2010 annual report

U.S. GEOLOGICAL SURVEY

NPS AIR RESOURCES DIVISION

INSTAAR, UNIVERSITY OF COLORADO

UNIVERSITY OF ALBERTA

GRAND TETON NATIONAL PARK

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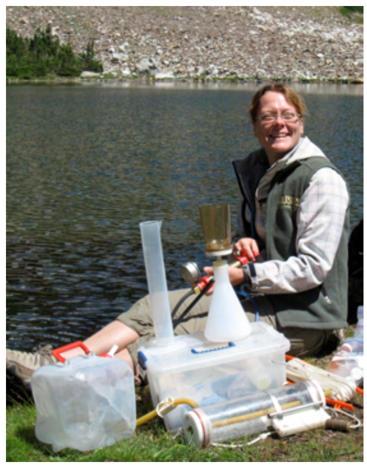

Atmospheric deposition of inorganic nitrogen in Grand Teton NP:

determining biological effects on algal communities in alpine lakes

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Project PMIS#: 119720
Funding Agency: NPS Air Resources Division
Funds spent: ~ $25,000

Highlights

The project was successful in obtaining sediment cores from nine lakes in GRTE. One of the lakes, Whitebark Moraine Pond, had particularly high dissolved organic carbon that was reflected in high sedimentary organic content and sedimentation rates. Additional cores from this site include a 1.6 m percussion core with a prehistoric ash layer measuring 1.5 cm thick. The source of this distinctive volcanic ash (potentially from the Mazama ash of approximately 7690 yBP) will allow accurate chronologic control, especially when combined with ^{14}C dates from the abundant macrofossils in the core. Water chemistry data for nitrogen show a compelling gradient, with TN concentrations following the amount of glacial input to each lake. Delta Lake, with direct input from Teton Glacier and high glacial suspended sediments, has the highest TN, primarily in the form of NO^{3-}. Whitebark Moraine Pond, with a very small unglaciated watershed, has a relatively low TN, dominated in by DON. This gradient of the form of N across the study lakes is likely to be reflected in the sediment diatom record and affords the opportunity to quantify a range of response to inorganic N deposition. The most striking observations from the smear slides are in the dominance of benthic, rather than planktonic, diatom species in the cores. The planktonic species *Asterionella formosa* and *Fragilaria crotonensis* are not dominant in any sections we examined.

Outline

A) Project Initiation and Fieldwork

The project started July 1, 2010. Field activities in Grand Teton NP took place July 24 - August 13 with participation by the field team:

Megan Otu - Postdoctoral Fellow, University of Colorado
Sarah Spaulding - co-PI, US Geological Survey
Alexander Wolfe - co-PI, University of Alberta
Jill Baron - co-PI, US Geological Survey
Heather Mosher - MS student, University of Alberta
Katie Williams - PhD student, Colorado State University
Brooke Osbourne - PhD student, Colorado State University
Julia Spencer - student, Colorado State University
Chad Whaley - Park Technician, Grand Teton National Park
Sue O'Ney - Park Biologist, Grand Teton National Park
Christine Kowalchuk - Volunteer, University of Alberta
Jeff Otu - Volunteer, University of Colorado
Lindsey Mills - Park Technician, Grand Teton National Park
Ed Mellander -Park Volunteer, Grand Teton National Park

Eight lakes were cored in GRTE (Delta, Surprise, Amphitheather, Ramshead (2), Holly, Whitebark Moraine (1 gravity, 2 percussion), Grizzly, and the Oxbow on the Snake River). The Whitebark Moraine cores include include a 1.6 m percussion core from with a 1.5 cm ash layer near the base. The source of this distinctive volcanic ash (potentially from the Mazama ash of approximately 7690 yBP) will allow accurate chronologic control, especially when combined with ^{14}C dates from the abundant macrofossils in the core. The sedimentation rate appears to be quite high, in contrast to most Rocky Mtn. alpine lakes. Careful consideration was given to selection of lakes for coring in project development (Spaulding et al. 2010) and again with additional information from reconnaissance in the field. A summary of the lakes and gravity cores retrieved is given in Table 1.

Table 1. Lakes that were successfully cored using the Glew coring device in 2010 and summary data. Lake ID is from Nanus et al. 2005. Lakes in bold text are currently monitored for long-term change by GRTE.

