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Susan huber**	Date Checked	Date Of Rate Sheet	Initials - ORG

1 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION	FOR NSF USE ONLY		
University of St. Thomas	PROPOSAL NO.	DURATION (months)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kyle D Zimmer**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months			Funds Requested By proposer	Funds granted by NSF (if different)
	CAL	ACAD	SUMR		
1. **Kyle D Zimmer - Assistant Professor**	0.00	0.00	1.00	$ **6,196**	$
2. **Kevin M Theissen - Assistant Professor**	0.00	0.00	0.50	**3,249**	
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**2**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.50	**9,445**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**36,050**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**4**) UNDERGRADUATE STUDENTS				**19,218**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**64,713**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**13,437**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**78,150**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**3,811**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**27,058**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**27,058**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**109,019**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs (Rate: 37.0000, Base: 109019)**					
TOTAL INDIRECT COSTS (F&A)				**40,337**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**149,356**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **149,356**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $

PI/PD NAME	FOR NSF USE ONLY		
Kyle D Zimmer	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Susan huber**	Date Checked	Date Of Rate Sheet	Initials - ORG

2 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION **University of St. Thomas**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	 Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kyle D Zimmer**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Kyle D Zimmer - Assistant Professor**	0.00	0.00	1.00	$ **6,382**	$
2. **Kevin M Theissen - Assistant Professor**	0.00	0.00	0.50	**3,347**	
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**2**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.50	**9,729**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**1**) POST DOCTORAL SCHOLARS	12.00	0.00	0.00	**37,132**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**4**) UNDERGRADUATE STUDENTS				**19,794**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**66,655**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**13,840**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**80,495**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**3,925**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**10,874**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**10,874**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**95,294**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Modified Total Direct Costs (Rate: 37.0000, Base: 95294)**					
TOTAL INDIRECT COSTS (F&A)				**35,259**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**130,553**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **130,553**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME **Kyle D Zimmer**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Susan huber**	Date Checked	Date Of Rate Sheet	Initials - ORG

3 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY
PROPOSAL BUDGET

Cumulative

ORGANIZATION **University of St. Thomas**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Kyle D Zimmer**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Kyle D Zimmer - Assistant Professor**	0.00	0.00	3.00	$ **18,594**	$
2. **Kevin M Theissen - Assistant Professor**	0.00	0.00	1.50	**9,750**	
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**2**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	4.50	**28,344**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**3**) POST DOCTORAL SCHOLARS	36.00	0.00	0.00	**108,182**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**12**) UNDERGRADUATE STUDENTS				**57,670**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**194,196**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**40,323**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**234,519**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **$ 2,200**					
TOTAL EQUIPMENT				**2,200**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**11,436**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**48,822**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**0**	
TOTAL OTHER DIRECT COSTS				**48,822**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**296,977**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**109,068**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**406,045**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **406,045**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME **Kyle D Zimmer**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Susan huber**	Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget justification

Salaries and Wages

Dr. Kyle Zimmer is the PI on this project and will be responsible for overall coordination among collaborators at the University of St. Thomas, the University of Minnesota, the St. Croix Watershed Research Station, and the Minnesota Department of Natural Resources. He will also be responsible for measuring macrophyte, phytoplankton, and periphyton biomass in the study sites, and will also conduct the in-lake decomposition experiments on macrophytes, algae, and terrestrial plants. He will also supervise one undergraduate and NSF one postdoc at the University of St Thomas. Zimmer requests 3 months of summer support over the three years of this grant to support these efforts (one month per year). Theissen is a Co-PI on the project and will be responsible for working with the St Croix Watershed Research Station to collect sediment cores from our study sites, as well as analysis of sediment cores for stable isotopes, redox sensitive elements, and carbon burial rates. He will also supervise one undergraduate student at St. Thomas. Theissen requests 1.5 months of summer support over three years (0.5 months per year) to support these activities.

We also request support for one postdoctoral associate at the University of St. Thomas (12 months of salary per year for three years). The postdoc will be responsible for assisting PI Zimmer with data collection on biomass decomposition of autotrophs in our study sites, and assist the other PIs with collection and analysis of data on lake cores, sediment resuspension, and dissolved oxygen dynamics. The postdoc will also mentor two undergraduate students involved with the project. For each year we also request support for four undergraduates working full time during the summer, and three undergraduates working part time during the academic school year.

All salaries are adjusted 3% for inflation in years 2 and 3. As per St. Thomas policy, fringe benefits are calculated at 7.65% for Theissen and Zimmer, 32% for the postdoc, 7.65% for undergraduates in the summer, and 0% for undergraduates during the school year.

