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SUBMITTED ELECTRONICALLY
Shannon Lotthammer (wildriceTSD.pca@state.mn.us)
Minnesota Pollution Control Agency
520 Lafayette Road North
St. Paul MN 55155-4194

RE: Draft Technical Support Document: Refinements to Minnesota's Sulfate Water Quality Standard to Protect Wild Rice, July 18, 2016.

Dear Ms. Lotthammer:

WaterLegacy submits the comments below in response to the above-captioned *Draft Technical Support Document: Refinements to Minnesota's Sulfate Water Quality Standard to Protect Wild Rice*, July 18, 2016 (hereinafter "*Draft TSD*") prepared by the Minnesota Pollution Control Agency (MPCA). WaterLegacy is a Minnesota non-profit organization formed to protect Minnesota water resources and the communities that depend on them.

WaterLegacy would express our profound disappointment in the MPCA's process and in its recent document.

We are troubled that the MPCA seems to have made no effort to evaluate any of the expert reports submitted with WaterLegacy's December 18, 2015 detailed technical comments (hereinafter "*WL Dec. 2015 Comments*") on the MPCA's *Proposed Approach for Minnesota's Sulfate Standard to Protect Wild Rice*, March 24, 2015. (hereinafter "*MPCA 2015 Proposal*").[1] We are also puzzled at the MPCA's failure even to mention in the *Draft TSD* the University of Minnesota Duluth research demonstrating that iron sulfide precipitates on wild rice roots, results in fewer and lighter seeds, and fails to mitigate the impacts of excessive sulfate on several critical endpoints for the growth and propagation of wild rice.

Our Data Practices Act discovery indicates that the MPCA had read Sophia LaFond-Hudson's complete manuscript, *Iron and Sulfur Cycling in the Rhizosphere of Wild Rice (Zizania palustris)*[2] as well as the Annual Report from Dr. John Pastor's SeaGrant research documenting the effects on wild rice when both sulfate and iron are added to mesocosms[3] by mid-June 2016,

[1] WaterLegacy has confirmed through a Data Practices Act request that MPCA conducted no analysis of expert reports or comments, other than an email dialogue with the Chamber of Commerce regarding its sponsored research.
[2] Lafond-Hudson, *Iron and Sulfur Cycling in the Rhizosphere of Wild Rice (Zizania palustris),* Masters Thesis Submittal to the University of Minnesota (May 2016), attached as Exhibit 1.
[3] John Pastor, Sea Grant Annual Report, *The Biogeochemical Habitat of Wild Rice*, Project No. R/CE-04-14, report date May 5, 2016, attached as Exhibit 2.

as reflected in the attached email string,[4] MPCA staff had concluded, "Sophie's thesis (which read like a paper ready to submit) is very impressive." MPCA had learned from consultation with Dr. Pastor that additional iron added to mesocosms "has no ameliorative effect on the decrease in growth with added sulfate." In response to questions asked him by MPCA regarding the biochemistry of the experiments with iron, Dr. Nate Johnson advised, "I'm happy to talk more about this iron addition experiment if you want to, but I think the most important (and potentially conceptual-model-altering) result we've seen over the last few years is the dynamic, near-rooting zone chemistry of iron and sulfur (both root surface and near-root sediment) that Sophie has measured."

Both Ms. Lafond-Hudson's and Dr. Pastor's research with sulfate, iron and wild rice has the potential to fundamentally undermine the MPCA's presumption that reduced sulfide in sediments protects wild rice. This research seriously calls into question the MPCA's theory that a predicted porewater sulfide or sediment sulfide level[5] can be used as a proxy for protection of wild rice. Yet, MPCA failed to mention the University of Minnesota iron amendment research in its *Draft TSD* and suggested a public position be taken to deny that they had seen any data on sulfide or iron concentrations, or on wild rice growth.[6] We expected a more scientifically transparent approach.

WaterLegacy believes that the MPCA has mischaracterized the *Draft TSD* as a "refinement" of the existing water quality standard "to protect wild rice." The proposed changes would eliminate, not refine the existing wild rice sulfate standard.

As Shannon Lotthammer explained at the Wild Rice Advisory Committee on August 18, 2016, the proposed water-body-by-water-body process of setting sulfate levels for just the 1,300 wild rice waters proposed to be listed by the MPCA would also take more than 10 years. Not only would the MPCA's equation predict a result (sulfide level) that is poorly correlated with the survival, let alone sustainable growth of wild rice, but the process by which this equation would be applied would guarantee more than a decade before sulfate discharges could be limited or wild rice/sulfate impaired waters designated throughout Minnesota. The *Draft TSD* proposal would not protect wild rice.

WaterLegacy is also troubled that MPCA failed to respond to the concerns raised in our *WL Dec. 2015 Comments* that the restriction of wild rice waters by acreage and density and the exclusion of wild rice waters previously identified by the Minnesota Department of Natural Resources (MDNR) was arbitrary, unreasonable and a violation of the Clean Water Act. The *Draft TSD* also fails to respond appropriately and protectively to the evidence in Dr. Nate Johnson's research that sulfide toxicity is not a seasonal phenomenon.

Below, WaterLegacy identifies concerns either raised or exacerbated by the *Draft TSD*.

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[4] Email exchange between Nate Johnson, John Pastor, Paula Maccabee and Ed Swain from June 13, 2016 through June 24, 2016, attached as Exhibit 3.
[5] The Draft TSD refers to both "porewater sulfide" and sulfide in the sediment (phrased in various ways) in discussing correlation with wild rice.
[6] Email exchange between Shannon Lotthammer and Ed Swain on July 19, 2016, attached as Exhibit 4.

1. WaterLegacy's *WL Dec. 2015 Comments* explained that requiring a density threshold and stem count for wild rice waters would fail to protect waters where pollutants had degraded wild rice and was inconsistent with practices for other beneficial uses of waters. The *Draft TSD* maintains a density threshold and stem count. (*Draft TSD*, p. 9)

2. The *Draft TSD* provides no justification for excluding wild rice water bodies identified in the MDNR 2008 report[7] unless the MDNR provided specific information that wild rice acreage was two acres or if the MPCA found "corroborating information." (*Draft TSD*, p. 8). The unreliability of the MDNR in performing this legislatively mandated listing has not been established by MPCA.

3. The requirement for acreage to identify wild rice waters proposed in the *Draft TSD* is inconsistent with the indicator of wild rice "presence" used by MPCA to formulate its wild rice equation. (*See e.g. Draft TSD*, pp. 11, 12, 16, 17, 19, 20, 21, 24, 25, 26, 28, 29). None of the field data provided by University of Minnesota researcher Amy Myrbo to indicate the presence of wild rice in the MPCA formula includes the acreage of wild rice present.[8]

4. The requirement for density to identify wild rice waters proposed in the *Draft TSD* is inconsistent with the indicator of wild rice "presence" used by MPCA to formulate its wild rice equation. (*See e.g. Draft TSD*, pp. 3, 11, 12, 16, 17, 19, 20, 21, 24, 25, 26, 28, 29). The *Draft TSD* rejects use of field data on density to calculate a protective sulfide level as scientifically inappropriate, since "density can be a function of factors unrelated to the long-term suitability of the habitat." (*Draft TSD*, p. 15).

5. The *Draft TSD* only includes wild rice with a documented history of human harvest after November 28, 1975, even as the document acknowledges that the amount of wild rice that would support a beneficial use for wildlife is "much less than the amount of wild rice that would attract human harvesters." (*Draft TSD*, pp. 9, 10)

6. The *Draft TSD* "aligns" the definition of a wild rice water with the 2011 legislative language pertaining to "acreage" and "density" (*Draft TSD*, p. 9) without analyzing whether either is an appropriate legal, technical or scientific threshold for wild rice beneficial use.

7. The *Draft TSD* provides no justification for limiting wild rice waters either to the nearest upstream and downstream tributary confluences or a location 800 meters and 800 meters downstream. (*Draft TSD*, p. 9). As noted in the Wild Rice Advisory Committee on August 18, 2016, there is no evidence that these arbitrary limits would reflect a change in underlying substrate or natural ecological conditions limiting potential wild rice habitat.

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[7] MDNR, *Natural Wild Rice in Minnesota: A Wild Rice Study document submitted to the Minnesota Legislature by the Minnesota Department of Natural Resources*, February 15, 2008, available at http://files.dnr.state.mn.us/fish_wildlife/wildlife/shallowlakes/natural-wild-rice-in-minnesota.pdf

[8] Myrbo *et al*. Field survey data attached as Exhibit 5 includes all fields containing quantitative data. The complete data, available on request, contains no information on "acreage" or other measures of the size of wild rice beds.

8. Recent University of Minnesota research regarding sulfate, sulfide, iron and wild rice as well as the expert opinions submitted with *WL Dec. 2015 Comments* call into question the use of a "protective sulfide concentration" as a proxy for the preservation of wild rice, the beneficial use sought to be protected. The *Draft TSD* fails to address research or expert opinion undermining the use of this equation to protect wild rice.

9. The *Draft TSD* inappropriately excludes sites with low transparency, rather than acknowledging that sulfate impairs wild rice by increasing phosphorus previously bound to iron as well as by increasing sulfide in the rooting zone. (*see Draft TSD*, pp. 42-43).

10. Neither the thresholds proposed to define wild rice waters nor the equation for sulfide levels proposed in the *Draft TSD* address the potential for degradation, reduction in population or even extinction of wild rice over time.

11. The *Draft TSD* states that sulfide formed as a result of sulfate has a number of non-exclusive potential fates. "The sulfide could 1) remain in the sediment porewater as free sulfide, 2) diffuse into the surface water, to be oxidized to sulfate, 3) be oxidized in the sediment, or 4) react with metals (usually forming iron-sulfide compounds), forming insoluble precipitates in the sediment." (*Draft TSD*, p. 60). Failure to include precipitation of iron-sulfide compounds on wild rice roots is misleading.

12. The *Draft TSD* purports to test Type I and Type II errors in applying a wild rice sulfate limit, such as the existing 10 mg/L wild rice sulfate standard. (*Draft TSD*, pp. 52-56). However, its analysis makes no effort to assess either under-prediction or over-prediction in terms of the beneficial use of waters for wild rice. Whether or not an equation designed to predict sulfide can do so more reliably than a sulfate standard does not answer the question of which approach better predicts the presence or sustainability of wild rice.

13. The *Draft TSD* removes from its analysis both Class B data sets (multiple years) and Class D data sets (multiple locations). The *Draft TSD* also eliminates the data and illustration in Figure 14 of the *MPCA 2015 Proposal* that revealed the variation in calculated protective sulfate concentrations based on multiple samples taken in the same water body. Omissions of this data may create a false impression of consistency in applying the MPCA proposed equation

14. The change in statistical methodology in the *Draft TSD* does not resolve the concerns raised in expert reports attached with *WL Dec. 2015 Comments* about the ability of MPCA's model to predict actual field sulfide levels. However, as explained in the August 18, 2016 Wild Rice Advisory Committee meeting, the new methodology by providing only a binary prediction, precludes the model's verification using actual field survey data.

15. The *Draft TSD* neither considers the large (over an order of magnitude) range of uncertainty in its calculated "protective sulfide concentration" or the equation's prediction of ecologically absurd "safe" levels of surface water sulfate (0.6, 1.7, 2.4

mg/L) as rendering the proposed equation unreliable or implausible to predict real world results. (*e.g. Draft TSD*, pp. 42, 54)

16. The *Draft TSD* provides no scientific or technical explanation for its proposal to apply a sulfate limit derived from its equation as an *annual average*. (*Draft TSD*, p. 64). In the August 18, 2016 Wild Rice Advisory Committee meeting, MPCA staff admitted that they knew of no scientific grounds for suggesting sulfate levels should be averaged over a year and no precedent or guidance supporting that approach.

17. Although noting a "concern" that sulfate loading can increase mercury methylation (*Draft TSD*, p. 59), the *Draft TS*D provides only a cursory mention of peer-reviewed literature pertaining to sulfate loading and increased mercury methylation. The *Draft TSD* fails to assess the impacts on mercury methylation of adopting its proposed equation as compared with retaining and enforcing Minnesota's existing wild rice sulfate standard.

WaterLegacy remains concerned that neither the MPCA's proposed approach to listing wild rice waters, nor the proposed use of an equation predicting sulfide water-by-body to replace the existing wild rice sulfate standard would sustain wild rice for wildlife and human harvest beneficial uses. Although we appreciate MPCA's recognition, based on Dr. Nate Johnson's data, that sulfate limitations must be applied year-round, we find the proposal to allow an annual averaging of discharge to be unsupported and unprotective of wild rice.

Although we appreciate the extent of political and industry pressure on the MPCA opposing a sulfate limitation that might effectively be implemented to require minimization, collection and treatment of sulfate pollution, WaterLegacy believes that such a limit on sulfate is needed to protect the beneficial use of wild rice and to address other ecologically significant consequences of sulfate pollution, including eutrophication as a the result of release of phosphorus previously bound with iron and damage to developing brains of fetuses, infants and children as well as wildlife as a result of bioaccumulation of methylmercury.

Sincerely yours,



Paula Goodman Maccabee
Advocacy Director/Counsel for WaterLegacy

cc: Christopher Korleski, U.S. EPA Region 5
Linda Holst, U.S. EPA Region 5
Katharine Marko, U.S. EPA Region 5
Barbara Wester, U.S. EPA Region 5

Enclosures

EXHIBITS

WaterLegacy Comment (September 2, 2016)

MPCA, *Draft Technical Support Document: Refinements to Minnesota's Sulfate Water Quality Standard to Protect Wild Rice*, July 18, 2016.

Exhibit 1 Sophia LaFond-Hudson, *Iron and Sulfur Cycling in the Rhizosphere of Wild Rice (Zizania palustris)*, Masters Thesis Submittal to the University of Minnesota (May 2016). (39 pages)

Exhibit 2 John Pastor, Sea Grant Annual Report, *The Biogeochemical Habitat of Wild Rice*, Project No. R/CE-04-14, report date May 5, 2016. (4 pages)

Exhibit 3 Email exchange between Nate Johnson, John Pastor, Paula Maccabee and Ed Swain from June 13, 2016 through June 24, 2016. (8 pages)

Exhibit 4 Email exchange between Shannon Lotthammer and Ed Swain on July 19, 2016. (2 pages)

Exhibit 5 Amy Myrbo *et al*. Field Survey Data including all fields with quantitative data, none of which include measures of the size of wild rice beds. (20 pages)

Iron and Sulfur Cycling in the Rhizosphere of Wild Rice (*Zizania palustris*)

A thesis
SUBMITTED TO FACULTY OF THE
UNIVERSITY OF MINNESOTA
BY

Sophia LaFond-Hudson

IN PARTIAL FULFILLMENT OF THE REQUIERMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

Nathan Johnson, John Pastor

May 2016

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Acknowledgements

I would like to acknowledge several people who contributed substantially to this project. The members of my committee, Dr. Nathan Johnson, Dr. John Pastor and Dr. Elizabeth Austin-Minor provided intellectual guidance during the experimental setup, data analysis, and writing process. Brad Dewey played an important role in this project by sampling the biological data, assisting with harvesting and cleaning roots, and answering question after question about the experimental setup and methods. Dan Fraser was likewise very helpful in answering any questions about equipment. I am very grateful for the help I received from Marissa Samuelson, who assisted considerably with geochemical sampling and cleaning roots. Finally, I would like to again thank my advisors, Dr. Johnson and Dr. Pastor, for being generous with their excellent advice and constant encouragement.

Abstract

Iron (hydr)oxides typically form on roots of many wetland plants, including wild rice (*Zizania palustris*), an annual macrophyte with significant cultural, economic, and ecological value. Iron (hydr)oxides are thought to protect macrophytes from toxic reduced species, such as sulfide, by providing an oxidized barrier around the roots. However, wild rice grown under high sulfate loading develops a black iron sulfide precipitate on the root surface, and produces fewer and lighter seeds, leading to a decreased population in the long term. In order to investigate the role of iron sulfide root precipitates in impaired seed production, wild rice plants grown in buckets were exposed to sulfate loading of 300 mg/L, and harvested biweekly for extraction of root acid volatile sulfide (AVS) and weak acid extractable iron and analysis of plant and seed N. In sulfate-amended plants, AVS on roots accumulated over the course of the growing season, and accumulated rapidly just prior to seed production. Simultaneously, iron speciation of the root precipitate shifted from Fe(III) to Fe(II), consistent with a transition from iron (hydr)oxide to iron sulfide. A mechanism is herein proposed by which sulfide-induced suberization of roots decreases radial oxygen loss that keeps the rhizosphere oxidized, leading to reduction of iron (hydr)oxides and subsequent iron sulfide accumulation. Plants amended with sulfate produced fewer, lighter seeds with less nitrogen. We suggest that sulfide inhibits N uptake, and seeds are disproportionately harmed because rapid AVS accumulation occurs during the reproductive life stage.

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Introduction

Iron (hydr)oxide plaques have been observed on the roots of wild rice (*Zizania palustris*), a culturally significant macrophyte that forms large monotypic stands in the lakes and rivers of Minnesota, Wisconsin, northern Michigan, and Ontario (Lee and McNaughton 2004, Jorgenson et al. 2013). Iron (hydr)oxide plaques commonly form on the roots of wetland plants growing in anoxic, reduced sediments as a result of a redox gradients found in the rooting zone (Mendelssohn and Postek 1982, Jacq et al. 1991, Snowden and Wheeler 1995, Christensen and Sand-Jensen 1998). Redox gradients in the rhizosphere are caused by radial oxygen loss, a process in which wetland plants release oxygen into the rhizosphere through their roots via arenchyma tissue (Armstrong and Armstrong 2005, Schmidt et al. 2011). When Fe(II) is transported from anoxic sediment into the oxygenated rhizosphere, it is oxidized to Fe(III), which combines with oxygen from the roots to form insoluble iron oxides or hydroxides. Iron plaque formation can occur abiotically, but it is also associated with iron-oxidizing bacteria in many cases (St. Cyr 1993, Neubauer et al. 2007). Iron plaques have been proposed as a mechanism to protect plants from reduced toxic substances such as hydrogen sulfide, because they form an oxidized barrier around the roots (Koch and Mendelssohn 1989, Mendelssohn et al. 1995). However, during previous sulfur addition experiments, black iron sulfide root coatings, characteristic of iron sulfide minerals, have been observed on wild rice roots (Pastor et al., in review). Black root coatings have also been observed in white rice grown in surface water with high sulfate concentrations (Jacq et al. 1991, Gao et al. 2003, Sun et al. 2015).