ID	Lake Name	Lat	Lon	Elev (ft)	Surface Area (km^2)	Depth (m)	T (°C)	Sediment Core Depth (cm)	Number of Sediment Samples
10	**Delta**	43 43 57.15	110 46 22.26	9017	0.028	9.4	4.4	11.5	46
100	**Surprise**	43 43 42.73	110 46 38.04	9565	0.009	7.0	14.4	40	81
1	**Amphitheater**	43 43 47.05	110 46 52.57	9703	0.019	8.5	NA	42	82
94	Ramshead	43 46 36.11	110 45 50.86	9497	0.011	6.6	14.6	17	54
28	Lake of the Crags	43 46 31.12	110 46 14.54	9570	0.045	19.1	12.6	NA	NA
22	Holly	43 47 33.56	110 47 52.95	9415	0.031	8.5	NA	18.5	57
83	Whitebark Moraine	43 47 18.13	110 47 39.46	9190	0.011	3.7	NA	37.5	96
17	Grizzly	43 48 10.81	110 48 37.84	9220	0.049	7.6	NA	11	44
-	Oxbow, Snake River	43 51 53.87	110 32 49.54	6736	NA	5.7	NA	25	50

Measuring lake water profiles relied on a Hydrolab multiprobe for temperature, dissolved O_2, conductivity and field pH. The cable to our instrument failed early in the field sampling. We obtained a second instrument from GRTE, but the results were unreliable. While not crucial, these data would be helpful in documenting the current limnological conditions. One option would be to obtain profiles in 2011 from Amphitheather, Holly, and Whitebark Moraine Pond. Grizzly Lake is difficult to access, but would also be considered.

B) Preliminary Results

a. Water Chemistry

Eight lakes were sampled for water chemistry (major anions, cations, nutrients) at three depths (surface, mid depth, bottom) for a total of 24 samples with complete chemistry (Appendix). Lakes ranged in pH from 6.4 to 7.0. Conductivity was low for all lakes, and ranged from 6-16 µS/cm. Dissolved organic carbon (DOC) was highest in Whitebark Moraine Pond, at 1.8 mg/L, where the organic sedimentation was also the greatest.

Water chemistry data for nitrogen and the forms (NH^{4+}, NO^{3-}, TN, TDN, DON) that dominate each lake shows a compelling gradient (Appendix, Fig. 1), with TN following the amount of glacial input to each lake. Delta Lake, with direct input from Teton Glacier and high glacial sediments, has the highest TN, primarily in the form of NO^{3-}. Whitebark Moraine Pond, with a very small unglaciated (and no perennial snowfields) watershed, has relatively low TN, dominated in by DON. This gradient of the form of N across the study lakes is likely to be reflected in the sediment diatom record and affords the opportunity to quantify a range of responses to inorganic N deposition.

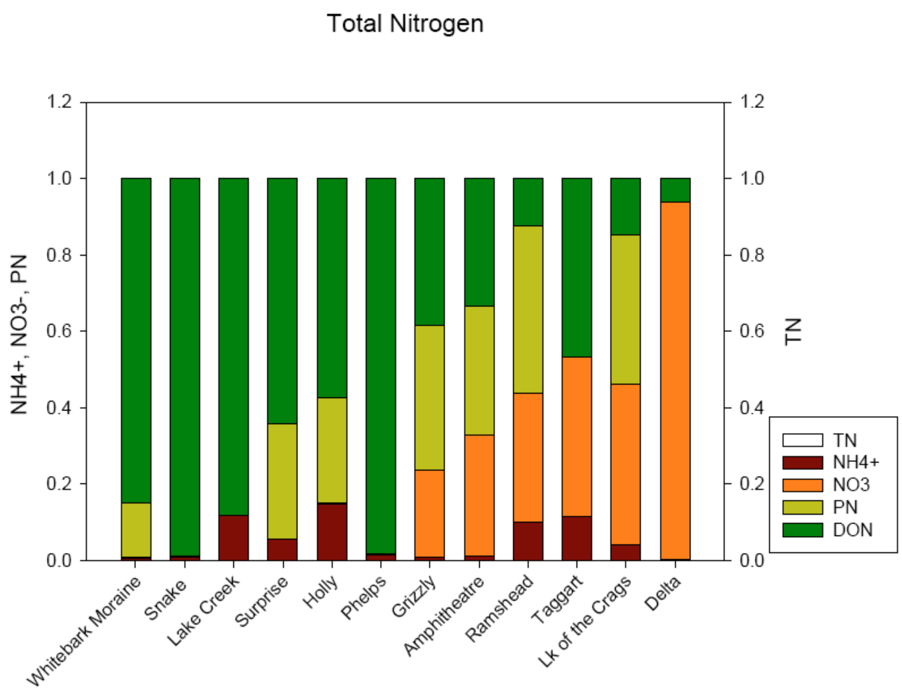

Figure 1. Plot of the form of N for lakes and streams in GRTE, expressed as fractions of the total N. Whitebark Moraine Pond is at one end of the spectrum, with most N as DON. In contrast, Delta Lake with its inflow from the Teton Glacier, has both the highest percentage of N as NO_3 (and total NO_3, see Appendix).