Equipment

In year 1 we request $1,400 for a square-back canoe necessary for this type of work. This boat will be supplemented by boats in Zimmer's lab and from our DNR collaborators. We also request $800 in year 1 for an automatic desiccator to preserve samples in the lab.

Materials and Supplies

In year 1 we request funds for a trolling motor ($400) and batteries ($240) for the canoe. We also request $1,000 for field supplies (sample jars, sediment traps, waders, coolers, etc.), $1500 for general lab supplies (supplies for decomposition measurements, reagents, etc.), $4,750 for off-site analysis of stable isotopes (δ^{13}C and δ^{15}N) and CN content in autotrophs, sediment cores, sediment traps, and surface sediments (based on $10 per sample), $1,000 for on-site analysis of CN content of decomposition bags (internal standards, gases, maintenance), and $2,000 to support on-site analysis of redox-sensitive elements (compressed gases for ICP-AES, internal standards, acids for sediment digestions). Field, lab, isotope, CN, and redox expenses are adjusted with a 3% inflation in years 2 and 3. We also request $16,500 in year 2 to purchase rotenone, which will be used to induce fish kills and shift our experimental lakes from phytoplankton dominance to macrophyte dominance.

Travel

We request $3,700 for travel in year 1 to cover costs associated with our field work. This includes mileage costs for an estimated 4,000 miles of travel, as well as per diem and lodging costs for field crews during over-night travel. This cost is increased 3% for inflation in years 2 and 3.

Indirect costs

The approved St. Thomas total modified indirect cost rate is 37% of all costs minus equipment costs (defined at St. Thomas as items costing more than $500).

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **University of Minnesota-Twin Cities**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	 Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **James B Cotner**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **James B Cotner - PI**	0.00	0.00	1.00	$ **9,717**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**9,717**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	6.00	0.00	0.00	**21,874**	
3. (**1**) GRADUATE STUDENTS				**9,277**	
4. (**2**) UNDERGRADUATE STUDENTS				**3,000**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**43,868**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**18,548**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**62,416**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **laptop computer and/or PDA** **$ 2,500** **Multi-sensor water quality sondes (9)** **45,000**					
TOTAL EQUIPMENT				**47,500**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**5,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**9,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**1,500**	
TOTAL OTHER DIRECT COSTS				**10,500**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**125,416**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 51.0000, Base: 69754)**					
TOTAL INDIRECT COSTS (F&A)				**35,575**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**160,991**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **160,991**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME **James B Cotner**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kevin McKoskey**	Date Checked	Date Of Rate Sheet	Initials - ORG

1 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION **University of Minnesota-Twin Cities**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	 Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **James B Cotner**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **James B Cotner - PI**	0.00	0.00	1.00	$ **10,008**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**10,008**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	6.00	0.00	0.00	**22,530**	
3. (**1**) GRADUATE STUDENTS				**9,834**	
4. (**2**) UNDERGRADUATE STUDENTS				**3,090**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**45,462**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**19,350**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**64,812**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**5,150**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**9,270**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**1,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**1,500**	
TOTAL OTHER DIRECT COSTS				**11,770**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**81,732**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 51.0000, Base: 73080)**					
TOTAL INDIRECT COSTS (F&A)				**37,271**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**119,003**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **119,003**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME **James B Cotner**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kevin McKoskey**	Date Checked	Date Of Rate Sheet	Initials - ORG

***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION **University of Minnesota-Twin Cities**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	 Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **James B Cotner**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **James B Cotner - PI**	0.00	0.00	1.00	$ **10,309**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	1.00	**10,309**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	6.00	0.00	0.00	**23,206**	
3. (**1**) GRADUATE STUDENTS				**10,424**	
4. (**2**) UNDERGRADUATE STUDENTS				**3,183**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**47,122**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**20,190**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**67,312**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**5,305**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**9,548**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**1,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**1,500**	
TOTAL OTHER DIRECT COSTS				**12,048**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**84,665**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **MTDC (Rate: 51.0000, Base: 75493)**					
TOTAL INDIRECT COSTS (F&A)				**38,501**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**123,166**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **123,166**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $			
PI/PD NAME **James B Cotner**		**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kevin McKoskey**		Date Checked	Date Of Rate Sheet	Initials - ORG