The iron and sulfur chemistry of aquatic plant rooting zones involves a set of interrelated biogeochemical processes. Sulfate and iron (III) oxides are both redox active species that play a role in degradation of organic matter in aquatic sediments. During aerobic respiration, electrons are transferred from organic compounds to oxygen, but in anaerobic respiration alternative electron acceptors are used, including nitrate, ferric iron, sulfate, and carbon dioxide. Organisms use the more thermodynamically favorable electron acceptors first; nitrate is used before ferric iron, and carbon dioxide is used only when more favorable electron acceptors have been consumed. This thermodynamic ordering manifests itself as stratified microbial communities with distance away from an

oxic-anoxic boundary (Boudreau 1996, Van Cappellen and Wang 1996). Anaerobic respiration produces reactive reduced species as byproducts, including ammonia, ferrous iron, sulfide, and methane. Iron-reducing and sulfate-reducing bacteria facilitate production of ferrous iron and sulfide respectively, after which ferrous iron and sulfide can combine to produce iron monosulfide (FeS) or pyrite (FeS_2). Alternatively, ferrous iron and sulfide can undergo oxidization back to ferric iron and sulfate abiotically via bioturbation or water level fluctuations (Thamdrup et al. 1994, Eimers et al. 2003) or biotically via iron or sulfide oxidizing bacteria (lithoautotrophy). Despite the predictability of the sequence of electron acceptors used in anaerobic respiration, coincident iron reduction and sulfate reduction in close proximity has been documented, during which the subsequently produced sulfide reacts abiotically with nearby iron (hydr)oxides to produce reduced iron and elemental sulfur (Hansel et al. 2014, Kwon et al. 2013).

Macrophytes can accelerate iron and sulfur cycling by enhancing redox gradients when radial oxygen loss creates an oxic layer around the root surface. Oxidation of Fe(II) to Fe(III) oxides immobilizes iron on or very near the root surface. Conversely, oxidation of sediment FeS by radial oxygen loss mobilizes previously bound sulfur as soluble sulfate (Choi et al. 2006). Cycling is dynamic near the rhizosphere because oxidation potential (Eh) changes abruptly over just a few millimeters. Just outside the oxic layer, the sediment can be strongly reducing. Heterotrophic iron and sulfate reduction can be stimulated by root exudates released by the plant (Kimura et al., 1981), and, in the case of an annual plant like wild rice, senesced plant material at the end of the growing season each year (Jacq et al. 1991). Several studies have compared sediment with and without vegetation and found higher sulfide or FeS concentrations in sites with plants (Holmer & Nielsen, 1997, Jacq et al. 1991, Lee & Dunton 2000). The increase in reduced species is attributed to larger pools of organic matter to drive reduction.

In Minnesota, surface water sulfate concentrations are regulated in wild rice waters because high surface water sulfate concentrations are associated with decreased wild rice abundance (Moyle, 1945, MPCA Analysis of the Wild Rice Sulfate Standard Study, 2014). It has recently been shown that sulfide, the reduced form of sulfate, is toxic to wild rice seedlings (Pastor et al., in review). In other wetland plants, sulfide is

thought to interrupt metabolism by inhibiting metallo-enzymes in the electron transport chain during respiration (Allam and Hollis 1972, Koch and Mendelssohn 1989, Koch et al. 1990, Lamers et al. 2013; Armstrong and Armstrong 2005, Martin and Maricle 2015). Inhibition of ATP production deprives a plant of energy required for nutrient uptake. Sulfide has been shown to reduce nutrient uptake in white rice (*Oryza sativa*), a plant physiologically similar to wild rice (Joshi et al. 1975), so it is plausible that sulfide may also inhibit nutrient uptake in wild rice.

Pastor et al. (in review) found that exposure to sulfide decreased mean seed weight and the proportion of filled seeds more significantly than by having immediate toxic effects on plant growth and physiology. Wild rice takes up nitrogen, its limiting nutrient, in three main bursts: 30% is taken up during early season vegetative growth, 50% is taken up during early flowering, and 20% is taken up during late flowering and seed production (Grava and Raisanen, 1978). The effects of sulfide exposure on wild rice are consistent with nitrogen limitation during seed production, but it is not well understood why the seed production life stage is disproportionately harmed by sulfide. Is iron sulfide plaque accumulation a geochemical mechanism that controls the impact of sulfide on nitrogen uptake?

The objective of this study is to understand how iron and sulfur cycle near root surfaces and how this cycling affects nitrogen uptake by wild rice during its life stages, especially seed production. We investigate the drivers of iron sulfide plaque formation and seek to answer if plant and seed nitrogen uptake are adversely affected by iron sulfide accumulation on root surfaces.

Methods

Experimental Design

Sediment was collected from Rice Portage Lake (MN Lake ID 09003700, 46.703810, -92.682921) on the Fond du Lac Band of Lake Superior Chippewa Reservation in Carlton County, Minnesota in late May, 2015 and placed in a 400L Rubbermaid stock tank where it was homogenized by shovel. Initial carbon in the sediment was 14.8 ± 1.70% and initial nitrogen was 1.12 ± 0.13 %. Eighty 4 L plastic pails were then filled with 3 L of the sediment. Each 4 L pail was placed inside of a 20 L bucket which was filled with 12 L of water to provide a 12-15 cm water column. The overlying water of 40 randomly chosen buckets was then amended with an aliquot of stock solution (5.15g of Na_2SO_4 dissolved in 200ml of deionized water) to result in 300 mg/L (3.125 mM) sodium sulfate. The amendment concentration was chosen as such because when used in previous mesocosm experiments, wild rice populations went extinct within five years (Pastor et al. in review), but it is only slightly higher than the EPA drinking water secondary standard (250mg/L) and is a concentration found in some Minnesota lakes (MPCA Analysis of the Wild Rice Sulfate Standard Study, 2014). The overlying water was sampled twice throughout the trial and adjusted to 300mg/L SO_4 with appropriate amounts of Na_2SO_4 stock solution. The other 40 buckets did not receive any sulfate and on 6/23/15 (day 174, Julian date) had an average surface water sulfate concentration of 14.44 ± 1.01 mg/L, consistent with the local groundwater sulfate concentration. In each bucket, two seeds which were harvested in 2014 from Swamp Lake on the Grand Portage Reservation (MN Lake ID 16000900, 47.951856, -89.856844) were planted on 5/15/15 (Julian day 135). Once shoots reached a height of approximately 20 cm during the aerial stage, plants were thinned to one plant per bucket.

Sampling of pore water, roots, and stems began midsummer (63 days after planting/germination), at the start of flowering and the second burst of nitrogen uptake (Grava and Raisanen, 1978), and continued until plants had thoroughly senesced, for a total of eight sample dates, not including initial sediment and pore water sampling. Sampling occurred every two weeks for the first four sample dates, (flowering, days 189-232) and weekly for the last four sample dates (seed production, days 238-265), for a total of eight sample dates. One week prior to each sampling date, 40 ml of enriched ^{15}N

solution were injected into the sediment of four randomly selected sulfate-amended buckets and four control buckets. For the first two sample dates, the labeling solution was prepared by adding 0.88 mg of 10% ^{15}N-NH_4Cl to 500 ml DI water. For all other sample dates, 2.2mg of 10% ^{15}N-NH_4Cl were added to 500 ml of DI water to account for an increase in plant biomass later in the growing season. The solution was injected into the sediment of the 4L pail in four locations uniformly spaced around the center of the pail, approximately 2 cm from the outer edge and 2 cm from the bottom. Immediately before injection, the overlying water was removed from the outer pail, leaving 2-5 cm above the sediment in the internal pail, to keep the ^{15}N-NH_4Cl contained in the sediment for uptake by the wild rice roots. On each sample date, one week after injection of ^{15}N, the four sulfate-amended and four control buckets were sampled for pore water sulfide, pore water sulfate, pore water iron, and pH. After pore water sampling, the wild rice plant was destructively harvested for analysis of vegetative ^{15}N, vegetative total N, and root AVS and weak acid extractable iron. The bulk sediment was sampled for solid phase S and Fe analysis at the beginning and at the end of the growing season.

Pore water sampling and analysis

Prior to extracting pore water samples, pH was measured *in-situ* with a ThermoScientific Orion pH electrode at a depth of 5 cm below the sediment surface and 2 cm from the stem of the wild rice plant. Pore water was sampled using 5-cm length, 2-mm diameter tension lysimeter filters (Rhizons, Seeberg-Elverfeldt et al., 2005) attached with a hypodermic needle to an evacuated, oxygen-free serum bottle sealed with a 20 mm thick butyl-rubber stopper (Bellco Glass, Inc). The entire filter end of the Rhizon was inserted vertically into the sediment just below the surface. The goal was to draw water from approximately the upper 5 cm of sediment without drawing surface water. The filter was placed with minimal jostling to avoid creating a cavity around the filter that would allow surface water to enter the sediment and contaminate the pore water. The Rhizon was placed approximately 2 cm away from the stem of the wild rice plant and on the opposite side from where pH was measured.

Pore water sulfide samples were drawn into 50-mL serum bottles preloaded with 0.2% 1 M ZnAc and 0.2% 6 M NaOH to preserve sulfide. Sulfide bottles were left to fill overnight, then stored at 4C in the sealed serum bottles used for sample collection for

approximately 30 days before sulfide was quantified. Samples for pore water sulfate analysis were withdrawn from sulfide sampling bottles and filtered through a Dionex 1cc metal cartridge and a 0.45 μm polyethersulfone filter approximately three months after they were collected. Pore water iron was collected in 8-mL serum bottles preloaded with 40% deionized water, 40% phenanthroline, 20% acetate buffer, and 1% concentrated hydrochloric acid. Iron bottles were filled until the solution turned light red, approximately ten minutes. If the solution turned red before 8 mL were collected, samples were diluted with deionized water to bring the total solution to 8 mL. Iron samples were quantified within two hours of sampling. Iron and sulfide were quantified colorimetrically using the phenanthroline and methylene blue methods, respectively, on a HACH DR5000 UV-Vis spectrophotometer (Eaton et al., 2005). Sulfate was quantified using a Dionex ICS-1100 Integrated IC system (AS-DV Autosampler) (Eaton et al., 2005).

Solid phase sampling and analysis

Samples for the bulk sediment initial conditions were obtained after homogenization of the sediment prior to placement in the buckets (day 152). Five replicate samples were placed in jars and analyzed for AVS and simultaneously extracted iron. At the end of the season, mini-cores of intact sediment were retrieved immediately before wild rice plants were sampled.

On each sample date throughout the summer, wild rice roots were collected for AVS and weak acid extractable iron. Each plant was removed from the sediment and immediately rinsed in buckets of deoxygenated water continuously bubbled with nitrogen. While submerged in deoxygenated water, the stem was cut just above the root ball so that the shoots and seeds could be saved for ^{15}N analysis. Roots were then placed in jars full of deoxygenated water, which were immediately placed in a plastic bag flushed with nitrogen and transported to an oxygen-free glove box. In the glove box, the roots were cleaned of extra organic matter prior to removing a 1-2 g section of wet root mass for AVS and iron analysis. From both sediment and roots, AVS was extracted using 7.5 ml 1 N HCl for 4 hours using a modified diffusion method (Brouwer and Murphy 1994). During a room temperature acid incubation with gentle mixing, sulfide was trapped in an inner vial containing Sulfide Antioxidant Buffer (SAOB) and

subsequently quantified using a ThermoScientific sulfide ion-selective electrode with a detection limit ranging from 0.01-40 mmol/L. Ferrous iron was quantified colorimetrically using the phenanthroline method on a HACH DR5000 UV-Vis spectrophotometer (Eaton et al., 2005), and weak acid extractable iron was quantified using a Varian fast sequential flame atomic absorption spectrometer with an acetylene torch.

A subset of roots was tested for chromium(II)-reducible sulfur (CRS) to determine whether AVS was extracting all total reduced inorganic sulfur on the roots. A diffusion-based CRS method was used, which can fully extract amorphous iron sulfide and pyrite and can partially extract elemental sulfur (Burton et al. 2008). Chromic acid for CRS analysis was prepared according to Burton et al. (2008). Inside an oxygen-free glove box, a section of root from a plant previously analyzed for AVS was placed in the analysis bottle. An inner vial containing SAOB was also placed inside the bottle prior to sealing. Bottles were taken out of the glove box and injected with chromic acid. CRS was extracted for 48 hours and quantified using a ThermoScientific sulfide ion-selective electrode.

Isotope sampling and analysis

For analysis of ^{15}N uptake, the plants were sub-sampled by cutting at the stem to root transition. If seeds were present, they were removed prior to sampling the plant and saved for separate analysis. The plants and seeds were rinsed with deionized water and dried in paper bags for seven days at 65C. The dried plants were weighed, placed in polycarbonate vials with stainless steel balls, and shaken in a SPEX 800M mixer mill until the samples were in a powdered form. Seeds were counted, weighed, and powdered using the same method. The samples were transferred to glass vials and dried again overnight at 65C with caps loosely covering the vials. Samples were quantified for total N and $\delta^{15}N$ on a Finnigan Delta Plus XP isotope ratio monitoring mass spectrometer.

Data analysis

Geochemical parameters and measured attributes of plants were analyzed using repeated measures analysis of variance to determine differences between sulfate amendments and controls. A paired *t* test was used to determine differences between AVS and CRS concentrations on roots. A two-factor ANOVA was used to compare pre-

planting and post-senescence sediment concentrations of iron and AVS between treatments. Analyses were performed using the statistical software SAS. Logarithmic transformations were used when data was non-normal. A reciprocal transformation was used for dry weight of plants, as a logarithmic transformation was not effective. Data for root AVS were split into pre-seed production and post-seed production because the full-season data was not able to be transformed.

The saturation index was calculated to determine if the pore water was saturated enough to precipitate iron sulfide (equation 1). A positive saturation index value indicates precipitation, and a negative value indicates dissolution. The K_{sp} value used was $10^{-2.95}$ (Stumm and Morgan, 1995).

$SI = log\frac{[IAP]}{K_{sp}}$ where $IAP = \frac{[Fe^{2+}][HS^{-}]}{[H^{+}]}$ Equation 1

Changes in the accumulation rates of root AVS and ferrous iron were tested by fitting linear regressions to the concentrations of root AVS and Fe^{2+} prior to seed production (days 189-231). The model was extrapolated to late season sample dates (days 232-264) to test if accumulation rates changed between flowering and seed production.

A mixing model was used to determine the proportion of seed nitrogen originating from the pore water and the proportion translocated from the stems (equations 2 and 3). The $\delta^{15}N$ of the seeds was measured, and the $\delta^{15}N$ of the pore water and the stems were approximated. In equation 2, δ_{sample} is the isotopic signature of nitrogen in the seed, $\delta_{source1}$ is the isotopic signature of the pore water ammonium, f_1 is the proportion of nitrogen coming from the pore water, $\delta_{source2}$ is the isotopic signature of nitrogen in the plant stem, and f_2 is the proportion of the nitrogen sourced from the plant stem. Seed nitrogen can be sourced only from the pore water or the stems, so the proportions from both components must sum to one (equation 3).

$\partial_{sample} = \partial_{source1} \times f_1 + \partial_{source2} \times f_2$ Equation 2

$f_1 + f_2 = 1$ Equation 3

Results

Pore water

Although sulfate was 40x higher in the overlying water of sulfate-amended plants, pore water sulfide concentrations were only approximately twice as high in the in the rooting zone of sulfate-amended plants compared to the control over the entire growing season. Sulfide concentration and variability increased in the pore water of both amended and control rooting zones one week after the first seeds were produced (day 238, Julian date) and returned to initial concentrations two weeks later (day 245, Fig. 1a). Pore water sulfide data did not fit any parametric model, so a repeated measures ANOVA was not performed.

Pore water iron concentrations were not correlated with sulfate amendment (Table 1). Pore water iron decreased until shortly after seed production began (day 238) in both amendments. The minimum iron concentration occurred at the same time that a peak in pore water sulfide developed (Fig 1b). Shortly before senescence (days 252 and 264), the iron concentrations returned to values similar to concentrations during the first month of data collection.

The pore water pH and saturation index were not correlated with sulfate amendment (Table 1). The pH of the pore water peaked at the start of seed production (days 231-238, Fig.1c). This peak occurred approximately one week before the iron minimum and the sulfide maximum. The saturation index peaked one week after the first seeds were produced, when pH and sulfide were elevated and iron was low (day 238, Appendix Table 1). The average saturation index was above zero only in the sulfate-amended buckets on day 238. The saturation index gradually declined for the rest of the growing season.

Sulfate concentrations ranged from 10-30 times higher in the pore water of plants amended with sulfate (Table 1). Sulfate increased in the amended pore water until seed production began, when it declined precipitously from 2300 μmol/L to 770 μmol/L over 15 days (Fig 1d). In the pore water of control plants, sulfate concentrations followed a similar trend, but at lower concentrations. Control sulfate peaked at 230 μmol/L before decreasing to 34 μmol/L. Sulfate declined just prior to an increase in pore water sulfide.

Table 1. Results of repeated measures ANOVA testing effect of sulfate, time and interaction of sulfate and time on geochemical and biological variables. Tests for pore water and root parameters include data from the entire growing season, whereas tests for biological parameters only include data from mature seed production. *F* values and degrees of freedom (*d.f.*) are given. Tests for time and sulfate x time have the same number of degrees of freedom. Significance levels are shown using asterisks (***indicates $p < 0.001$, **indicates $0.001 < p < 0.05$, *indicates $0.05 < p < 0.10$).