Concentrations of P are all very low (Appendix). Along with the gradient in TN, we expect that lakes may experience a range of P limitation, which may be intense in some sites.

Each sample was also filtered onto GF/F for chlorophyll *a* analysis and QMA quartz filter for C, N, $\delta^{13}C$ and $\delta^{15}N$ fractionation, results are pending.

b. Paleolimnology

Gravity cores were extruded in the field (0.25 cm intervals for the top 10 cm and 0.50 cm intervals for the lower core sections) and kept cool for transport to the University of

Colorado. Core sections were weighed and freeze-dried at INSTAAR before further processing.

Freeze dried sediment was then analyzed for organic content by loss of ignition at 550°C for 2 hours. Percent weight of organic content was then used to estimate mg/g of carbon and nitrogen per sample, which is required for accurate isotopic analyses.

Subsamples of freeze dried sediment were then weighed and packed into tin cups for analysis of C, N, $\delta^{13}C$ and $\delta^{15}N$ with Isotope Ratio Mass Spectrometer (IRMS) at the UC Davis Stable Isotope Facility (David Harris, Agronomy Department, University of California, Davis CA).

We found that some of the lakes (Holly, Ramshead and Grizzly lakes) had distinct inorganic deposits in the sediment cores. These deposits include the presence of rocks and coarse inorganic material suggestive of avalanche debris, a part of the paleorecord that may not be influenced by either N deposition or climate. Based on this inorganic to organic content, lake sediments fell into two categories: high IM:OM ~14 and low IM:OM ~ 3. Figure 2 represents high IM:OM in the top row, low IM:OM in the bottom row. The high inorganic sedimentation suppresses the percent content of organic matter and will likely reduce the concentration of Pb^{210} activity needed to establish chronology within these sediments. These short sediment cores show marked changes in inorganic content and have the potential to be dynamic tracers of catchment disturbances with well established chronologies. The long sediment cores, however, show little variability through time. These lakes have greater organic matter deposition likely generated internally, and are not the result of catchment disturbances. Paleolimnological reconstructions of diatom records in these sediments will be of particular interest because a quiescent lake may be more sensitive to long-term regional climate patterns.

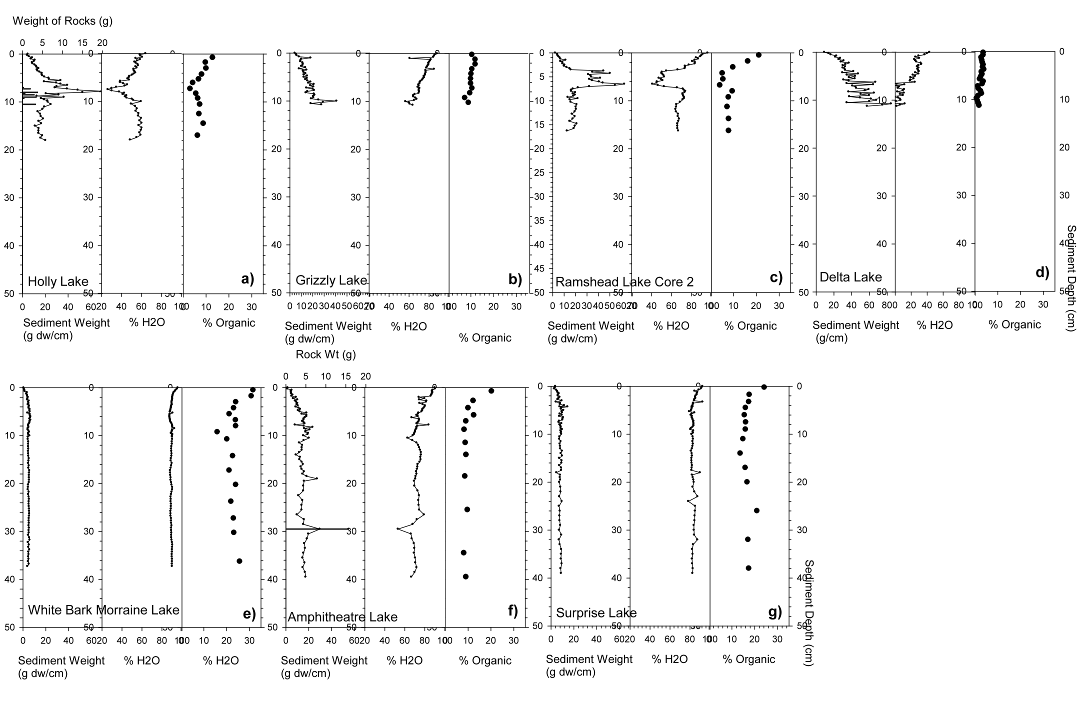

Figure 2. Plot of sediment dry weight per centimeter, percent water and percent organic content of sediments for a) Holly, b) Grizzly, c) Ramshead, d) Delta, e) Whitebark Moraine, f) Amphitheather and g) Surprise lakes.