3 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION **University of Minnesota-Twin Cities**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **James B Cotner**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **James B Cotner - PI**	0.00	0.00	3.00	$ **30,034**	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	3.00	**30,034**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**3**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	18.00	0.00	0.00	**67,610**	
3. (**3**) GRADUATE STUDENTS				**29,535**	
4. (**6**) UNDERGRADUATE STUDENTS				**9,273**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**136,452**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**58,088**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**194,540**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **$ 47,500**					
TOTAL EQUIPMENT				**47,500**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**15,455**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**27,818**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**2,000**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**4,500**	
TOTAL OTHER DIRECT COSTS				**34,318**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**291,813**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**111,347**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**403,160**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **403,160**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME **James B Cotner**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Kevin McKoskey**	Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Justification

SALARIES & WAGES

Dr. James Cotner will have overall responsibility for the development and implementation of the project at the University of Minnesota. His research group will be responsible for measuring production, decomposition (via sondes), and respiration, and he will supervise a technician, and one graduate student (50% one semester) and two undergraduates in the summer. Cotner has asked for 3 months summer support over the 3 years of the project for these efforts. His technician will be supported for a total of 18 months over the 3 years of the project.

The fringe benefit rates are pro-rated to the budget periods based on the following rates: academic (30.4%), post-docs (17.14%), graduate students (60%), and civil service (32.7%).

PERMANENT EQUIPMENT

We have requested $45,000 (ca. $5,000 each) for nine multi-sensor water quality sondes. These new instruments will be combined with several in Cotner's laboratory already (3) to be deployed in the shallow lakes for measuring dissolved oxygen and temperature dynamics. We expect that the new sondes will be Hydrolab or Eureka instruments that will measure DO, temperature, pH, conductivity and turbidity.

We have also requested $2,500 for a laptop computer and/or PDA that will be used for calibrating, setting up parameter files and downloading data from these field instruments.

EXPENDABLE SUPPLIES AND EQUIPMENT

Laboratory supplies include analytical standards, reagents, solvents, disposable labware, filters, fluorescent probes, maintenance costs associated with sondes, fluorometer, microplate readers, etc.

OTHER COSTS

Other costs include lab services; we have also included $1500 in years 1-3 for nutrient analyses (CHN and dissolved nutrients) and stable isotope (del^{13}C) measurements.

TRAVEL

We have requested funds for travel to and housing during work at the field site ($3500; 14 trips x $250 per trip plus one scientific meeting @ $1,500) and 3% inflation in following years.

PUBLICATIONS

We request $2,000 for publishing costs. The publishing budget should be sufficient to partially defray the cost of several publications in societal journals.

INDIRECT COSTS

The currently approved (MDTC) overhead rate is 51% of all costs minus permanent equipment, graduate student fringe benefits and participant support costs.

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION **Science Museum of Minnesota**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	 Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Mark B Edlund**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Mark B Edlund - co-PI**	1.00	0.00	0.00	$ **5,625**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	1.00	0.00	0.00	**5,625**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	4.00	0.00	0.00	**16,871**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**22,496**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**9,223**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**31,719**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**3,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**3,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**29,000**	
TOTAL OTHER DIRECT COSTS				**32,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**66,719**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Other direct costs (Rate: 43.0900, Base: 32000) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**28,750**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**95,469**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **95,469**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME **Mark B Edlund**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Eric Jolly**	Date Checked	Date Of Rate Sheet	Initials - ORG

1 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

**** I- Indirect Costs**
Salaries and fringe benefits (Rate: 43.0900, Base 31719)
Travel (Rate: 43.0900, Base 3000)

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION **Science Museum of Minnesota**	**FOR NSF USE ONLY**		
	PROPOSAL NO.	DURATION (months)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Mark B Edlund**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Mark B Edlund - co-PI**	1.00	0.00	0.00	$ **5,794**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	1.00	0.00	0.00	**5,794**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**2**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	4.50	0.00	0.00	**19,877**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**25,671**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**10,525**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**36,196**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**4,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**4,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**46,000**	
TOTAL OTHER DIRECT COSTS				**50,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**90,196**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Other direct costs (Rate: 43.0900, Base: 50000) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**38,866**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**129,062**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **129,062**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME **Mark B Edlund**	**FOR NSF USE ONLY**		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Eric Jolly**	Date Checked	Date Of Rate Sheet	Initials - ORG