Repeated measures ANOVA (F values)	Sulfate	d.f.	Time	Sulfate x Time	d.f.
Pore water geochemistry					
Iron	5.16	1, 5	5.51***	1.14	6, 35
pH	3.25	1, 6	12.5***	1.45	6, 36
Saturation index	2.68	1, 4	2.19*	0.50	6, 34
Sulfate	239***	1, 3	8.17***	1.09	5, 27
Root geochemistry					
AVS (during flowering)	66.1***	1, 5	1.10	0.40	3, 17
AVS (during seed production)	148***	1, 6	5.46**	1.76	4, 24
Weak acid extractable iron	0.53	1, 6	2.65	2.42**	7, 42
Ferrous Iron	127***	1, 6	57.2***	3.34**	6, 36
% Ferrous Iron	235***	1, 6	41.5***	4.91***	6, 36
Biological variables (during seed maturity)					
Plant N (total mass)	1.53	1, 6	0.35	0.25	2, 12
Plant weight	5.00*	1, 6	0.40	0.31	3, 18
Seed N (total mass)	5.84*	1, 6	1.10	1.22	2, 12
Seed weight	4.88*	1, 6	0.59	0.94	2, 12
Seed count	5.00*	1, 6	1.89	0.70	2, 12
Seed $\delta_{15}N$	1.47	1, 6	2.45	0.05	2, 12
Seed N%	1.70	1, 6	3.04*	0.40	2, 12
Vegetative N (plant+seed mass)	5.43*	1, 6	0.32	1.71	2, 12

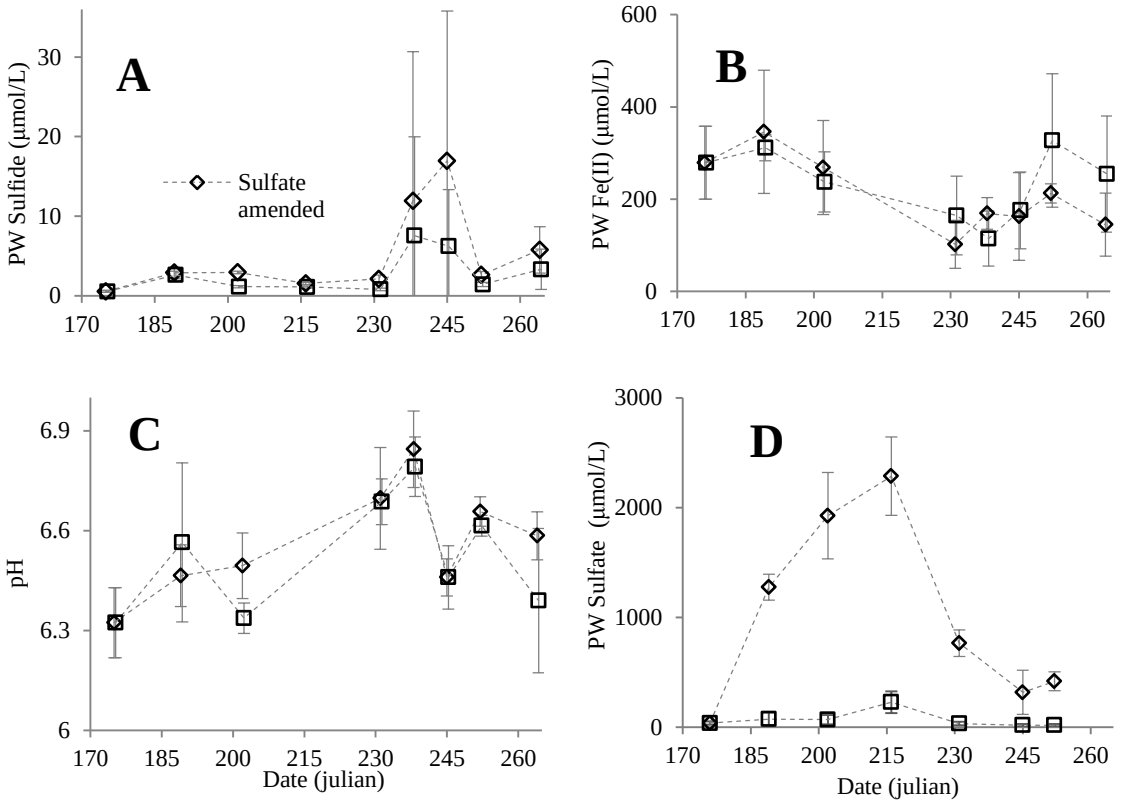


Figure 1. Pore water (PW) data measured in buckets during summer of 2015. Diamonds indicate data from buckets amended with 300 mg/L sulfate. Squares represent data from control buckets. Time is shown in Julian days. Error bars indicate one standard deviation. Control data points are slightly offset to show overlap in error bars.

Roots

Wild rice plants grown in sediment with high overlying water sulfate concentrations developed a black coating on their root surfaces (Appendix Fig. 1). A SEM scan of the roots showed that the root precipitate contained iron and sulfur in approximately a 1:1 ratio (Dan Jones, unpublished data). The oxic/anoxic interface was often recorded on the root; the black coating started on the stem just above the root ball and extended downwards along the entire length of the roots. Adventitious roots that grew at the surface of the sediment remained white, the natural color of wild rice root tissue. Control plants, grown in sediment with low overlying water sulfate, formed very little black color on their roots, instead appearing amber, a color characteristic of iron (hydr)oxides.

Roots grown under elevated sulfate (hereafter "amended roots") accumulated AVS concentrations up to two orders of magnitude higher than the control roots by late summer. Amended root AVS peaked at 298 ± 74 umol/g dw immediately prior to senescence (Fig 2a). Concentrations of AVS on roots grown under control surface water sulfate (hereafter "control roots") did not consistently increase, and averaged of 3.2±1.7 umol/g dw. For amended roots, the rate of accumulation of root AVS appeared relatively constant (linear) until the first day seeds were produced (day 232), when the rate of AVS accumulation appeared to increase abruptly. During seed production, AVS concentrations were greater than that predicted by a linear model (constant accumulation rate), suggesting that the net rate of AVS accumulation on amended roots increased rapidly when seed production began. Points after the first day of seed production (day 231) fell outside of a 95% CI of a linear regression on the points during flowering (days 190-231, Appendix Fig. 2). Concentrations of CRS on both amended and control roots did not differ from AVS concentrations on the same roots, indicating that crystalline forms of FeS did not make up a significant proportion of reduced sulfur (paired *t* test, p=0.27, t=0.63, n=20).

Ferrous iron accumulation paralleled AVS accumulation on amended roots (Fig 2b). Root ferrous iron concentrations were elevated and accumulated faster on the amended roots compared to the control (Table 1). Ferrous iron on control roots and amended roots increased linearly, but ferrous iron on amended roots increased at a higher

rate until the first seeds were produced (day 232). During seed production, ferrous iron concentrations on amended roots were greater than those predicted by a linear model, while Fe(II) accumulation on control roots appeared to slow.

Weak acid extractable iron (sum of Fe(II) + Fe(III) concentrations on roots, hereafter "total extractable iron") was variable, but did not differ significantly between treatments (Table 1). The average total extractable iron remained relatively constant in both treatments during flowering; however, during the first week of seed production (days 232 and 239) the total extractable iron dropped by about 150-250 umol/g on both the amended and control roots, and then gradually increased over the following three weeks (Fig. 3). Total extractable iron changed seasonally from mostly Fe(III) to mostly Fe(II) on sulfate-amended roots, especially during the first week of seed production (days 232 and 239). This abrupt shift in iron speciation occurred the same week that total extractable iron decreased and at about the same time as the increase in AVS accumulation rate (Fig. 3). Immediately prior to seed production, total extractable iron on the amended roots was 46 ± 11% Fe(II), and after one week of seed production, the composition of iron was 87 ± 10% Fe (II). During this same week, control root Fe(II) increased from 20 ± 11% to 48 ± 16%.

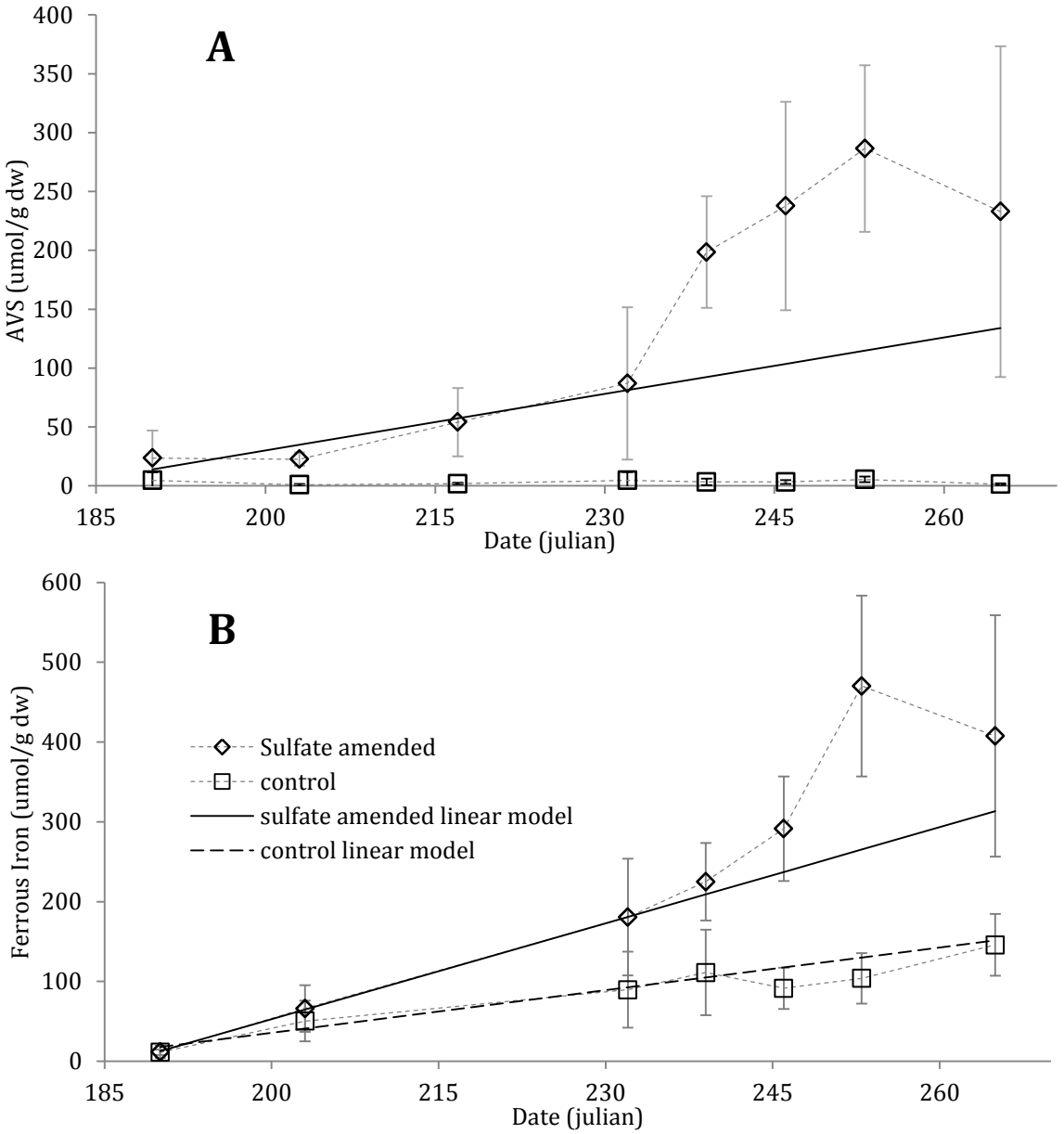


Figure 2. Solid phase acid volatile sulfide (A) and ferrous iron (B) concentrations on roots. Diamonds represent the average concentration on roots of four sulfate-amended plants, and squares represent the average of four control plants. The dashed line shows a linear model fit to the data from day 190 to day 232. Time is expressed in Julian dates. Error bars show one standard deviation.

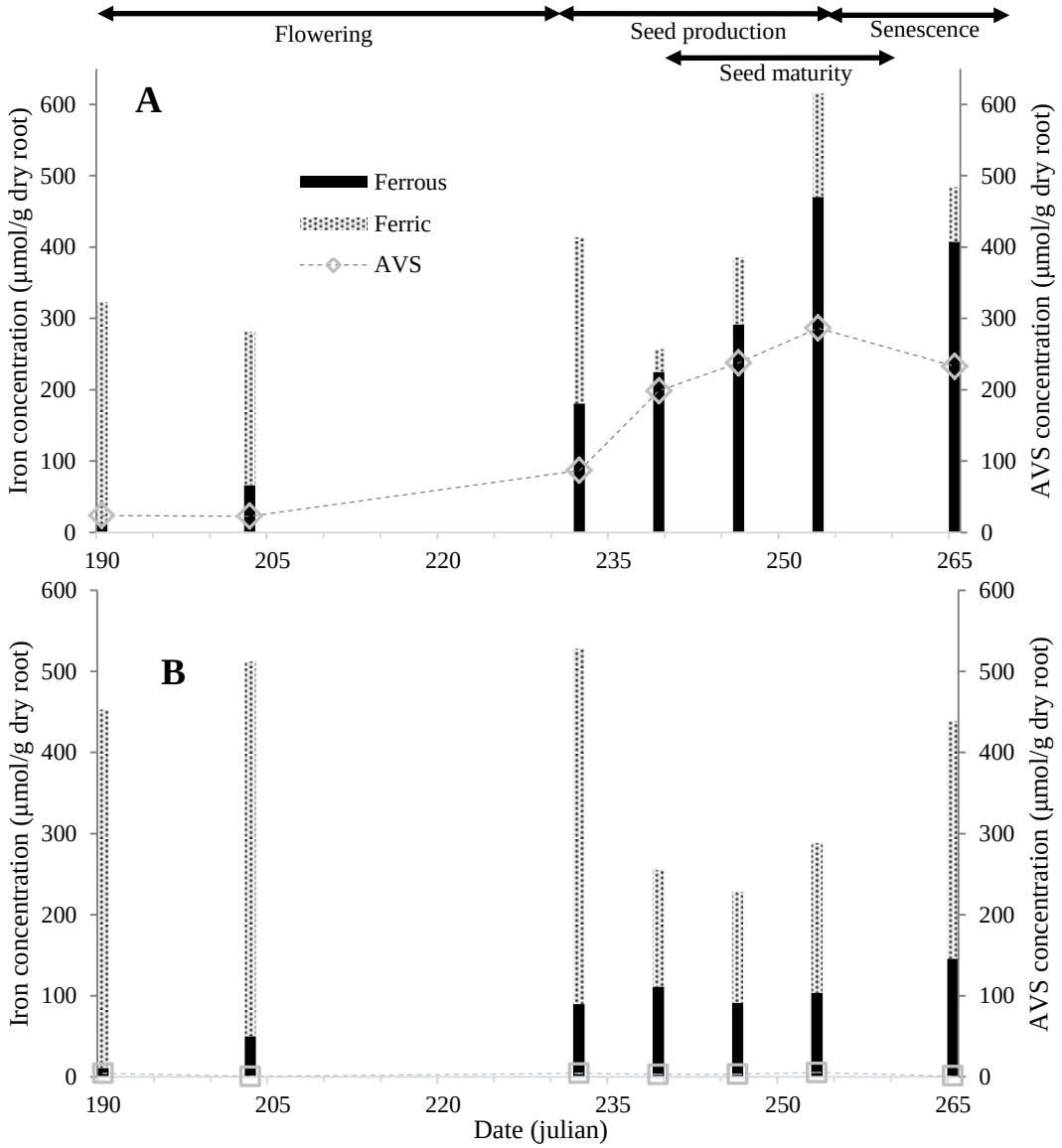


Figure 3. Seasonal iron speciation with root AVS overlain in sulfate-amended bucket. The dotted pattern indicates ferric iron and the solid black represents ferrous iron. A). Sulfate-amended bucket iron. Grey diamonds show root AVS concentrations in sulfate-amended buckets. B). Control bucket iron. Grey squares show root AVS concentrations in control buckets. Error bars are omitted for clarity.

Sediment

Sediment AVS was significantly different between treatments, but total extractable iron was not. In both the sulfate-amended and control sediment, AVS increased during the growing season, but more AVS accumulated in the amended sediment (2-factor ANOVA, time x treatment interaction, f=5.08, df=1,18, p=0.037). Amended sediment AVS increased from 0.39 umol/g in early summer to 4.7 μmol/g at the end of the growing season, whereas the control sediment only increased from 0.39 μmol/g to 0.88 umol/g. There was no difference in total extractable iron between the amended and control sediment at the beginning or end of the growing season (2-factor ANOVA, f=0.65, df=1,18, p=0.429).

Biological effects

Plant sampling began at the start of the flowering stage (days 190-230). The first seeds were collected on 8/20/15 (day 232), but were unripe and not yet filled. In this paper, seed production is referred to as days 230 to day 264, but mature seeds were not produced until one week after the start of seed production (day 239). On the last sample date (day 265) seeds were collected, but were unfilled. Stems and leaves were no longer green, indicating that the plants had senesced. Of the four replicates in the sulfate amendment on this date, two plants did not produce seeds. Thus, "mature seed production" refers to dates 239-253.

Total seed nitrogen, total seed weight, and seed count were all lower in sulfate-amended plants during mature seed production, a time that coincided with elevated FeS on roots (days 239-253, Table 1, Fig 4). Sulfate addition was not correlated with seed $\delta^{15}N$ or seed N %. During mature seed production and senescence, the dry weight of the sulfate-amended plants was lower than that of control plants. Total vegetative (plant + seeds) N was unaffected by sulfate until the last two sample dates prior to senescence, when it was lower in sulfate-amended plants (Fig 4d, two-sample t test, p=0.031, p=0.047, n=8 for both dates).