Whitebark Moraine Pond core. This core will provide a long-term (millenial) context for environmental change in the GRTE high elevation lakes. This 1.6 m core was split at the INSTAAR Sediment Processing Lab, X-rayed, and subjected to colorometric analysis to determine quantitative changes in the sediment (Fig. 3). The core was then subsampled at 1 cm intervals and freeze dried. The remaining core has been archived and is stored in the INSTAAR cold room. Results indicate multiple periods of changing sediment characteristics that may prove to be shifts in sedimentation processes driven by climate patterns, catchment development and anthropogenic impacts.

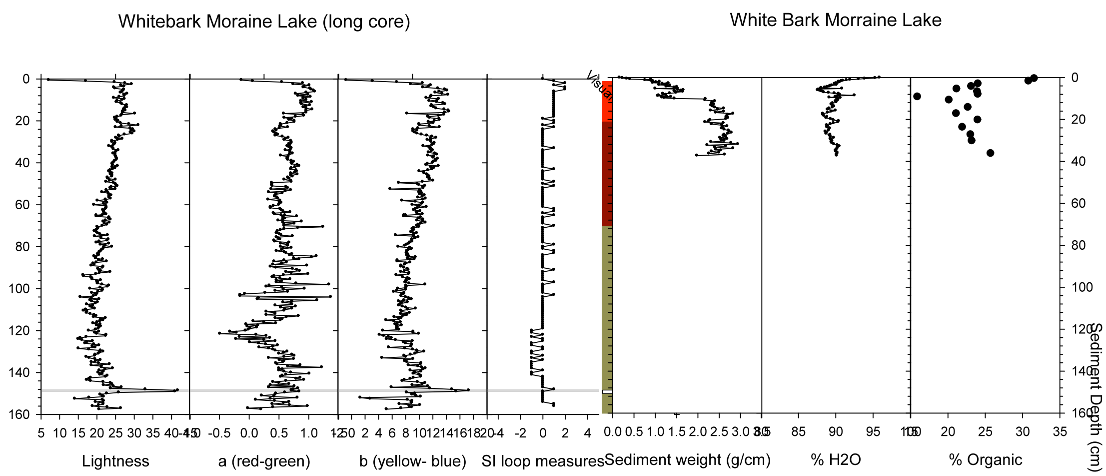

Figure 3. Plots of colorometric data lightness, a(red-green), b(yellow-blue), magnetic susceptibility measure from SI loop and visual color identifications for the Whitebark Moraine Pond long core. Grey horizontal band denotes the ash layer. A comparison with the gravity core is shown to the right (representation of Figure 2e).

c. Diatom species composition and abundance

Two-three smear slides were prepared from core surface sections and deep sections from each lake. The slides were used to 1) determine the quality of diatom preservation and signs of dissolution of silica valves, 2) evaluate the continuity of the record in each core, 3) determine dominant taxa and major taxonomic shifts and, 4) prioritize cores for freeze drying. We found that preservation is excellent in all cores, and valve dissolution was not observed. The records appear continuous, although some are punctuated by deposits of coarse inorganic debris. The most striking observations from the smear slides are in the dominance of benthic, rather than planktonic, diatom species in the cores. The planktonic species *Asterionella formosa* and *Fragilaria crotonensis* are not dominant in any sections we examined.

There are few diatoms in the Delta Lake sediments, but this core will be important to analyze for diatoms at the surface and for inorganic geochemistry. Although inorganics dominate the core composition, this record will be critical in terms of geochemical markers from a lake with high concentrations of N species in relation to glacial inputs.

In contrast to recent paleolimnological reconstructions in Rocky Mountain lakes (Wolfe et al. 2001, Saros et al. 2003, Wolfe et al. 2003), the only lake with a distinct abundance of *Asterionella formosa* in the surface core sections is Holly. *Pinnularia* spp. and *A. formosa* are abundant in the surface with *Aulacoseira* spp. becoming more abundant downcore. Amphitheatre, Ramshead, and Whitebark Moraine Pond lack sweeping species replacement, but do show compositional shifts downcore. At a coarse, qualitative level we did not observe changes in diatom community composition in Surprise and Grizzly lakes. It is important to emphasize that analysis of quantitative slides for species composition and abundance may reveal different results.

Permanent slides for quantitative identification and analysis of diatom assemblages are now being made, and pending analysis. An extensive image library of species has been developed, including over 80 scanning electron images of small, difficult to identify species (Fig. 4).