2 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 2

**** I- Indirect Costs**
Salaries and fringe benefits (Rate: 43.0900, Base 36196)
Travel (Rate: 43.0900, Base 4000)

SUMMARY PROPOSAL BUDGET

YEAR 3

	FOR NSF USE ONLY		
ORGANIZATION **Science Museum of Minnesota**	PROPOSAL NO.	DURATION (months)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Mark B Edlund**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Mark B Edlund - co-PI**	1.00	0.00	0.00	$ **5,968**	$
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	1.00	0.00	0.00	**5,968**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**1**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	4.50	0.00	0.00	**20,473**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**26,441**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**10,841**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**37,282**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**2,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**3,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**15,000**	
TOTAL OTHER DIRECT COSTS				**18,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**57,282**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **Other direct costs (Rate: 43.0900, Base: 18000) (Cont. on Comments Page)**					
TOTAL INDIRECT COSTS (F&A)				**24,683**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**81,965**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **81,965**	$

M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $		
PI/PD NAME **Mark B Edlund**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Eric Jolly**	Date Checked	Date Of Rate Sheet	Initials - ORG

3 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET COMMENTS - Year 3

**** I- Indirect Costs**
Salaries and fringe benefits (Rate: 43.0900, Base 37282)
Travel (Rate: 43.0900, Base 2000)

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION **Science Museum of Minnesota**	**FOR NSF USE ONLY** PROPOSAL NO.	DURATION (months) Proposed	 Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Mark B Edlund**	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Mark B Edlund - co-PI**	3.00	0.00	0.00	$ **17,387**	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	3.00	0.00	0.00	**17,387**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**4**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	13.00	0.00	0.00	**57,221**	
3. (**0**) GRADUATE STUDENTS				**0**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**74,608**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**30,589**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**105,197**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**9,000**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ **0** 2. TRAVEL **0** 3. SUBSISTENCE **0** 4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**10,000**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**0**	
3. CONSULTANT SERVICES				**0**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**90,000**	
TOTAL OTHER DIRECT COSTS				**100,000**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**214,197**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				**92,299**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**306,496**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ **306,496**	$

M. COST SHARING PROPOSED LEVEL $ **0** AGREED LEVEL IF DIFFERENT $

PI/PD NAME **Mark B Edlund**	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Eric Jolly**	Date Checked	Date Of Rate Sheet	Initials - ORG

C ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

Budget Justification

Funding for this portion of the proposal will be used to cover six general expense lines that include: (1) co-PI (Edlund) salary and fringe benefits, (2) professional personnel (Ramstack) salary and fringe benefits, (3) technician salary and fringe benefits, (4) other direct costs associated with supplies and sample analysis, (5) domestic travel and (6) indirect costs.

Year 1

Senior Personnel and Fringe Benefits: Edlund requests 1 month of salary; fringe rate (including benefits and PTO) at the Science Museum of Minnesota is 41%. Edlund will manage the SCWRS portion of the project and will coordinate coring efforts.

Other Personnel: Ramstack requests 4 months of salary; fringe rate (including benefits and PTO) at the Science Museum of Minnesota is 41%. Ramstack will coordinate the dating of the cores, and will be responsible for the diatom and biochemical analyses.

At no expense to this portion of the project, the SCWRS will be co-hosting (throughout all three years of the project) the post-doctoral scholar who is appointed at the University of St. Thomas, as well as two undergraduates from the University of St. Thomas. The post-doc will be responsible for the macrophyte and zooplankton analyses in the cores; the undergraduates will work with Ramstack and the post-doc on the biochemical and macrophyte analyses.

Other Direct Costs: Miscellaneous lab, field, and office supplies are budgeted in Year 1 ($3,000) to support fieldwork, diatom, multi-proxy, and biogenic silica analyses. Other costs (Line G6) include $29,000 for 7-Be gamma analysis for modern burial estimates (sediment trap and short cores) and 210-Pb dating of seven sediment cores collected in Year 1. These costs are standard analytical charges for isotopic analysis at SCWRS.

Travel: In Year 1, $3,000 is budgeted for domestic travel to collect sediment cores from seven lakes.

Indirects: Science Museum of Minnesota federal indirect rate is 43.09%.

Year 2

Senior Personnel and Fringe Benefits: Edlund requests 1 month of salary; fringe rate (including benefits and PTO) at the Science Museum of Minnesota is 41%. Edlund will manage the SCWRS portion of the project and will coordinate coring efforts.

Other Personnel: Ramstack requests 4 months of salary; fringe rate (including benefits and PTO) at the Science Museum of Minnesota is 41%. Ramstack will coordinate the dating of the cores, and will be responsible for the diatom and biochemical analyses. Funds are requested for 0.5 months of salary for an SMM technician to create a project website; fringe rate (including benefits and PTO) at the Science Museum of Minnesota is 41%. SCWRS will continue to co-host the post-doctoral scholar and undergraduate researcher (see Year 1 for details).