A mixing model was used to determine the fraction of total seed nitrogen coming from the pore water and the fraction translocated from the stem (Appendix Fig. 3). In the days following a spike of enriched nitrogen to sediment pore water, there were two possible sources of nitrogen in the seeds; wild rice can translocate nitrogen from its stem

or take nitrogen up from the pore water. The plant $\delta^{15}N$ was estimated to be 4.5‰ from the average of 12 unlabeled plants harvested on the first two sample dates. The pore water $\delta^{15}N$ was approximated to be 180‰ and calculated from the percent by mass of $^{15}NH_4$ added ($\delta^{15}N$ =26,200‰) and the percent by mass of ammonia already present in the pore water ($\delta^{15}N$ assumed to be 0‰). The two-component mixing model showed no difference in fraction of nitrogen uptake from pore water between the amended and control plants (repeated measures ANOVA, p=0.83, f=0.05, df=1,6). In both control and amended plants, the fraction of total seed nitrogen originating from the pore water increased two weeks into seed production (day 246) from 27 ± 18 % to 51 ± 19%, but returned to 29 ± 19 % a week later (day 253). The elevated proportion coming from the pore water coincides with the day seeds contained the most nitrogen (Fig 4c). On this day, total seed nitrogen was significantly lower in the sulfate amended plants than in the control plants (two-sample t test, p=0.047, n=8). Plant N (excluding seeds), however, was not different between amended and control plants on this day (two-sample t test, p=0.41, n=8).

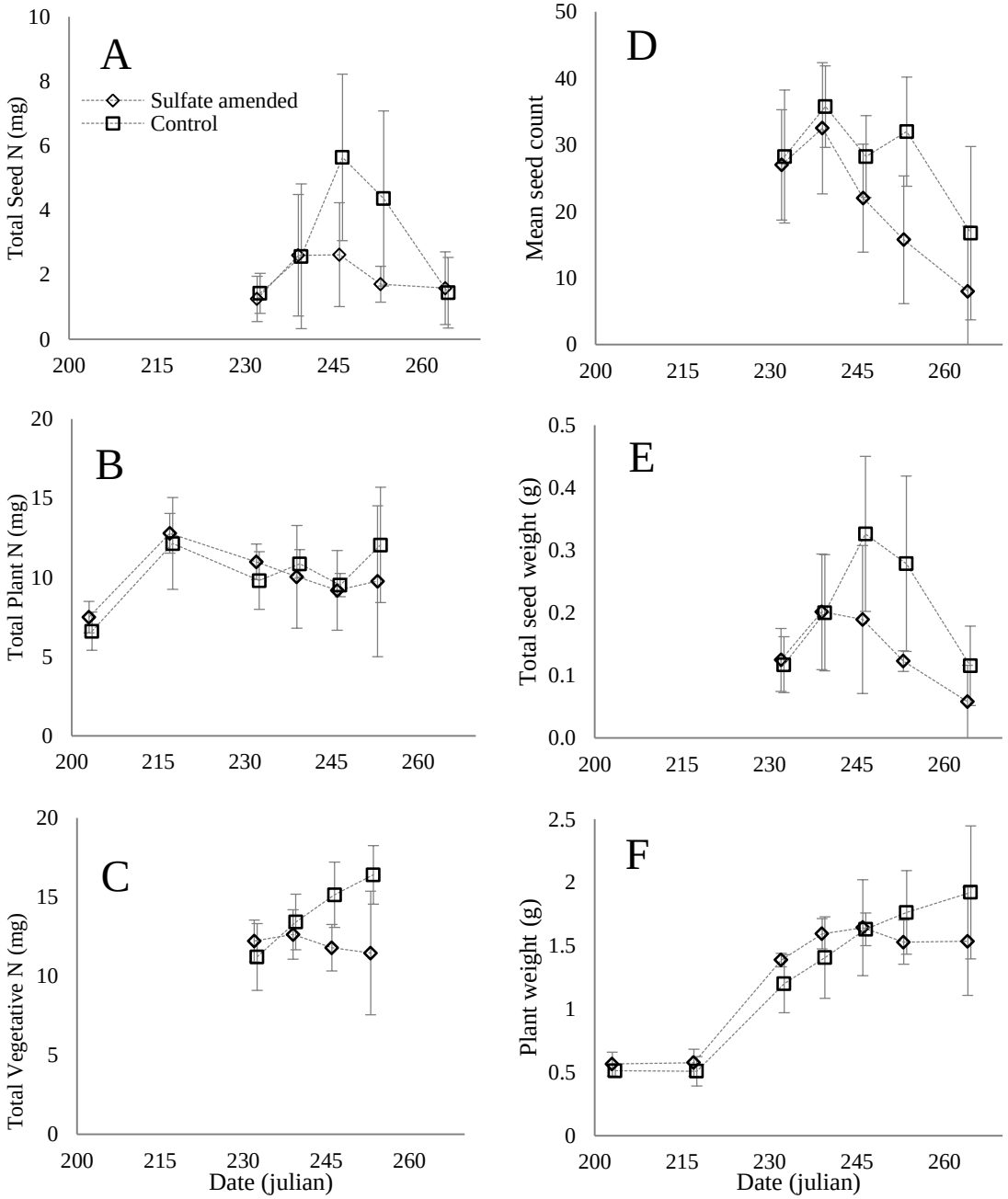


Figure 4. Biological endpoints. Diamonds represent plants grown in surface water with 300 mg/L sulfate added while squares show data from control plants. Each data point represents four replicates. Error bars represent one standard deviation. A) Weekly total mass of nitrogen in seeds of sulfate amended and control plants. B) Total mass of nitrogen in the plant (stems+leaves), excluding seeds, over the course of the growing season. C) Weekly total vegetative nitrogen in amended and control plants. Total vegetative nitrogen was calculated by summing nitrogen from seeds, stems, and leaves. D) Weekly seed count in amended plants and control plants. E) Weekly total seed mass in amended plants and control plants. F) Dry mass of plants over the course of the growing season.

Discussion

Our observations suggest a tight coupling of iron and sulfur cycling in the rooting zone of wild rice. Iron (hydr)oxides form on wild rice roots early in the growing season, but roots that are exposed to high sulfate loading (300 mg/L) develop iron sulfides later in the growing season. An inflection point in iron sulfide accumulation occurs at the start of seed production, shortly after rapid depletion of sulfate in the pore water, and defines an increase in the net rate of FeS accumulation. The rapid increase in net FeS accumulation suggests a change in a process that controls the way iron and sulfur cycle in the rhizosphere, and the timing suggests that this process may be tied to and have important implications for rice physiology. Previous research has suggested that an accumulation of FeS occurs after plant senescence (Jacq 1991), but our observations clearly show accumulation of FeS during the reproductive life stage of wild rice.

The change in FeS accumulation rate is consistent with an inhibition of radial oxygen loss. Sulfate accumulation in the pore water during the flowering stage suggests that the rhizosphere is relatively oxidized. The initially linear FeS accumulation rate on plant roots suggests constant rates of sulfide production and sulfide oxidation, with a higher rate of sulfide production than oxidization (net accumulation). However, sulfide exposure in white rice leads to the formation of suberin in the cell walls of roots which is hypothesized to create a barrier that limits diffusion of toxic solutes into the plant (Armstrong and Armstrong, 2005). The barrier not only excludes toxic solutes like sulfide, but also traps oxygen inside the roots, suppressing radial oxygen loss (Krishnamurthy et al. 2009, Soukup et al. 2006). A relatively rapid transition to anoxia of the rhizosphere appears to have occurred at the onset of seed production, possibly as a result of suberin-induced suppression of radial oxygen loss. Under the anoxic conditions, the net accumulation of reduced species likely increased because fewer reduced species cycled back to their oxidized form.

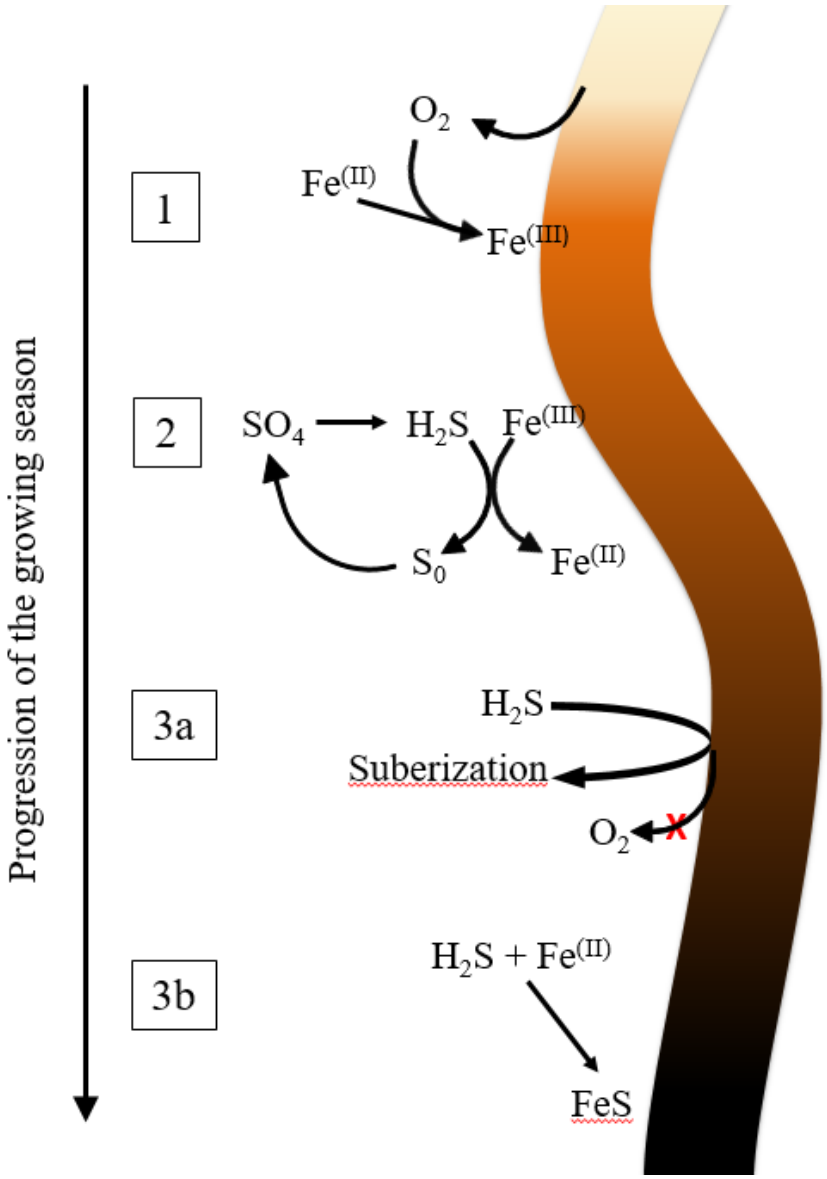


Figure 5. Proposed mechanism of iron sulfide formation on wild rice roots. Roots are protected by iron (hydr)oxides [1], but reduced by sulfide [2]. Exposure of roots to sulfide induces suberization of root cells, which leads to decreased radial oxygen loss [3a]. Rhizosphere anoxia allows iron sulfides to precipitate [3b].

A hypothesized pathway for how the rice roots might transition from iron (hydr)oxide plaques to iron sulfide plaques over the growing season is outlined in Figure 5. Initially, radial oxygen loss creates oxic conditions in the rooting zone, causing ferrous iron within the rhizosphere to precipitate as iron (hydr)oxides and accumulate on root surfaces (Fig. 5, [1] label). At this initial stage, the root is protected from reduced species by both radial oxygen loss and iron (hydr)oxide plaques, an electron accepting sink. Before sulfide can penetrate to the root, the iron (hydr)oxide plaques, effectively acting as an electron accepting buffer, must be reduced (Fig. 5, [2] label). As sulfide erodes the accumulated ferric iron barrier (Hansel et al. 2014, Kwon et al. 2013), sulfide can then reach the root surface and cause suberization (Fig. 5, [3a] label). Once radial oxygen loss is suppressed by suberin formation, the electron accepting buffer capacity of iron (hydr)oxides can no longer be replenished. The remaining quantity of iron (hydr)oxides can be more rapidly reduced due to a net change in the flow of electrons to the rooting zone. Upon depletion of iron (hydr)oxides, sulfide accumulates rapidly, since neither iron (hydr)oxides or a supply of radial oxygen loss are available to oxidize sulfide (Fig 5, [3b] label). As sulfide penetrates closer to the root surface, it precipitates with available iron, and the redox potential of the rhizosphere shifts to more reducing conditions.

The rapid accumulation of sulfur on roots in amended plants seems inconsistent with the relatively small difference in sulfur and iron concentrations in pore water. The saturation index (SI), which is calculated from pore water concentrations two centimeters from the stem, indicates that the pore water is undersaturated with respect to iron sulfide. The thermodynamic understanding of mineral precipitation and dissolution is that minerals precipitate when pore water is saturated and dissolve when pore waters are undersaturated (Stumm & Morgan, 1995). The rapid accumulation of iron sulfide on roots in the setting of undersaturated pore water suggests that the transition of iron (hydr)oxide to iron sulfide on the roots occurs very close to the surface of the root, and thus depends on near-root-surface processes more than on pore water concentrations. Sulfide on root surfaces must be supplied externally, either from reduction of surface water sulfate, or from mobilization of AVS on sediment, but ferrous iron in the FeS plaques could be sourced from the reduction of iron (hydr)oxides already accumulated on

the root surface earlier in the season. Indeed, a decrease in solid-phase iron on the roots, a shift in iron speciation, and an accumulation of pore water iron all occur simultaneously, which is consistent with loss of soluble ferrous iron off of the root surface during the redox transition. Thus, if the ferrous iron in FeS plaques is sourced from the iron (hydr)oxides on the root, saturation index calculations based on pore water iron concentrations may not be relevant to understanding FeS formation on roots. Additionally, the decline of pore water sulfate followed by rapid accumulation of AVS on the root surfaces suggests that a large amount of sulfur passes through the pore water pool very quickly. Iron sulfide formation is strongly favorable thermodynamically and kinetically rapid (Rickard, 1995). Using pore water sulfide concentrations to calculate the saturation index may underestimate the amount of sulfur available to precipitate on root surfaces, as pore water sulfide may act as a transient phase between pore water sulfate and root AVS. The transience of sulfide in pore waters near rice rhizospheres was noted by Hara (2013) who observed black iron sulfide zones around white rice seeds grown in sulfate-amended sediment, but was unable to quantify any sulfide, despite measuring redox potentials low enough to support sulfide production.

In this experiment, iron sulfide plaques occurred concomitantly with lower seed nitrogen and fewer seeds. Less nitrogen was present in the total seed mass of the amended plants, and fewer seeds were produced. This is likely a strategy for optimizing reproduction; amended plants produce fewer filled seeds but each filled seed is fully viable (Pastor et al., in reveiw). The two-component isotope mixing model suggests that the amended plants were not able to compensate for inhibition of nitrogen uptake by translocating a greater percentage of seed nitrogen from the stem and leaves. Between the sulfate and control, no difference was observed in the fraction of N uptake from the pore water. The decreased total seed N in sulfate amended plants appears to be an equally proportioned result of decreased uptake from pore water and decreased translocation from the plant.

Biological variables were only affected during seed production. During the biomass growth life stages, little difference in total plant weight and total plant N was observed. Biomass may not have been impacted because sulfide can produce a fertilization effect by sequestering iron bound with phosphate, releasing free phosphate

(Geurts et al. 2009, Caraco et al. 1989, Smolders et al. 2003, Lamers et al. 2002). However, nitrogen, rather than phosphorus, is the limiting nutrient for wild rice (Sims et al. 2012), so the fertilization effect is likely minimal in wild rice. In the long term, Pastor et al. (in review) showed that sulfide takes several years to affect a population of wild rice, because although sulfide showed no effect on germination and very little effect on biomass of wild rice, sulfide greatly decreased the number of juvenile seedlings that survive and the number of filled seeds produced by the plant. The results from our study suggest that during seed production, the buffering capacity of iron (hydr)oxides has been overwhelmed by sulfide and no longer protects the plant from sulfide. Similarly, juvenile seedlings may be vulnerable to sulfide because they have not yet grown out of the water column and are thus unable to transport oxygen from the atmosphere to their roots. The life stages of wild rice affected by sulfide are consistent with times during which an oxic barrier around the roots is absent.

Accumulation of FeS on roots may have implications for wetland cycling of iron and sulfide. After senescence, roots coated with FeS decay and become incorporated into the bulk sediment. Jacq et al. (1991) found significant accumulation of FeS on white rice roots after senescence, likely because the dead root material stimulated continued iron and sulfate reduction. Additionally, Jacq et al. (1991) found that sediment in a planted rice paddy contained higher FeS concentrations than an unplanted rice paddy. Because wild rice is an annual plant, the amount of root FeS that accumulates over a growing season is added to the sediment each year. Choi et al. (2006) likewise found that in a riparian wetland containing *Phragmites australis* and *Zizania latifolia*, AVS concentrations were higher in the top 6 cm of non-vegetated sediment, but vegetated sediment had higher concentrations of AVS 6-14 cm below the sediment-water interface. If AVS on roots is supplied mainly from reduction of surface water sulfate, burial of FeS coated roots may be supplying sulfide to the sediment faster than pore water precipitation of iron sulfide in the bulk sediment. If root AVS is supplied largely by mobilization of sediment AVS, which Choi et al. suggests can be caused by radial oxygen loss, then sediment AVS concentration may be an important parameter in determining iron sulfide accumulation and concomitant inhibition of nitrogen uptake in wild rice. Knowledge of

the main sources of sulfur for root AVS will be crucial in managing wild rice in sulfur-impacted systems.