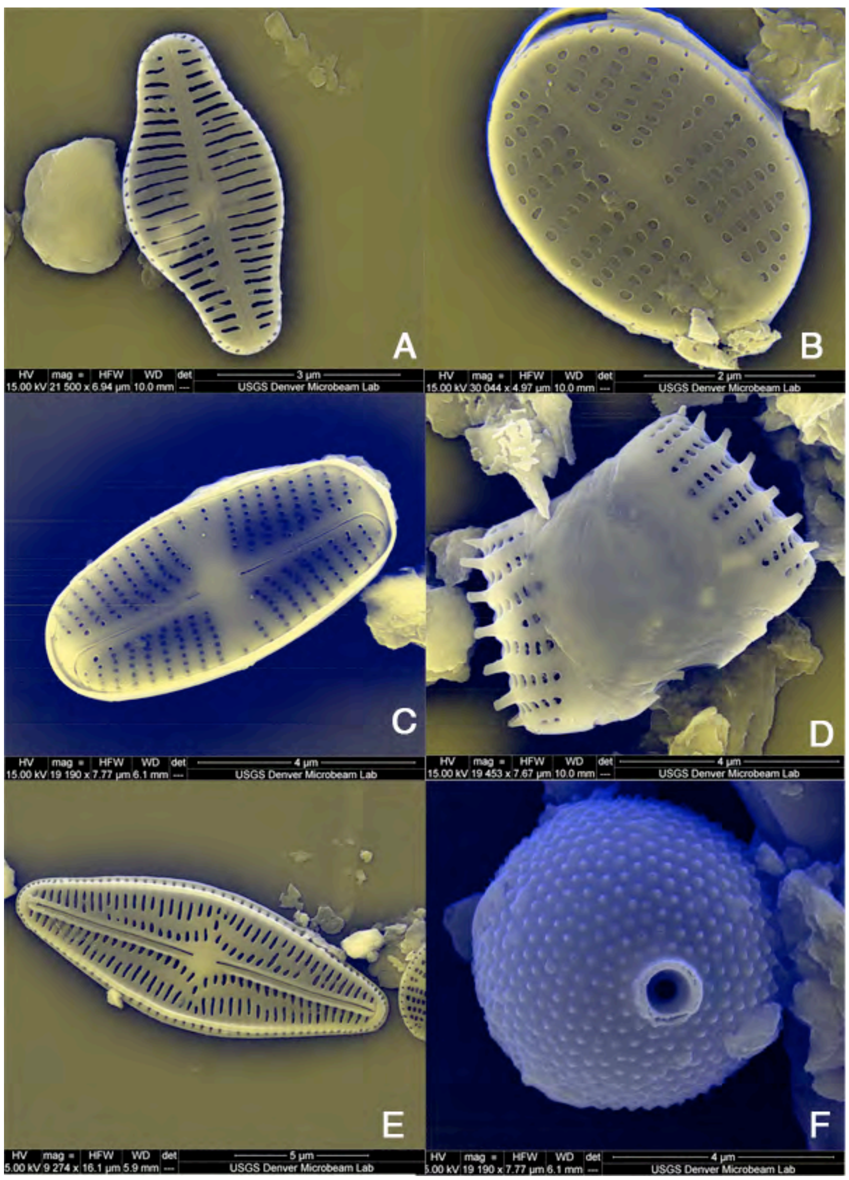

Figure 4. Example of benthic diatom species, imaged in canning electron micrographs. A) *Chaemopinnularia* sp., Ramshead Lake B) unknown monoraphid diatom, C) *Eolimna* sp., Holly Lake, D) *Staurosira* sp., Ramshead Lake, E) *Brachysira* sp., Amphitheather Lake, F) chrysophyte cyst, Holly Lake.

C) Synergistic Activities

Jill Baron and students are working on chemical and microbial analyses of the soils/protosoils from Teton watersheds. The group plans to examine NO_3, NH_4, DOC, TON in leachate, %C, %N, microbial biomass, qPCR for nitrifiers, and net and gross N mineralization rates.

Three soils samples were collected this summer for chemical and microbial analysis. One was collected in poorly vegetated talus above Amphitheatre Lake and two from the fine-grain substrates from Teton Glacier directly above Delta Lake. The values are similar to those from comparable substrates in Rocky Mountain National Park. Note that %C and %N were below detection limits for the Delta soil samples.

Soil Site	NO_3-N	NH_4-N	%C	%N
Amphitheatre	0.33	0.16	2.3	0.18
Delta Upper	0.07	0.03	0.31	0.02
Delta Mid	0.09	0.06	0.16	0.01

Soil microbial DNA has been quantified, and qPCR analyses will be conducted this winter. The DNA values are low, and again similar to those found in comparable soils of Rocky Mountain National Park.