Other Direct Costs: Miscellaneous lab, field, and office supplies are budgeted in Year 2 ($4,000) to support fieldwork, diatom, multi-proxy, and biogenic silica analyses. Other costs (Line G6) include $46,000 for 7-Be gamma analysis for modern burial estimates (sediment trap and short cores) and 210-Pb dating of eight sediment cores collected in Year 2. These costs are standard analytical charges for isotopic analysis at SCWRS.

Travel: In Year 1, $4,000 is budgeted for domestic travel to collect sediment cores from eight lakes.

Indirects: Science Museum of Minnesota federal indirect rate is 43.09%.

Year 3

Senior Personnel and Fringe Benefits: Edlund requests 1 month salary; fringe rate (including benefits and PTO) at the Science Museum of Minnesota is 41%. Edlund will manage the SCWRS portion of the project.

Other Personnel: Ramstack requests 4 months of salary; fringe rate (including benefits and PTO) at the Science Museum of Minnesota is 41%. Ramstack will be responsible for the diatom and biochemical analyses. Funds are requested for 0.5 months of salary for an SMM technician to create a project website; fringe rate (including benefits and PTO) at the Science Museum of Minnesota is 41%. SCWRS will continue to co-host the post-doctoral scholar and undergraduate researcher (see Year 1 for details).

Other Direct Costs: Miscellaneous lab, field, and office supplies are budgeted in Year 3 ($3,000) to support fieldwork, diatom, multi-proxy, and biogenic silica analyses. Other costs (Line G6) include $15,000 for 7-Be gamma analysis for modern burial estimates (sediment trap and short cores) in Year 3. These costs are standard analytical charges for isotopic analysis at SCWRS.

Travel: Funds are requested ($2,000) for Edlund and Ramstack to attend a domestic meeting (e.g., GSA, AGU, ASLO).

Indirects: Science Museum of Minnesota federal indirect rate is 43.09%.

Kyle Zimmer
Current and Pending Support

Project/Proposal Title: Collaborative Research (RUI): Burial of organic carbon in temperate, shallow lakes.
Source of Support: NSF
Project Location: University of St. Thomas
Total Award Amount: $406,046
Starting Date (MM/DD/YY): 07/01/09
Ending Date (MM/DD/YY): 06/30/12
Support Type: Pending (this proposal)
Person-months Per Year Committed to the Project:
Calendar: Academic: 0.0 Summer: 1.0

Project/Proposal Title: Development of best-management practices (BMPs) for aquaculture in Minnesota
Source of Support: Minnesota Department of Natural Resources
Project Location: University of St. Thomas
Total Award Amount: $11,148
Starting Date (MM/DD/YY): 11/03/08
Ending Date (MM/DD/YY): 06/30/09
Support Type: Current
Person-months Per Year Committed to the Project:
Calendar: Academic: 0.0 Summer: 1.0

Project/Proposal Title: Regional comparisons of relationships among landscape setting, ambient nutrients, land use, fish communities, and ecological characteristics of shallow lakes.
Source of Support: State of Minnesota
Project Location: University of St. Thomas
Total Award Amount: $44,056
Starting Date (MM/DD/YY): 07/01/08
Ending Date (MM/DD/YY): 06/30/12
Support Type: Current
Person-months Per Year Committed to the Project:
Calendar: 0.0 Academic: 0.0 Summer: 0.0

Project/Proposal Title: Undergraduate Science Research Program.
Source of Support: Merck/AAAS
Project Location: University of St. Thomas
Total Award Amount: $60,000
Starting Date (MM/DD/YY): 06/01/07
Ending Date (MM/DD/YY): 06/1/10
Support Type: Current
Person-months Per Year Committed to the Project:
Calendar: 0.0 Academic: 0.0 Summer: 0.0

Project/Proposal Title: Carbon sequestration in Minnesota’s wetlands: An important sink with management implications.
Source of Support: Inst. Renewable Energy in the Environment (Univ. Minnesota)
Project Location: University of St. Thomas
Total Award Amount: $333,000
Starting Date (MM/DD/YY): 08/01/05

Ending Date (MM/DD/YY): 07/31/09
Support Type: Current
Person-months Per Year Committed to the Project:
Calendar: 0.0 Academic: 0.0 Summer: 0.0