Conclusion & Directions for Future Work

The timing of our observations of rhizosphere AVS accumulation in conjunction with decreased total seed N in sulfate-amended plants suggests that nitrogen uptake by wild rice is affected only after significant sulfide accumulation on root surfaces. In this experiment, elevated sulfide on plant roots coincides with the plant's reproductive stage. We propose that root surface iron (hydr)oxides delay sulfide from entering the plant, effectively acting as a buffer against early and mid-season sulfide exposure. When the oxic barrier on the root surface is overwhelmed, iron sulfide accumulates rapidly, as shown by the doubling of AVS and the shift in iron speciation from about 50% Fe(II) to 90% Fe(II) within just one week. In this experiment, the oxic barrier was overwhelmed just prior to seed production; concurrently, reduced seed count, total seed weight, and total seed nitrogen were observed.

Many questions remain about the cause of the redox shift in the rhizosphere. We propose a mechanism in which sulfide-induced suberization of roots facilitates reduction of the oxic barrier, but a seasonal change in wild rice physiology could also facilitate a rapid transition to anoxia. Control roots, like sulfate-amended roots, lost about half of their total extractable iron at the start of seed production, and accumulated some ferrous iron even in the absence of significant S accumulation. Is there a seasonal shift in redox potential in wild rice rhizospheres, regardless of the presence of sulfur? Seasonal measurements of redox potential and magnitude of radial oxygen loss may provide insight into the comparative influence of plant processes and sulfur loading on shifting redox conditions in the rhizosphere. Is the bacterial community affected more by rhizosphere geochemistry or by life stages of the plant? Seasonal microbial community analysis could also elucidate the relative causes of the rhizosphere anoxia, as a significant seasonal shift in the microbial community of control plants would indicate plant controlled redox conditions. If the redox conditions of the rhizosphere are controlled by iron and sulfur geochemistry as proposed, would a lower initial concentration of iron on roots result in erosion of the iron (hydr)oxide barrier and subsequent inhibition of nitrogen uptake earlier in the growing season? If so, would plant biomass and nitrogen

also be decreased? A similar study to this one could be done in which total iron concentrations of the sediment were varied to produce different initial concentrations of iron (hydr)oxides on roots.

Finally, from a management perspective, it would be useful to understand the sources of sulfur on root surfaces and the sediment parameters that control those sources. Is the sulfide on the roots sourced primarily from surface water sulfate or from mobilization of sediment AVS? Could a lake that has previously received high sulfur loads but currently has low surface water sulfate contain wild rice with significant iron sulfide plaques? This question has implications for restoration of wild rice in sulfur-impacted lakes.

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Appendix

Table 1. Average and standard deviation of the saturation index in sulfate amended and control pore waters. The K_{sp} value used was $10^{-2.95}$.

Date (julian)	Sulfate-amended	Control
177	-1.436 ± 0.228	-1.436 ± 0.228
190	-0.282 ± 0.346	-0.175 ± 0.354
203	-0.390 ± 0.189	-1.061 ± 0.204
232	-0.560 ± 0.195	-0.802 ± 0.242
239	0.099 ± 0.969	-0.232 ± 0.435
245	-0.140 ± 0.580	-0.410 ± 0.837
256	-0.302 ± 0.376	-0.365 ± 0.333
263	-0.199 ± 0.198	-0.597 ±0.581



Figure 1. Sulfate-amended root (left) and control root (right). Sulfate-amended root has black color extending from about 0.5 cm above the root ball down to the tips of the roots (not shown). Control root has amber color characteristic of iron (hydr)oxides, especially 2-3 cm below root ball.

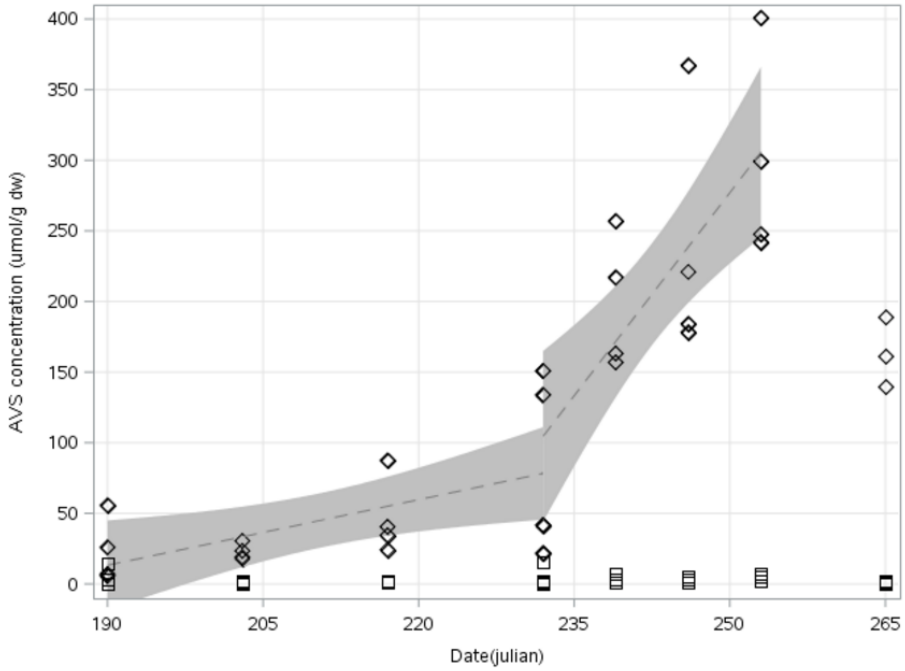


Figure 2. A 95% confidence interval around a regression of time and AVS on sulfate amended roots depicting the change in rate of sulfide accumulation. Diamonds represent sulfate amended plants, and squares represent control plants. The plant is in the flowering stage until day 232, when it starts producing seeds. The last sample date was during senescence, and is therefore not included in the 95% confidence interval.

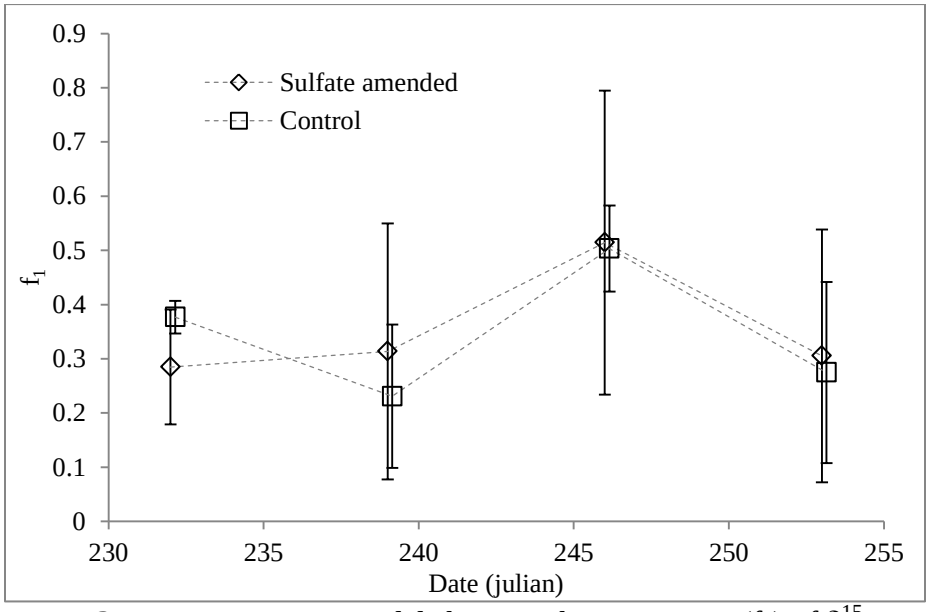


Figure 3. Isotopic mixing model showing the proportion (f_1) of $\delta^{15}N$ in seeds that originated from ammonium in the pore water during seed production. Diamonds represent sulfate amended plants, and squares represent control plants. Each data point is the average of four replicates. Error bars are one standard deviation.

[redacted]

MINNESOTA SEA GRANT COLLEGE PROGRAM RESEARCH ANNUAL REPORT

PI NAME: John Pastor

PROJECT NUMBER: R/CE-04-14
Chart String: 1000 10340 20857 00041968

PROJECT END DATE: June 30, 2016

REPORT DATE: May 5, 2016

PROJECT TITLE: The Biogeochemical Habitat of Wild Rice

PROGRESS TOWARD OBJECTIVES: (summarize your progress over the last 12 months)

With Sea Grant funding, we continued one long-term experiment and initiated two others. The long-term experiment consisted of adding sulfate to tanks containing wild rice grown in wild rice sediment to achieve surface water concentrations of ambient (7), 50, 100, 150, and 300 ppm SO4. After five years (two under SeaGrant funding, the wild rice populations in the 300 ppm tanks have gone extinct and the populations in the 150 ppm tanks are nearing extinction (Pastor et al. submitted). Extinction was caused by toxic levels of sulfide (from sulfate reduction) to seedlings and from reduced seed production. Proportional decreases in population productivity have happened in the other amended tanks.

During the course of these experiments, wild rice roots in tanks with more than 50 mg/L sulfate had become blackened. In contrast, plants grown in the low sulfate treatments had orange stains on the roots throughout the annual life cycle (Fig. 1). Using SEM elemental scans, we identified the black plaques as iron sulfide (FeS) plaques whereas the orange stains had iron but no sulfide and are most likely iron (hydr)oxides.

To sort out these two potential effects of FeS precipitation in roots and on sediments, we initiated two additional experiments. One is a large scale tank experiment in which additions of sulfate to 300 ppm, a tripling of sediment iron, and removal of litter (to reduced labile carbon for microbes) were applied in a crossed factorial design. After two years, sulfate amendments had the greatest effect, reducing production as in the first experiment regardless of iron amendment and litter removal. Iron amendment had no statistically significant effect, but plants grown under both sulfate and iron amendments had the lowest vegetative and seed production of all. Litter removal had no effect. While we cannot yet conclude from this experiment that iron has a strong depressive effect on wild rice growth via FeS plaques on roots, we can conclude that iron has no beneficial effect by reducing the toxicity of sulfide.

We also initiated a third experiments aimed at quantifying the development of these FeS root plaques. In this experiment, wild rice was grown individually in buckets with and without sulfate amendments (to 300 ppm). We sampled plants every two weeks to determine the phenology of the development of FeS plaques on the roots. We made two surprising observations. First, accumulation of FeS plaques on roots of plants grown under high sulfate concentrations increased very rapidly and suddenly in midsummer even while porewater sulfide in the bulk sediment remained unchanged. And second, by the end of the growing season, FeS concentrations were two orders of magnitude higher on black root surfaces than in the surrounding sediment; after a single annual growing season, the black roots contained approximately 5% (by mass) of the total amount of sulfur in the experimental sediments. FeS in the bulk sediment also increased during the growing season but much more slowly and without an obvious breakpoint in accumulation rate. These observations suggest an overwhelmingly dominant, plant-induced change towards conditions more conducive to FeS precipitation in the immediate vicinity of the roots that begins in the middle of the growing season and controls the rates and location of sulfur transformations.

Plants with the black FeS plaques on their roots produced fewer and less viable seeds, perhaps because the plaques potentially impair the uptake of phosphorus and nitrogen (Pastor et al. submitted). The rapid accumulation of FeS plaques occurs at the time that wild rice plants are beginning to flower and take up additional nutrients for the ripening seeds. This suggests that even if the precipitation of FeS in

the bulk sediment reduces aqueous sulfide, precipitation on the root surfaces somehow impedes seed formation, perhaps by blocking nutrient uptake.

Last summer, we also added ^{15}N periodically throughout the growing season to plants amended with 300 mg/L sulfate and plants without sulfate addition. These experiments are providing a more detailed look at the plant-side nutrient fluxes in the context of the changing rates of sulfur accumulation on root surfaces. Preliminary results suggest that nitrogen uptake by wild rice may be inhibited by plaque formations, especially during the period of seed filling and ripening. If nitrogen uptake is inhibited by FeS plaques, then this may explain why wild rice plants with FeS plaques on roots had smaller seeds and a greater proportion of the seeds were not filled (Pastor et al. submitted).

DIFFICULTIES ENCOUNTERED AND ACTIONS TAKEN TO OVERCOME THEM:

Before we began the ^{15}N experiment last year, we had to spend the previous summer in pilot trials determining how much ^{15}N to add to create a measureable signal in the plants while overcoming the strength of the microbial sink in the sediment. This took up one entire summer The following summer was spent determining the approximate joint phenology of FeS plaque formation and ^{15}N uptake. Now that we know the proper amount of ^{15}N to add and the approximate joint phenology of its uptake in relation to FeS plaque formation, we have devised a sampling schedule wherein we will sample at high frequencies during the time of FeS plaque formation to determine how it coincides with nitrogen uptake. This will allow us to determine whether FeS plaques form at a constant increment controlled entirely by inorganic geochemistry of the sediments, or whether FeS plaques grow exponentially as they progressively cut off radial oxygen losses from the roots. We are, under separate documentation, requesting a no-cost extension of unspent graduate student funds to support Ms. Sophie LaFond-Hudson to continue these experiments which will be part of her Ph.D. thesis in Water Resources Sciences at the University of Minnesota.

RESULTS TO DATE: (please provide a brief summary of your results)

See above. Paper submitted acknowledging SeaGrant support:

Pastor, J., B. Dewey, N. W. Johnson, E.B. Swain, P. Monson, E.B. Peters, and A. Myrbo. Effects of sulfate and sulfide on the life cycle of wild rice (*Zizania palustris*) in hydroponic and mesocosm experiments. Ecological Applications: submitted.

ASSESS PROGRESS RELATIVE TO ORIGINAL SCHEDULE AND FINAL DEADLINE:

We have accomplished all of our original goals involving the tank experiments. The ^{15}N experiments were begun in response to a recommendation of the proposal review panel that we include some isotopic amendments to determine the effect of sulfate amendments on nutrient cycling. However, in order to do that with any precision, we needed to spend two years in pilot experiments to determine the amount of ^{15}N to add and its phenology relative to the growth of FeS plaques at high sulfate concentrations. With one more year's fieldwork we will be able to accomplish this objective.

OUTREACH OR PRODUCTS: Please list any products (Web or print), presentations, articles, media interviews, teacher training, K-12 education, etc. that you or your student(s) have from this research thus far. Is there anything our Communications or Extension staff can do to help you connect your research with stakeholders?

PERFORMANCE MEASURES: We are required to provide performance measures to National Sea Grant each year. You may not have anything at all in some of these categories, and that is expected. All we need at this point is your best guess and an explanation of how you arrived at your answer.

Measure 1: Economic and societal benefits derived from the discovery and application of new sustainable coastal, ocean, and Great Lakes products from the sea.

We are reporting these results to the Minnesota Pollution Control Agency and to the various tribal units of Lake Superior Chippewa who are in discussion about setting sulfate standards for waters entering wild rice beds. Many of these waters also enter Lake Superior and the estuaries of some major rivers such as the St. Louis and Fish Rivers once supported extensive wild rice beds which the states of Minnesota and Wisconsin are trying to restore. These results will help inform these restoration efforts by helping the state agencies determine how many and which acres could be restored to wild rice populations.

Measure 2: Cumulative number of coastal, marine, and Great Lakes issue-based forecast capabilities developed and used for management. *(typically interpreted to include most computer models)*

Not applicable

Measure 3: Percentage/number of tools, technologies, and information services that are used by managers (NOAA and/or its partners and customers) to improve ecosystem-based management.

See answer to Measure 1.

Measure 4: Acres of ecosystems protected or restored as a result of Sea Grant's involvement.

Not directly applicable, but see answer to Measure 1.

Measure 5: Number of environmentally-responsible fisheries and/or aquaculture production or harvesting techniques implemented.

Not applicable.

Measure 6: Number of communities who adopt/implement sustainable, economic and environmental development practices and policies, or hazard resiliency practices.

See answer to Measure 1.

Measure 7: Number of environmental curricula adopted by formal and informal educators.

John Pastor uses these results in his class in Integrated Biological Systems and Nathan Johnson uses these results in his class in Environmental Modelling. In addition, classes from Fond du Lac Community College routinely tour these experiments as part of their curriculum in wild rice management.

OTHER METRICS OF INTEREST TO NOAA: Please answer any that apply to your project (none may, and that is fine).

1. Did or will your project help develop or update sustainable development ordinances, policies, or plans? If so, in what community?

   See answer to Measure 1 above. The communities are the States of Minnesota and Wisconsin and the Fond du Lac and Grand Portage Bands of Lake Superior Chippewa.

2. Did your project help a community implement a sustainable development plan? If so, what community?

   Potentially it will help the Fond du Lac and Grand Portage Bands of Lake Superior Chippewa.

3. Did your project help develop or update a port or waterfront redevelopment ordinance, policy, or plan? If so, what port or community?

Not applicable

4. Did you help a port or waterfront implement a redevelopment plan? If so, what port or community?

Not applicable

5. Did your project help develop or update polluted runoff management ordinances, policies, or plans? If so, for what community?

Potentially the results of this research will help inform the State of Minnesota as it reviews its sulfate criteria for wild rice beds, especially in regard to runoff from iron and copper-nickel mines in northern Minnesota.

6. Did your project help implement a polluted runoff management ordinance, policy, or plan? If so, for what community?

Not applicable (yet).

PLANS FOR THE NEXT 6 MONTHS:

Continue to monitor the changes in wild rice populations in the tank experiments and initiate another ^{15}N addition experiment to distinguish between different models of FeS plaque formation and their effect on nitrogen uptake.