Snow samples were collected from late-lying snowfields in the basins of Delta, Ramshead, and Holly Lakes. The snow was dilute, as expected, with moderately high concentrations of nitrate, ammonia, and organic carbon. TN in the table below includes all N in the sample, including organic N.

Snow Site	Sample Date	pH	COND (µS/cm)	NO_3-N (mg/L)	NH_4-N (mg/L)	DOC (mg/L)	TN (mg/L)
Delta	07/29/10	6.00	3.5	0.44	0.34	0.5211	0.1948
Ramshead	07/31/10	6.23	5.4	0.21	0.30	0.8272	0.2093
Holly	08/03/10	5.80	2.4	0.16	0.32	0.4451	0.1917

Heather Mosher, M.S. student at University of Alberta, collected tree cores from trees surrounding the study lakes. She is working with Alex Wolfe to develop methods to quantify the $\delta^{15}N$ fractionation in wood, across species, and determine if the record is correlated to changes recorded in lake sediments.

Mabruka Abubeira, Ph.D. student at Colorado State University, is working with Jill Baron. Mabruka is considering reconstruction of the chironomid (midge larvae) paleolimnological record in Whitebark Moraine Pond to as a proxy for regional temperature change in GRTE. She may also measure uv-absorbance from Cladoceran fossil exuviae extracted from sediments, using laser-scanning confocal microscopy. This will inform on changes in ultraviolet radiation on the lakes over time.

Alex Wolfe and Neil Michelutti (Queen's University, Ontario) are evaluating the Whitebark Moraine Pond sediments for charcoal, and therefore, fire history, by VIS-NIR spectroscopy. The work will develop a calibration of the quantitative abundance of charcoal in lake sediments and evaluate this approach in comparison to traditional approaches. The results will address the relationship between fire, DOC and algal impacts.

D) Remaining Tasks and Challenges

Send subsample of freeze cores to Jack Cornet, Mycore, Durunen Ontario for ^{210}Pb activity analyses – cost is $100 for 60 samples at the CSU Soil Testing Laboratory. Funding is possible from Baron.

Quantitative metals analysis of sediments for Pb, Hg (ICPMS). Consider other elemental analyses, including P, As, Ti, Fe, Mn, Mg, K- estimated cost for processing is 60-100 samples per hour at a cost of $100/hour and will be covered by Jill Baron.

Determine cores and macrofossils to submit for ^{14}C dating by John Southen, UC Riverside - cost per sample is not yet known, funding source not determined.

We have not yet determined if we will run sediment pigment analysis at INSTAAR using HPLC. Costs would be minimal, but would require technician time. Not budgeted.

Four sedimentation traps were placed in Whitebark Moraine Pond to determine the annual diatom sedimentation pattern and seasonal change in species composition in relation to chemistry. These traps need to be retrieved in 2011, funding source not yet determined

Megan plans to attend the Society of Canadian Limnologists conference in January 2011 to present preliminary results, funding source not yet determined.

The main light microscope at INSTAAR has developed problems in the stage and focusing mechanisms. It is currently being repaired, but should be replaced in the near future. Spaulding is working to obtain support for replacement, funding source not yet determined.

E) Summary

Initial data suggests that the sediment record may not contain the same dominance of *A. formosa* and *F. crotonensis* that has appeared in other Rocky Mountain lakes. We hope to determine what contributes to these lakes being dominated by benthic species, and why the planktonic species are rare. An obvious factor is the influence of UV on planktonic abundance, and there is substantially less wind intensity over this region of the Rockies. The towering cover of high elevation white bark and lodge pole pine do not have stunted growth from prevailing high winds. The cores cover a gradient of watershed influence, from the small watershed and autochthonous Whitebark Moraine Pond to the glacial watershed and allochthonous inputs of Delta Lake. As we interpret the paleorecord, it will be important to evaluate catchment influence on each lake. It should become feasible to disentangle the lakes that were natively P not N limited versus those that have become P limited from enhanced N deposition, but were N or N-

P co-limited sometime in the past and N isotopes be crucial for understanding the record and developing critical loads for GRTE.