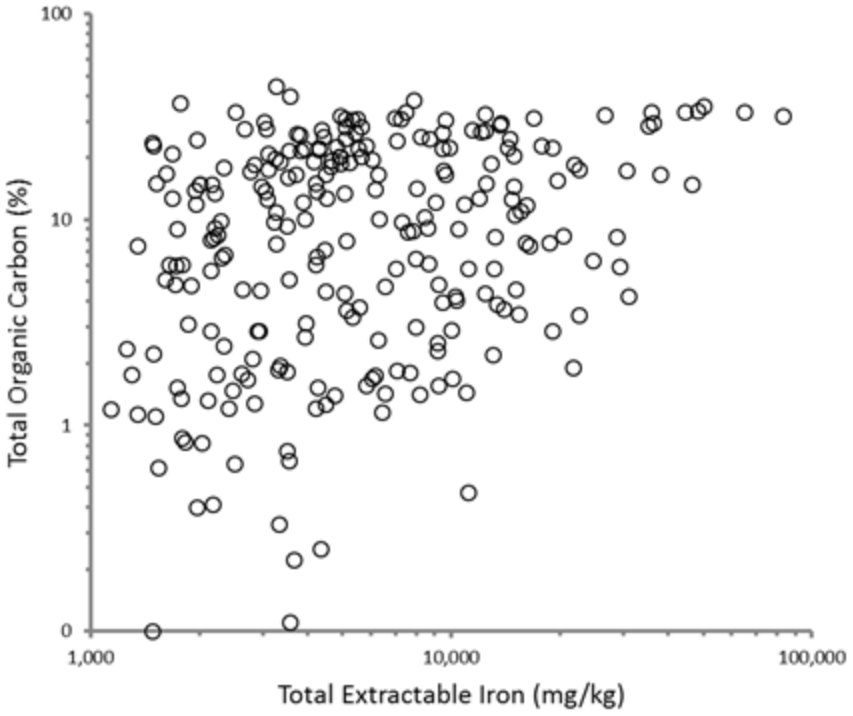
NAMES OF STUDENTS BEING SUPPORTED BY THIS GRANT AND THEIR LEVEL (e.g, grad (MS, PhD), undergrad, etc). For grad students, please indicate whether their thesis research is related to this project.

Ms. Sophie LaFond-Hudson, completed MS - WRS research on this project and is initiating Ph.D. –WRS research on it as well. Advisors: Profs. Nathan Johnson and John Pastor

From: Swain, Ed (MPCA)
To: "Nathan Johnson"
Subject: RE: FW: Wild Rice Sulfate, Sulfide and Iron Research
Date: Thursday, June 30, 2016 10:48:00 AM
Attachments: image001.png

Nate,

The idea that ferrous iron is bound to solid organic matter has some support in the plot below—all the sites from the wild rice field survey. The extractable iron is present in all quadrants except low TOC and high iron, implying that extractable iron needs organic matter.



From: Nathan Johnson [mailto:nwjohnso@d.umn.edu]
Sent: Friday, June 24, 2016 3:13 PM
To: Swain, Ed (MPCA)
Subject: Re: FW: Wild Rice Sulfate, Sulfide and Iron Research

Yes, Sophie has done very well and already been through manuscript-style revisions with John and me. Thanks for taking the time to read her thesis and for your comments.

I suspect that most of the ferrous iron is weakly bound (almost like adsorbed) to organics (not totally sure which functional group) on the solid phase. I seem to recall that that was the implications of the modeling done by a colleague of mine, YS Hong at UT Austin. I attached one of his papers (another link below), but think he has done some more work since (he's a professor in Korea now).

http://link.springer.com/article/10.1007/s11270-013-1800-1

Also, in the modeling work of Van Cappellen and others (pg 203, 209-211 in the attached suggests it's a thiol group), ferrous iron "adsorption" to the solid phase is sometimes used (with an effective partition coefficient of ~50-100) to describe the association of iron with the solid phase.

-nj

On Fri, Jun 24, 2016 at 11:46 AM, Swain, Ed (MPCA) <edward.swain@state.mn.us> wrote:

Nate, thanks for the invitation to watch Sophie's presentation. Unfortunately, I need to be with my mother at exactly that time for a doctor's appointment (she's 94 and has some kind of dementia).

One follow-up question: based on your speciation of iron (described below), what form do you think all that reduced iron is in? Before sulfate additions, it isn't in FeS compounds. My calculations are that only a small proportion is in the porewater. So if it is in solid form, what is it bound to?

Sophie's thesis (which read like a paper ready to submit) is very impressive.

Ed

From: Nathan Johnson [mailto:nwjohnso@d.umn.edu]
Sent: Monday, June 20, 2016 10:06 AM
To: Swain, Ed (MPCA)
Cc: John Pastor
Subject: Re: FW: Wild Rice Sulfate, Sulfide and Iron Research

Ed-
Thanks for your thoughts. I find it highly implausible that in the high organic, strongly reducing environments of the "natural conditions" present in many wild rice beds, the "pool of iron would be mostly in a semicrystalline ferric form." We have measured speciated iron in dozens of sediment samples from both the mesocosms and field sites and never found any significant amount of ferric iron. Right on the surface of wild rice roots, the story is a bit different, but in the organic sediments we typically have encountered the iron has all been very reduced. The Bethke article you attached brings up some points that may be generally applicable from a thermodynamic/kinetic standpoint, however, it is mostly describing conditions and processes in the context of (presumably low carbon) pristine and contaminated aquifer conditions. It is my impression, based on many measurements of sulfur, iron, and carbon speciation in wild rice sediment, that the amount of organics present in most wild rice beds drives the redox deep enough that significant contributions to carbon metabolism from "semicrystalline ferric iron" is likely to be small in the rice rooting zone.

I'm happy to talk more about this iron addition experiment if you want to, but I think the most important (and potentially conceptual-model-altering) result we've seen over the last few years is the dynamic, near-rooting zone chemistry of iron and sulfur (both root surface and near-root sediment) that Sophie has measured. Sophie will be defending her thesis next week and I will encourage her to forward you a copy of it. I'll let you read it for yourself, but she has seen some significant seasonally varying discrepancies in terms of iron and sulfur speciation among sediment porewater, sediment soild phase, and rice root surfaces, all of which may be relevant locations for understanding (and potentially managing) sulfur in wild

rice waters.

If you want to talk more about either the iron addition results or Sophie's results, please let us know.

-Nate

On Sat, Jun 18, 2016 at 9:45 AM, Swain, Ed (MPCA) <edward.swain@state.mn.us> wrote:

John and Nate,

Your experimental results are very interesting. I'm thinking about whether the addition of ferrous chloride successfully mimicked the high-iron sites that were encountered in the field survey. We didn't speciate the iron to a significant degree in the field sites, which in retrospect would have allowed us to try to understand the mechanisms (see Maynard et al., attached—a fairly similar effort, but with more speciation on just one restored wetland in California). But I'm concerned that the addition of relatively large amounts of ferrous iron may have changed the microbial environment in ways that changed the net effect of elevated sulfate on wild rice. One hint might be supplied by the hypothesis posed by Bethke et al. (attached), in which they propose that iron and sulfate reducers develop a mutualism—something that would have been completely disrupted by flooding the system with ferrous iron, given that under natural conditions the pool of iron would be mostly in a semicrystalline ferric form. Achtnich et al. (attached) describe the preparation of crystalline ferric iron for addition to experimental media, in an effort to mimic the natural environment.

In the development of the MPCA scientific understanding of the effect of elevated sulfate, we are resigned to accepting that we don't understand the microbial world, and are relying on empirical observations from the field. Using statistical relationships, our understanding of the effect of increasing sulfate to a system with given TOC and extractable iron is essentially to ask what the steady state is at sites with similar TOC and iron but higher sulfate.

But keep experimenting! The MPCA has to make decisions with the information we have at any given time, but we are open to revising our understanding when new knowledge is produced.

-Ed

From: John Pastor [mailto:jpastor@d.umn.edu]
Sent: Tuesday, June 14, 2016 5:39 PM
To: Swain, Ed (MPCA)
Subject: Re: FW: Wild Rice Sulfate, Sulfide and Iron Research

Hi Ed,
Sorry, typo. FeCl2. Ferrous chloride. Fe(II).
John

On Tue, Jun 14, 2016 at 5:24 PM, Swain, Ed (MPCA) <edward.swain@state.mn.us> wrote:

John said iron was added as Fe2Cl – what is that? Ferric or Ferrous?

Ferrous chloride Fe(II)Cl FeCl2 ?

Or

Ferric chloride Fe(III) FeCl3 ?

Thanks, Ed

From: Nathan Johnson [mailto:nwjohnso@d.umn.edu]
Sent: Tuesday, June 14, 2016 5:04 PM
To: John Pastor
Cc: Swain, Ed (MPCA)
Subject: Re: FW: Wild Rice Sulfate, Sulfide and Iron Research

Yes, it was with respect to the 1 N HCl (room-temperature) extractable iron.

-nj

On Tue, Jun 14, 2016 at 3:18 PM, John Pastor <jpastor@d.umn.edu> wrote:
I think it was 1.0N HCL extractable iron. Nate - you made these calculations, what did you use?
John

On Tue, Jun 14, 2016 at 2:03 PM, Swain, Ed (MPCA) <edward.swain@state.mn.us> wrote:
John, did you triple the iron compared to 1.0 N HCl extractable iron, or triple compared to porewater iron?

Ed

From: John Pastor [mailto:jpastor@d.umn.edu]
Sent: Tuesday, June 14, 2016 1:58 PM
To: Swain, Ed (MPCA)
Cc: Nathan Johnson
Subject: Re: FW: Wild Rice Sulfate, Sulfide and Iron Research

Hi Ed,
What this means statistically is that the main effect of sulfate was highly significant (and negative) for vegetative growth and seed production, the main effect of iron was not, and there was no sulfate X iron interaction. We added iron as Fe2Cl in dissolved form directly into the sediment. We tripled the amount fo iron, and still it has no ameliorative effect of the decrease in growth with added sulfate. As you say, this may be because there was plenty of iron in the sediment already, but in that case, why would we see a detrimental effect of sulfate (via sulfide production) at all? Although not statistically significant, the tanks with both iron and sulfate added had the smallest amount of growth and seed production.
Hope this helps.
John

On Tue, Jun 14, 2016 at 11:25 AM, Swain, Ed (MPCA) <edward.swain@state.mn.us> wrote:
Hi John and Nate,
You can see, below, that Paula Maccabee just sent us your Sea Grant progress report, and copied a bunch of people in the USEPA.
The most interesting thing to me in the progress report is:

After two years, sulfate amendments had the greatest effect, reducing production as in the first experiment regardless of iron amendment and litter removal. Iron amendment had no statistically significant effect, but plants grown under both sulfate and iron amendments had the lowest vegetative and seed production of all.

(I am a bit confused; the first sentence says that the sulfate amendment had the greatest effect regardless of iron (effect on what?), but the second sentence says that the combination of sulfate and iron had the lowest vegetative and seed production (different effect than the first sentence?).)

Regardless, if iron was added in a dissolved form (rather than as a solid phase oxyhydroxide), then the lesson might be that adding sulfate when there is already a lot of iron in porewater isn't good for wild rice. Or am I reading too much into this?

Take care of children and grandchildren,
Ed

From: Paula Maccabee [mailto:pmaccabee@justchangelaw.com]
Sent: Monday, June 13, 2016 9:26 PM
To: Swain, Ed (MPCA); Lotthammer, Shannon (MPCA)
Cc: Linda Holst; David Pfeifer; Katharine Marko; Krista McKim; Barbara Wester

Subject: Wild Rice Sulfate, Sulfide and Iron Research

Hi Ed, Shannon,

When we last spoke on the phone, you stated that the MPCA would soon be releasing a technical report providing the basis for rulemaking related to Minnesota's wild rice sulfate standard. I mentioned that we'd heard that Dr. John Pastor and others in his lab at the University of Minnesota have been conducting research pertaining to wild rice, sulfate, sulfide and iron. It seemed from my conversations with you that the MPCA was not aware in any detail of this ongoing U of M research and was not planning to consider its results in preparing the Agency's upcoming technical report. WaterLegacy believes that this would be a mistake.

You may remember from the MPCA's 2014 Scientific Peer Review Panel for the wild rice sulfate rule that several of the peer reviewers suggested that it would be useful to have experimental data pertaining to iron, sulfate and sulfide interactions. The September 25, 2014 Final *Summary Report of the Meeting to Peer Review MPCA's Draft Analysis of the Wild Rice Sulfate Standard Study* explained,

"It would be useful to have an experiment that examines whether iron would mitigate the ecological effects on wild rice of added sulfide levels. Additionally, current models do not account for the effects from oxygenated rhizospheres and iron plaques on root systems. MPCA needs to understand the mechanism of toxicity better before claiming to understand how iron mitigates sulfide stress." (*Peer Review Report*, Summary of Discussions, p. 28).

Since our brief conversations, I've obtained a copy of Dr. Pastor's May 5, 2016 Annual Report on the U of M research project funded by SeaGrant, *The Biogeochemical Habitat of Wild Rice*. This Annual Report is attached, and a few excerpts are provided below:

"After five years (two under SeaGrant funding, the wild rice populations in the 300 ppm tanks have gone extinct and the populations in the 150 ppm tanks are nearing extinction (Pastor et al. submitted). Extinction was caused by toxic levels of sulfide (from sulfate reduction) to seedlings and

from reduced seed production. Proportional decreases in population productivity have happened in the other amended tanks."

"During the course of these experiments, wild rice roots in tanks with more than 50 mg/L sulfate had become blackened. In contrast, plants grown in the low sulfate treatments had orange stains on the roots throughout the annual life cycle (Fig. 1). Using SEM elemental scans, we identified the black plaques as iron sulfide (FeS) plaques whereas the orange stains had iron but no sulfide and are most likely iron (hydr)oxides."

"After two years, sulfate amendments had the greatest effect, reducing production as in the first experiment regardless of iron amendment and litter removal. Iron amendment had no statistically significant effect, but plants grown under both sulfate and iron amendments had the lowest vegetative and seed production of all."

"We made two surprising observations. First, accumulation of FeS plaques on roots of plants grown under high sulfate concentrations increased very rapidly and suddenly in midsummer even while porewater sulfide in the bulk sediment remained unchanged. And second, by the end of the growing season, FeS concentrations were two orders of magnitude higher on black root surfaces than in the surrounding sediment."

"Plants with the black FeS plaques on their roots produced fewer and less viable seeds, perhaps because the plaques potentially impair the uptake of phosphorus and nitrogen (Pastor et al. submitted). The rapid accumulation of FeS plaques occurs at the time that wild rice plants are beginning to flower and take up additional nutrients for the ripening seeds. This suggests that even if the precipitation of FeS in the bulk sediment reduces aqueous sulfide, precipitation on the root surfaces somehow impedes seed formation, perhaps by blocking nutrient uptake."

WaterLegacy believes that this scientific research - the type of research explicitly called for in the peer review process - seriously undermines the theory on which MPCA's proposal to replace the existing wild rice sulfate standard with an equation relies. It would seem irresponsible to proceed with an equation deriving permissible sulfate levels from calculations based on levels of iron in the biogeochemical habitat of wild rice without first reviewing all of this directly pertinent experimental data.

As we read the recent SeaGrant Annual Report, it appears that high levels of iron do not ameliorate and may in fact increase the threat of wild rice extinction when high levels of sulfate are introduced to wild rice waters. An equation based on the theory that iron mitigates the effects of sulfate reduction to sulfide would not protect the beneficial use of water for wild rice and might even hasten the degradation and removal of that use.

As we have stated previously in various comments, WaterLegacy supports retention of Minnesota's 10 milligrams per liter sulfate standard and application of this water quality standard year-round to control sulfate discharge in all wild rice waters.

Please feel free to contact me if you have any questions.

Sincerely yours,

Paula Maccabee, Esq.
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http://islandpress.org/what-should-a-clever-moose-eat

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Subject: RE: Need a couple talking points when you get a chance
Date: Tuesday, July 19, 2016 at 6:05:07 PM Central Daylight Time
From: Swain, Ed (MPCA), MPCA ED DF5A38E7-D527-432E-AE58-D0C51F03E974>
To: Lotthammer, Shannon (MPCA), Shannon1835b629-b400-428a-a65e-945195224c52>

Shannon,

My talking points would be:

We haven ’t seen any information except a few non –technical paragraphs in the final report to the funding agency (Sea Grant). We haven ’t seen any data on sulfide or iron concentrations, or the data on wild rice growth.

The chemical reactions in the sediment are very complicated, and adding one form of iron (a solution of ferrous chloride, in this case) may not mimic the iron that we studied in the lakes and rivers across Minnesota (most of which is in a solid form in the sediment).

We are not interested in mitigating the effect of elevated sulfate by allowing the addition of iron to the public waters of Minnesota, so we have not pursued an understanding of the effects of adding iron.

Nevertheless, we are surprised that the addition of iron did not seem to mitigate the effect of elevated sulfate, since 1) one would expect, based on basic chemistry, that added iron would decrease the toxicity of sulfide, and 2) experiments by others on other plant species have shown that adding iron does reduce sulfide toxicity. (Plus the Fort lab sulfide experiment showed reduced toxicity when iron was added).

The experiment was conducted with very high sulfate (300 mg/L); we expect that the use of the MPCA ’s use of the proposed equation will limit sulfate additions so that sulfide concentrations would not increase above 120 micrograms per liter, which would likely be a very different chemical environment than was studied with the iron addition. (Because sulfate and sulfide are natural chemicals in the environment, wild rice waters already have sulfide in the sediment porewater; the median concentration we observed in wild rice waters was 85 micrograms per liter(page 43 in the draft TSD)).

From: Lotthammer, Shannon (MPCA)
Sent: Tuesday, July 19, 2016 4:39 PM
To: Swain, Ed (MPCA)
Subject: Need a couple talking points when you get a chance

Hi Ed –

I ’ve received 2 questions now regrading Dr. Pastor ’s research on iron addition not mitigating sulfate impacts, and the build-up on roots hypothesis. Here ’s a summary pf how I responded:

Does the current approach take Dr. John Pastor ’s research into account and do your conclusions diverge from his? We are aware of his data but can ’t speak to precisely how they are related. His work may not focus on exactly what ours focused on.

Do you have any brief points that I could add to my notes to help address this question when it comes up? Feel free to stop by to chat and I can just take notes – I ’m heading out now for the day, but I ’ll be in all day tomorrow.

Thanks!