F) References

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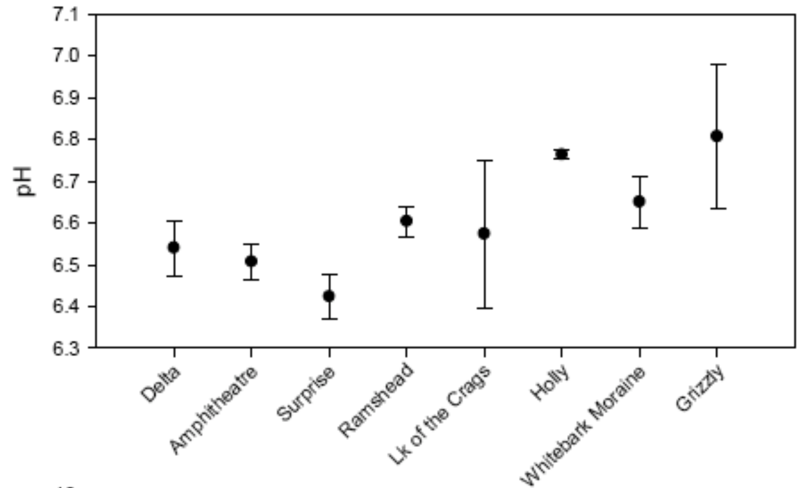
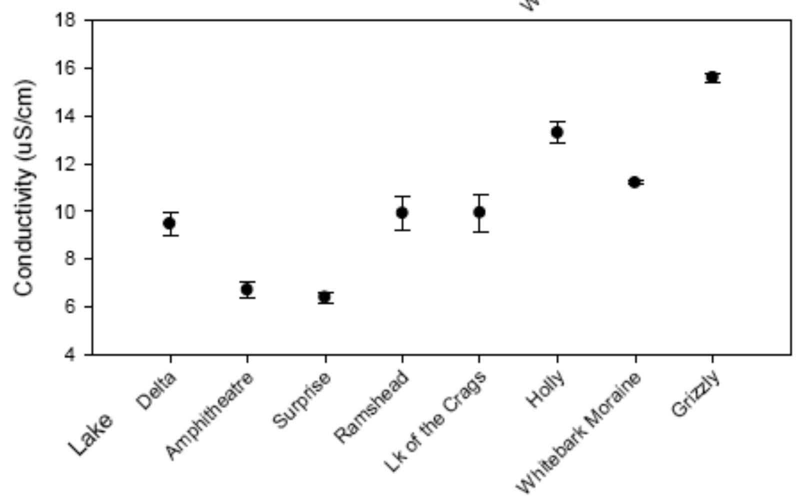
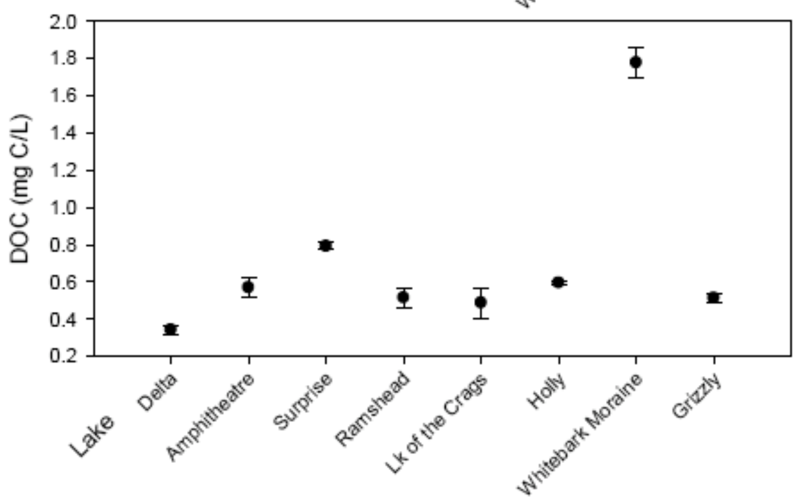
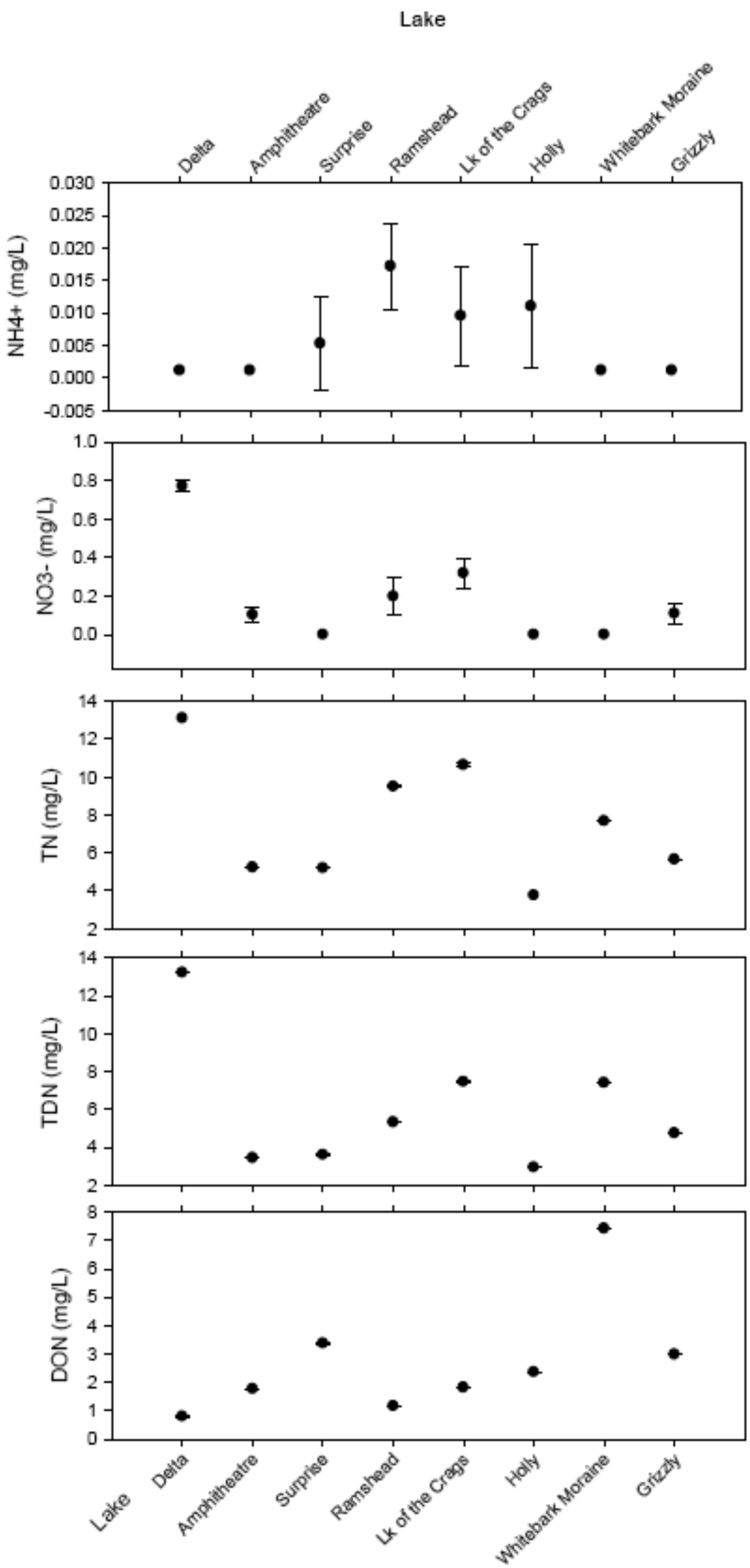
G) Appendix. Plots of water chemistry data from lakes sampled in 2010. Samples were collected at three depths in each lake, and presented here as a single collection with error bars. These are preliminary plots, and in later works we will present each depth separately.

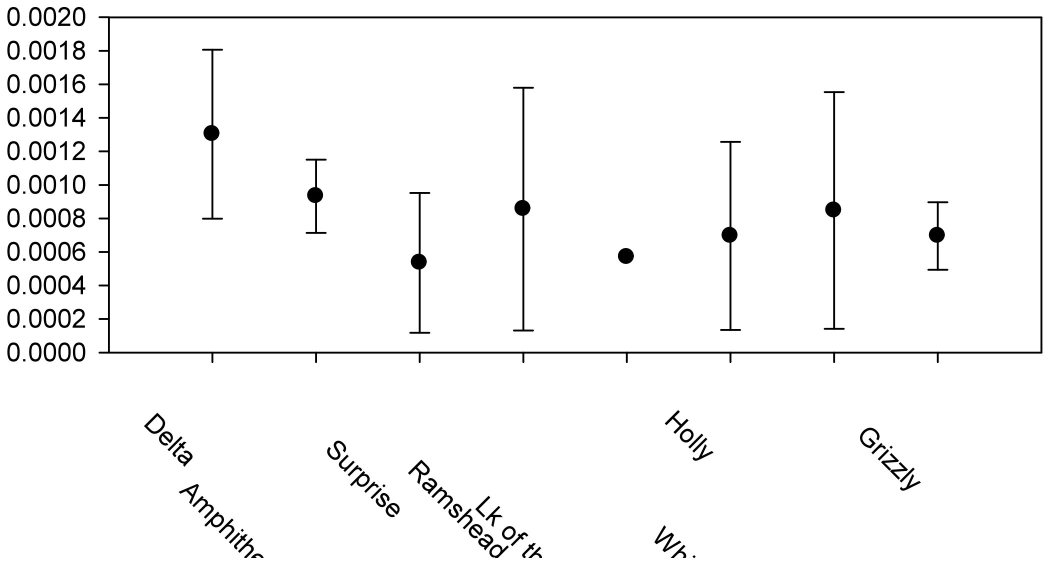








Lake
Delta
Amphitheatre
Surprise
Ramshead
Lk of the Crags
Holly
Whitebark Moraine
Grizzly
NH4+ (mg/L)
NO3- (mg/L)
TN (mg/L)
TDN (mg/L)
DON (mg/L)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