Shannon

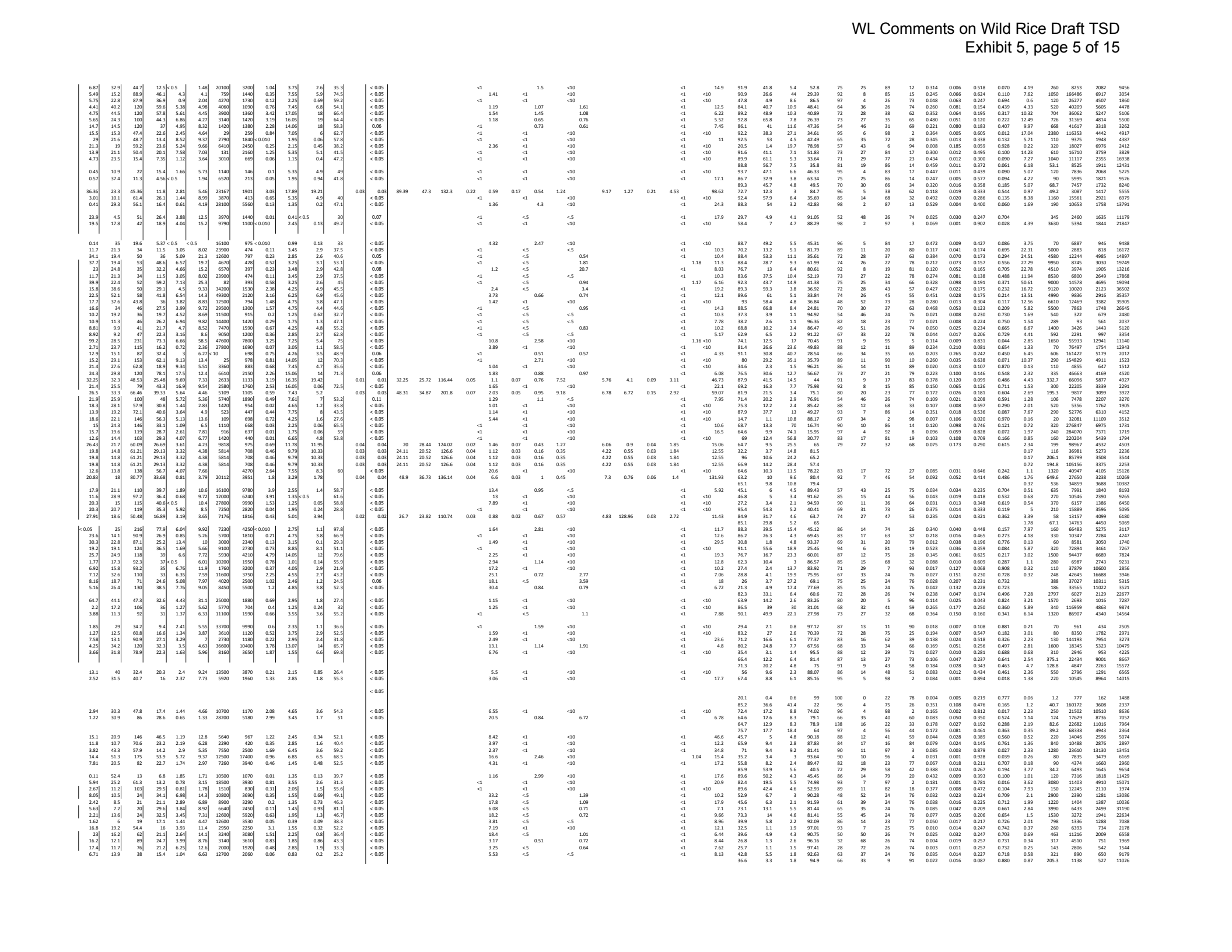
LacCore_field_ID	Site_name	Unique site ID	DNR/State ID	Date	YEAR SAMPLED	Lat	Long	Class B (1 per site)	Class D (for SEM) (unique site ID)	Wild rice ring % cover	Wild Rice Ave stems/m2	Calculated Wild rice ave stems/m2	Lilypad presence (yes/no)	Floating leaf % cover	Water depth (m)	T-tube Transparency (cm)	surface water pH	surface water Temp (C)	surface water Conductance (µS/cm)
P-51	Flowage	1	01-0061-00-205	9/22/11	2011	46.6896	-93.338		1	70		160.2	no	2.3		101	7.34	11.73	155
FS-81	Flowage	1	01-0061-00-204	8/7/12	2012	46.688	-93.337	1	1	0	0.0	0.0	yes	38	0.7	39	6.94	25.5	123.8
P-52	Flowage	1	01-0061-00-206	9/22/11	2011	46.6895	-93.338		1	53.8		123.1	no	3					
P-52	Flowage	1	01-0061-00-205	9/22/11	2011	46.6895	-93.338			53.8		123.1	no	3					
P-52	Flowage	1	01-0061-00-206	9/22/11	2011	46.6895	-93.338			53.8		123.1	no	3					
FS-231	Rice	2	02-0008-00-206	8/17/12	2012	45.1604	-93.121	1	2	0	0.0	0.0	yes	35	0.4	31	9.33	23.1	351
P-22	Ham	3	02-0053-00-201	9/6/11	2011	45.2572	-93.2264			0		0.0	yes	0		76	7.64	21.83	290
FS-109	Carlos Avery Pool 9	4	02-0504-00-202	7/3/12	2012	45.3192	-93.0611	1	4	23.8	52.8	52.8	yes	4.5	0.5	74	5.9	27.73	200
P-53	Carlos Avery Pool 9	4	02-0504-00-201	8/19/11	2011	45.3179	-93.0587			18.8		43.0	yes	9.3			6.83	23.5	187
FS-338	Height of Land	5	03-0195-00-210	7/30/13	2013	46.913	-95.6116		5	36.3	94.2	94.2	yes	30.3	0.68	101	7.63	18.82	302
FS-318	Height of Land	5	03-0195-00-210	6/26/13	2013	46.9135	-95.6124			22.5	43.0	43.0	yes	0.8	0.6	101	8.68	28.01	275
FS-127	Height of Land	5	03-0195-00-210	8/21/12	2012	46.9133	-95.6095	1	5	70	111.1	111.1	yes	3.8	0.5	101	7.86	21	313
FS-375	Height of Land	5	03-0195-00-210	9/10/13	2013	46.913	-95.6111		5	63.8	117.5	117.5	yes	0.5	0.4	101	7.73	22	268
P-1	Height of Land	5	03-0195-00-209	8/22/11	2011	46.9129	-95.6095			27.5		62.9	yes	1.3		65	8.72	22.2	234
P-4	Little Flat	6	03-0217-00-201	8/24/11	2011	46.9981	-95.6641			36.3		83.1	yes	15		101	8.13	23.1	392
FS-374	Little Round	7	03-0302-00-202	9/10/13	2013	46.9745	-95.738		7	21.3	37.6	37.6	yes	42.5	0.5	101	7.49	19.3	230
P-3	Little Round	7	03-0302-00-202	8/24/11	2011	46.9759	-95.7404			25		57.2	yes	10		101	7.65	21.8	284
FS-319	Little Round	7	03-0302-00-203	6/27/13	2013	46.9724	-95.735		7	5	17.5	17.5	no	23.3	0.46	61	6.69	21.47	266
FS-138	Little Round	7	03-0302-00-203	9/20/12	2012	46.9726	-95.735		7	46.3	78.0	78.0	no	0.5	0.2	51	8.66	13.7	467
FS-342	Little Round	7	03-0302-00-203	8/5/13	2013	46.9721	-95.7358	1	7	18.8	58.3	58.3	yes	78.8	0.3	14	6.95	18.81	329
FS-85	Bean	8	03-0411-00-201	8/21/12	2012	46.9337	-95.8706	1		0	0.0	0.0	no	1.3	0.7	101	9.76	20.2	411
FS-213	Gull	9	04-0120-00-204	9/10/12	2012	47.6558	-94.6945	1	9	4.5	9.5	9.5	yes	38.8	0.2	101	7.31	14.9	226
P-20	Gull	9	04-0120-00-203	9/6/11	2011	47.6559	-94.6944			6.8		15.6	yes	3.8		98	7.03	19.41	177
FS-104	Gourd	10	04-0253-00-201	6/27/12	2012	47.8121	-94.965			0	0.0	0.0	yes	0	0.5	101	6.27	24.24	254
P-23	Gourd	10	04-0253-00-201	9/7/11	2011	47.812	-94.9654			16.8		38.4	yes	0		101	6.97	20.66	235
FS-65	Wild Rice	11	09-0023-00-202	9/4/12	2012	46.6712	-92.6055	1	11	0	0.0	0.0	yes	66.3	0.9	73	6.8	26.3	107.2
P-43	Wild Rice	11	09-0023-00-201	9/20/11	2011	46.6735	-92.6023			0		0.0	no	0		3	7.15	12.61	130
FS-64	Dead Fish	12	09-0051-00-202	9/4/12	2012	46.7454	-92.6865	1	12	0	0.0	0.0	no	0.8	0.6	26	7.41	23.8	155.7
P-44	Dead Fish	12	09-0051-00-202	9/20/11	2011	46.7451	-92.6863		12	21.3		48.7	no	2.8		8	7.69	12.82	196
FS-84	Pleasant	13	11-0383-00-207	8/10/12	2012	46.9228	-94.4874	1	13	0	0.0	0.0	yes	73.8	0.7	101	7.34	20.7	210.3
P-27	Pleasant	13	11-0383-00-206	9/9/11	2011	46.928	-94.4757			12.5		28.6	yes	50		101	7.64	21.4	171
FS-128	Cromwell	14	14-0103-00-201	8/22/12	2012	46.9651	-96.3171	1	14	0	0.0	0.0	no	0	0.5	11	9.57	23.7	591
FS-137	Elk	15	15-0010-00-204	9/19/12	2012	47.1952	-95.2249	1	15	7.3	42.7	42.7	yes	0	0.7	101	9.19	16.5	273
P-6	Elk	15	15-0010-00-203	8/25/11	2011	47.1946	-95.2254			11.3		25.9	yes	1.3		101	7.23	22.76	231
P-5	Itasca	16	15-0016-00-208	8/25/11	2011	47.2381	-95.2065			20		45.8	yes	2.5		88	8.67	22.9	266
FS-136	Itasca	16	15-0016-00-208	9/19/12	2012	47.2343	-95.2049	1	16	7.5	23.6	23.6	yes	1.8	0.5	78	9.35	16.3	288
P-7	Itasca	16	15-0016-00-207	8/25/11	2011	47.2332	-95.1985			8.8		20.1	no	7.5					
FS-105	Second	17	15-0091-00-202	6/27/12	2012	47.8258	-95.3637	1	17	13	48.4	48.4	no	0	0.2	101	8.07	32.39	265
P-24	Second	17	15-0091-00-201	9/7/11	2011	47.8255	-95.3635			16.3		37.3	yes	0		101	7.7	24.13	252
FS-190	Pine	18	15-0149-00-205	8/28/12	2012	47.6841	-95.5414	1	18	47.5	114.9	114.9	yes	32.5	0.4	58	8.55	26.4	369
FS-304	Rice	19	18-0053-00-203	6/10/13	2013	46.3387	-93.8906		19	2.5	5.7	5.7	yes	4.8	0.8	101	7.71	15.89	127
P-69	Rice	19	18-0053-00-203	9/27/11	2011	46.3394	-93.8913		19	18.8		43.0	yes	51.3		95	7.24	17.68	224
FS-56	Rice	19	18-0053-00-203	8/27/12	2012	46.3389	-93.8915	1	19	3.5	19.4	19.4	yes	78.3	0.6	81	7.36	20.9	234
FS-324	Rice	19	18-0053-00-203	7/15/13	2013	46.3392	-93.8918		19	27.5	56.7	56.7	yes	51.3	0.4	66	6.22	21.36	120
P-56	Rice	19	18-0053-00-203	9/23/11	2011	46.3396	-93.8901			0		0.0	no	0		56	7.56	11.57	276
FS-376	Rice	19	18-0053-00-203	9/11/13	2013	46.3394	-93.8918		19	22.5	46.5	46.5	yes	46.3	0.49	21	6.85	19.8	174.8
FS-82	Rabbit	20	18-0093-02-204	8/8/12	2012	46.5313	-93.9285	1	20	0	0.0	0.0	yes	86.8	0.8	101	7.48	22.9	272
FS-133	Mahnomen	21	18-0126-02-201	9/17/12	2012	46.4985	-93.9958		21	0	0.0	0.0	yes	52.5	0.7	101	8.97	18.1	349
FS-377	Mahnomen	21	18-0126-02-201	9/11/13	2013	46.4986	-93.9956	1	21	0	0.0	0.0	yes	22.5	0.8	28	8.82	23.3	232
FS-378	Duck Lake WMA	22	18-0178-00-202	9/12/13	2013	46.7521	-93.8851	1	22	42.5	113.0	113.0	yes	21.3	0.45	101	7.25	19.7	96.8
FS-230	Mill Pond	23	21-0034-00-202	8/16/12	2012	46.0715	-95.2218		23	21.5	80.9	80.9	yes	90.5	0.4	101	7.69	22.3	491
FS-229	Mill Pond	23	21-0034-00-202	8/16/12	2012	46.0716	-95.2218	1	23	30	102.2	102.2	yes	67.9	0.3	101	7.59	21.1	495
FS-225	Miltona	24	21-0083-00-205	8/13/12	2012	46.0496	-95.4217	1	24	0	0.0	0.0	yes	21.3	0.5	101	8.52	24.8	326
FS-226	Louise	25	21-0094-00-202	8/14/12	2012	45.9331	-95.4148	1	25	17	46.5	46.5	no	0.3	1	101	8.69	23.6	366
FS-192	Anka	26	21-0353-00-202	8/29/12	2012	46.07689	-95.7292	1	26	1		2.3	no	0	0.1	101	8.4	32.9	441
P-34	Anka	26	21-0353-00-201	9/16/11	2011	46.0769	-95.7292		26	11.3		25.9	no	0		77	7.98	15.47	370
P-35	Anka	26	21-0353-00-201	9/16/11	2011	46.0769	-95.7377		26	1.3		3.0	no	0					
FS-191	Ina	27	21-0355-00-202	8/29/12	2012	46.0715	-95.7281	1	27	8.5	30.2	30.2	yes	0.3	0.2	101	8.6	23.3	379
P-37	Ina	27	21-0355-00-201	9/16/11	2011	46.0822	-95.726			0		0.0	no	0		101	7.78	17.73	420
FS-339	Christina	28	21-0375-00-315	7/31/13	2013	46.0734	-95.7567	1	28	0.3	0.6	0.6	no	0	0.71	49	9.64	22.96	334
FS-176	North Geneva	29	24-0015-00-209	7/24/12	2012	43.7876	-93.271	1	29	0	0.0	0.0	yes	51.8	0.7	18	8.91	30.1	298
FS-177	South Geneva	30	24-0015-02-208	7/24/12	2012	43.7709	-93.2851	1	30	0	0.0	0.0	yes	95	0.5	15	8.69	32	306
FS-178	Bear	31	24-0028-00-206	7/25/12	2012	43.5465	-93.5028			0	0.0	0.0	no	0	0.5	6	8.71	27.7	297
P-33	Pelican	32	26-0002-00-219	9/15/11	2011	46.0616	-95.8296			0		0.0	no	0		38	8.48	18.31	363
P-8	Pelican	32	26-0002-00-219	8/26/11	2011	46.0616	-95.8296			0		0.0	no	0					
FS-130	Hay	33	31-0037-00-202	9/6/12	2012	47.2874	-93.102		33	53.8	141.0	141.0	yes	3	0.4	101	7.96	19.5	434
P-45	Hay	33	31-0037-00-201	9/21/11	2011	47.2874	-93.1017		33	0		0.0	yes	18.3		101	8.28	13.05	388
FS-367	Hay	33	31-0037-00-202	9/4/13	2013	47.287	-93.1009	1	33	83.8	141.0	141.0	yes	2.5	0.45	72	7.33	20.52	393
P-46	Hay	33	31-0037-00-201	9/21/11	2011	47.2869	-93.1018		33	0		0.0	no	0					
FS-62	Swan	34	31-0067-02-206	8/30/12	2012	47.289	-93.2124	1	34	0.8	3.8	3.8	yes	98.8	0.7	101	8.29	26.8	301
FS-61	Swan	34	31-0067-02-206	8/30/12	2012	47.2888	-93.2127		34	3	12.4	12.4	yes	98	0.7	101	7.81	23.6	299
FS-350	Ox Hide	35	31-0106-00-203	8/14/13	2013	47.3351	-93.2132	1	35	0	0.0	0.0	yes	56.3	0.97	101	8.4	20	322
FS-132	Ox Hide	35	31-0106-00-203	9/7/12	2012	47.335	-93.2134		35	4	10.5	10.5	yes	52.5	0.7	101	8.01	20.3	373
FS-198	Ox Hide	35	31-0106-00-203	9/7/12	2012	47.335	-93.2134		35	0.3	0.6	0.6	yes	50	0.7	101	7.94	20	373
FS-197	Snowball	36	31-0108-00-202	9/4/12	2012	47.3355	-93.244		36	0	0.0	0.0	yes	85	0.7	101	8.4	22.3	210.9
FS-347	Snowball	36	31-0108-00-202	8/12/13	2013	47.3356	-93.2439	1	36	0	0.0	0.0	yes	52.5	0.64	101	8.7	23.3	211.3
FS-59	Upper Panasa	37	31-0111-00-202	8/29/12	2012	47.306	-93.2652	1	37	0	0.0	0.0	yes	10.5	0.5	77	8.7	23.1	345
FS-383	Upper Panasa	37	31-0111-00-204	9/18/13	2013	47.3059	-93.2676		37	0	0.0	0.0	yes	10.8	0.55	35	9.26	17.7	400
FS-60	Lower Panasa	38	31-0112-00-205	8/29/12	2012	47.3018	-93.2521		38	0	0.0	0.0	yes	10.8	1	101	8.71	26.2	329
FS-357	Lower Panasa	38	31-0112-00-204	8/15/13	2013	47.3026	-93.2561	1	38	0	0.0	0.0	yes	45	0.8	49	9.13	21.75	338
FS-216	Big Sucker	39	31-0124-00-203	9/12/12	2012	47.3919	-93.2658	1	39	1.3	3.8	3.8	yes	32.5	0.8	101	7.32	17.9	200.5
FS-223	Little Sucker	40	31-0126-00-202	9/14/12	2012	47.3765	-93.246	1	40	0	0.0	0.0	yes	46.3	0.5	101	7.18	16	261
FS-219	Trout	41	31-0216-00-212	9/13/12	2012	47.2592	-93.3942		41	0	0.0	0.0	yes	66.3	0.9	101	8.66	19.7	325
FS-356	Trout	41	31-0216-00-212	8/14/13	2013	47.2591	-93.3942	1	41	0	0.0	0.0	yes	28.8	0.7	101	8.79	20.12	362
FS-353	Holman	42	31-0227-00-202	8/12/13	2013	47.3009	-93.3444	1	42	0	0.0	0.0	yes	76.3	0.6	101	8.24	22.53	499
FS-218	Holman	42	31-0227-00-202	9/13/12	2012	47.3005	-93.3445		42	0	0.0	0.0	yes	35	0.5	101	7.65	15.9	355
FS-134	Bass	43	31-0576-00-207	9/18/12	2012	47.2844	-93.6276	1	43	32.5	64.0	64.0	yes	23.8	0.1	72	8.05	13.4	266
FS-75	Mortenson	44	34-0150-02-201	7/24/12	2012	45.3	-94.9062	1	44	0	0.0	0.0	no	0.8	1	101	7.88	27.9	262
FS-76	Field	45	34-0151-00-201	7/25/12	2012	45.2964	-94.9058	1	45	0	0.0	0.0	yes	38.8	0.8	101	8.51	27.4	177
P-42	Monongalia (Middle Fork Crow R)	45.5	34-0158-01-201	9/20/11	2011	45.3481	-94.9509		45.5	2.5		5.7	yes	36.3		101	6.88	13.04	680
FS-77	Monongalia (near hwy embankment)	46	34-0158-02-204	7/26/12	2012	45.3331	-94.9268		46	38.8	121.3	121.3	yes	3.5	0.7	101	8.19	28.4	347
FS-379	Monongalia	46	34-0158-02-203	9/13/13	2013	45.3332	-94.9292		46	62.5	154.4	154.4	yes	62.5	0.5	101	7.68	19.2	359
FS-340	Monongalia	46	34-0158-02-203	7/31/13	2013	45.3331	-94.9292	1	46	60	87.9	87.9	yes	28.5	0.73	80	8.6	25.56	416
FS-313	Monongalia	46	34-0158-01-203	6/23/13	2013	45.3334	-94.9293		46	32.5	50.0	50.0	no	3.8	0.6		8.57	25.42	422
FS-50	Swan	47	34-0223-00-201	7/30/12	2012	45.326	-95.067			0	0.0	0.0	yes	0	0.9	101	8.1	28.4	429
FS-52	Blaamyhre	48	34-0345-00-203	8/1/12	2012	45.364	-95.186	1	48	15	102.2	102.2	yes	15.3	0.6	101	8.18	28.5	326
FS-51	Glesne Slough	49	34-0353-00-201	7/31/12	2012	45.3514	-95.1887	1	49	22.5	99.6	99.6	yes	3	0.5	49	7.16	25.6	513
FS-183	Unnamed	50	34-0611-00-201	7/30/12	2012	45.2675	-94.865	1	50	16.3	64.9	64.9	yes	52.5	0.7	101	8.55	25.4	360
P-57	Unnamed	50	34-0611-00-201	9/23/11	2011	45.2675	-94.865		50	32.5		74.4	yes	11.3		101	7.72	16.9	362
P-57	Unnamed	50	34-0611-00-201	9/23/11	2011	45.2675	-94.865		50	32.5		74.4	yes	11.3		101	7.72	16.9	362
P-57	Unnamed	50	34-0611-00-201	9/23/11	2011	45.2675	-94.865			32.5		74.4	yes	11.3		101	7.72	16.9	362
P-57	Unnamed	50	34-0611-00-201	9/23/11	2011	45.2675	-94.865			32.5		74.4	yes	11.3		101	7.72	16.9	362
P-18	Lax	51	38-0406-00-203	9/2/11	2011	47.3508	-91.2921			0		0.0	no	0			7.85	21.38	79
P-31	Cloquet	52	38-0539-00-201	9/14/11	2011	47.4313	-91.4844		52	32.5		74.4	yes	0		101	7.17	12.67	59
FS-79	Lady Slipper	53	42-0020-00-203	7/27/12	2012	44.5723	-95.6216		53	0	0.0	0.0	no	0	1	56	9.31	26.4	1125
FS-78	Lady Slipper	53	42-0020-00-202	7/27/12	2012	44.5699	-95.6275	1	53	0	0.0	0.0	no	0	0.7	55	9.21	25.1	1136
P-55	Lady Slipper	53	42-0020-00-204	9/22/11	2011	44.5702	-95.6274			0		0.0	no	0		28	8.65	13.63	1082
FS-188	Stella	54	47-0068-00-204	8/27/12	2012	45.0683	-94.4334	1	54	0.3	0.3	0.3	no	3.8	0.5	101	8.7	26	337
FS-341	Stella	54	47-0068-00-205	8/1/13	2013	45.066	-94.4339			28.8	57.6	57.6	no	20	0.49	101	8.54	22.07	382
P-30	Stella	54	47-0068-00-203	9/14/11	2011	45.0659	-94.4339		54	13.8		31.6	yes	0		101	7.87	20.49	374
FS-55	Pelkey	55	49-0030-00-202	8/26/12	2012	45.9962	-94.2273	1	55	0	0.0	0.0	yes	88.8	0.9	101	9.42	29.6	208.2
FS-125	Tamarac	56	56-0192-00-203	8/19/12	2012	46.3637	-95.5714	1	56	0	0.0	0.0	no	0	0.7	101	8.84	27.8	300
FS-228	West battle	57	56-0239-00-204	8/15/12	2012	46.2906	-95.6049	1	57	35	144.8	144.8	yes	50	1	101	8.61	25.8	330
FS-126	Bray	58	56-0472-00-202	8/20/12	2012	46.4518	-95.8783	1	58	1.8	7.6	7.6	no	0.3	0.7	101	9.35	24.6	229

LacCore_field_ID	surface water Ca (mg/L)	surface water Mg (mg/L)	surface water K (mg/L)	surface water Na (mg/L)	surface water Fe (µg/L)	surface water SO4 (mg SO4/L)	surface water Cl (mg/L)	surface water Alk (meq/L)	surface water TP (mg P/L)	surface water TN (mg N/L)	Surface Water NO2NO3 (mg N/L)	Surface Water NO3 (mg N/L)	Surface Water NH4 (mg N/L)	Surface Water DOC (mg C/L)	Surface Water SUVA Fe correct	Surface Water UV ABS 254 nm	Surface Water DO surface (mg/L)	Surface Water Color (Pt-Co units)	pore water pH	pore water Total Sulfide (TS, mg S/L)	pore water H2S (% of TS)	H2S (ug/L)	pore water HS- (% of TS)
P-51	18.48	7.12	1.49	5.98	1188.9	0.56	6.05	1.21	0.039	1.35			0.019	27.55	3.54	1.077	7.04		6.41	0.014	80%	11	20%
FS-81	17	5.13	1.28	3.58	3750	0.78	3.73	1.02	0.079	1.65	< 0.05		0.194					425	6.46	0.134	78%	105	22%
P-52	18.48	7.12	1.49	5.98	1188.9	0.56	6.05	1.21	0.039	1.35			0.019	27.55	3.54	1.077				0.018			
P-52	18.48	7.12	1.49	5.98	1188.9	0.56	6.05	1.21	0.039	1.35			0.019	27.55	3.54	1.077				0.018			
P-52	18.48	7.12	1.49	5.98	1188.9	0.56	6.05	1.21	0.039	1.35			0.019	27.55	3.54	1.077				0.018			
FS-231	35	11.3	2.89	24.8	5.7	3.6	45.6	2.2	0.105	2.25	< 0.05		0.156					80	6.71	0.145	67%	97	33%
P-22	33.58	9.63	1.54	12.72	119.7	0.95	23.68	2.24	0.029	0.91		0.005	0.034	10.89	2	0.228	4.75						
FS-109	29	5.28		4.08	1020	< 0.5	5.57	1.74	0.041	1.01	< 0.05		<.039					90	5.89	< 0.011	93%	< 10	7%
P-53	28.64	5.25	0.36	3.78	1020	0.35	7.25	1.32	0.177	1.32		0.009	0.09	18.22	2.94	0.617	2.1		6.52	0.029	76%	22	24%
FS-338	34	19.7		2.04	100	< 0.5	0.54	3.2	0.034	0.74	< 0.05		<.039				6.5	35	6.76	0.0554	65%	36	35%
FS-318	37	16.9	0.98	2.63	181	1.21	0.75	3	0.059	0.76	< 0.05		<.039				10.39	60	6.99	0.0658	52%	34	48%
FS-127	39	21.5	0.6	3.66	< 5.0	< 0.5	1.47	3.6	0.014	0.72	< 0.05		0.054					34	7.14	< 0.011	43%	<5	57%
FS-375	46	25.7	1.47	4.77	152	< 0.5	1.39	4.4	0.035	0.95	< 0.05		<.039				7.34	45	7.02	< 0.011	50%	<6	50%
P-1	25.13	17.41	1.19	3.47	22.5	0.24	1.82	2.82	0.035	0.77		0.006	0.01	10.59	1.31	0.141	9.79		6.85	0.053	60%	32	40%
P-4	43.8	26.82	2.42	5.14	147.7	0.22	0.97	4.74	0.058	0.63		0.004	0.01	7.68	1.47	0.125	9.62		6.5	0.011	77%	8	23%
FS-374	41	21.9	2.29	2.05	28.6	0.12	1.17	3.6	0.023	1.15	< 0.05		<.039				1.77	45	7	0.0391	51%	20	49%
P-3	31.98	19.64	1.83	1.76	54.1	0.46	1.04	3.24	0.026	0.75		0.006	0.019	10.09	2.12	0.219	6.14		6.52	0.032	76%	24	24%
FS-319	38	14.2	2.34	1.95	239	< 0.5	0.36	2.8	0.046	1.25	< 0.05		<.039				3.68	150	6.47	0.117	78%	91	22%
FS-138	67	26.4	3.33	3.86	< 5.0	< 0.5	2.84	5.19	0.041	1.03	< 0.05		<.039					59	7.76	0.128	15%	19	85%
FS-342	45	17.7		2.1	96	< 0.5	0.15	3.6	0.061	1.15	< 0.05		0.078				2.53	73	6.67	0.0676	69%	47	31%
FS-85	26	39.8	2.91	5.41	< 5.0	85	3.95	2.4	0.027	1.85	< 0.05		<.039					55	7.34	16	32%	5120	68%
FS-213	25	13.1	2.18	2.71	< 5.0	1.14	5.01	2.2	0.015	0.86	< 0.05		<.039					40	6.31	0.0778	84%	65	16%
P-20	22.68	11.48	2.32	2.6	19.9	0.78	4.72	1.68	0.031	0.97		0.002	0	18.11	1.05	0.193	8.21		6.87	0.103	59%	61	41%
FS-104	32	13.5	1.39	0.91	6.6	0.27	0.12	2.6	0.015	1.05	< 0.05		<.039					47.5					
P-23	32.76	13.25	1.21	0.95	32	0.69	0.65	2.3	0.016	1.14		0.004	0.003	16.24	1.63	0.267	7.86		6.67	0.038	69%	26	31%
FS-65	15	5.05		2.26	4120	< 0.5	4.41	0.84	0.012	0.98	< 0.05		<.039					325	6.57	0.083	74%	61	26%
P-43	18.21	6.33	0.64	2.68	7274.8	0.37	4.76	0.85	0.033	0.79		0.008	0.053	39.27	3.67	2.06	4.81						
FS-64	22	8.26		2.93	3820	0.71	0.53	1.52	0.074	1.35	< 0.05		<.039					450	7.46	0.0608	27%	16	73%
P-44	28.02	11.35	1.13	2.96	4739.9	0.3	0.75	1.95	0.122	1.57			0.016	43.62	3.75	2.037	6.63		6.25	0.056	85%	48	15%
FS-84	25	10.8	1.28	3.55	20.2	< 0.5	2.96	2.2	0.015	0.51	< 0.05		<.039					50	6.27	0.0218	85%	19	15%
P-27	20.21	10.12	1.49	5.84	15.9	0.49	3.22	2	0.012	0.34		0.004	0.002	6.99	0.85	0.06	8.2		6.33				
FS-128	9.4	83.9	16.6	13.4	< 5.0	41.2	17.9	6.19	0.065	3.15	< 0.05		0.109					175	7.01	1.22	51%	622	49%
FS-137	29	17.9	1.63	7.06	< 5.0	< 0.5	0.65	3	< 0.010	0.44	< 0.05		<.039					12	7.83	0.0936	13%	12	87%
P-6	25.62	16.37	1.79	6.66	21.7	0.28	0.84	2.58	0.013	0.53		0.004	0.006	9.21	1.2	0.112	9.31		6.4	0.04	81%	32	19%
P-5	27.69	17.21	1.73	5.79	10.5	0.26	1.13	3.24	0.041	0.64		0.004	0.008	6.94	1.08	0.076	8.11		6.78	0.056	63%	35	37%
FS-136	31	19.9	1.83	6.41	< 5.0	< 0.5	1.13	3.2	0.02	0.46	< 0.05		<.039					32	8.07	0.0636	8%	5	92%
P-7	27.69	17.21	1.73	5.79	10.5	0.26	1.13	3.24	0.041	0.64		0.004	0.008	6.94	1.08	0.076			6.48	0.064	78%	50	22%
FS-105	39	13.4	0.52	3.56	35.9	0.74	0.41	2.8	0.021	1.25	< 0.05		<.039					70	5.8	0.119	94%	112	6%
P-24	36.6	14.41	1.4	3.03	63.4	0.87	2.68	2.43	0.019	1.13		0.003	0.012	26.17	2.47	0.651	9.06		6.61	0.139	72%	100	28%
FS-190	30	32.9	4.97	8.81	< 5.0	14.7	4.46	4	0.156	1.25	< 0.05		<.039					43	6.61	0.368	72%	265	28%
FS-304	20	4.7	1.35	2.58	2540	< 0.5	3.52	1.24	0.036	0.71	< 0.05		<.039				6.53	185	6.73	0.0236	66%	16	34%
P-69	38.5	9.12	1.21	4.4	1158.8	0.23	2.7	2.51	0.042	0.69		0.003	0.005	19.63	2.68	0.625	8.84		6.35	0.021	82%	17	18%
FS-56	39	8.17	0.65	2.33	98	< 0.5	1.57	2.4	0.012	0.71	< 0.05		<.039					91	6.52	0.0259	76%	20	24%
FS-324	21	4.44		1.82	5320	< 0.5	1.94	1.24	0.062	0.96	< 0.05		<.039				1.7	365	6.67	0.11	69%	76	31%
P-56	41.98	9.09	1.29	4.36	1310.8	0.38	3.04	2.8	0.107	0.96			0.011	16.75	2.87	0.591	5.25						
FS-376	35	8.56	1.11	2.12	2520	< 0.5	2.82	2.2	0.095	1.04	< 0.05		0.132				1.59	275	6.7	0.0451	68%	31	32%
FS-82	30	13.8	2.28	5.15	< 5.0	15.3	2.64	2.4	0.068	0.75	< 0.05		<.039					25	6.81	0.22	62%	136	38%
FS-133	46	15.6	2.31	8.33	< 5.0	16.9	9.98	3	0.018	0.59	< 0.05		<.039					22	7.07	0.308	47%	145	53%
FS-377	35	15.6	2.47	11.7	10.1	21.1	15.2	2.6	0.082	1.05	< 0.05		<.039				16.13	48	7.08	0.0283	47%	13	53%
FS-378	18	6.73	0.54	2.47	1020	< 0.5	0.33	1.32	0.032	1.15	< 0.05		<.039				5.92	70	6.66	0.0251	70%	18	30%
FS-230	67	26.6	1.72	3.91	< 5.0	7.36	8.5	4.8	0.024	0.54	< 0.05		<.039					22	6.9	0.192	57%	109	43%
FS-229	65	26.2	1.83	3.84	< 5.0	7.16	8.52	4.8	0.026	0.52	< 0.05		<.039					21	6.74	0.109	66%	72	34%
FS-225	25	26.4	3.37	5.9	< 5.0	4.11	8.67	3.2	< 0.010	0.54	< 0.05		<.039					30	6.9	0.0694	57%	40	43%
FS-226	29	27.6	3.85	6.11	< 5.0	4.09	9.52	3.4	< 0.010	0.63	< 0.05		<.039					10	7.97	0.0746	10%	7	90%
FS-192	18	37.4	4.48	10.8	< 5.0	8.44	10.6	3.8	0.015	1.05	< 0.05							20	6.75	0.53	65%	345	35%
P-34	26.12	34.06	4	8.57	12.3	2.23	22.87	3.35	0.026	0.64		0.004	0.002	11.99	1.4	0.169	10.12		7.15	0.671	43%	289	57%
P-35	26.12	34.06	4	8.57	12.3	2.23	22.87	3.35	0.026	0.64		0.004	0.002	11.99	1.4	0.169				0.493			
FS-191	24	36.7	4.31	9.11	< 5.0	7.08	10.4	4	< 0.010	0.74	< 0.05		<.039					15	6.71	0.274	67%	184	33%
P-37	31.46	32.83	3.81	7.46	9.1	2.17	9.56	4.14	0.022	0.79		0.042	0.038	9.4	1.58	0.149	8.9						
FS-339	17	33.2	3.08	10.6	< 5.0	14.6	4.55	3.6	0.021	0.82	< 0.05		<.039				9.49	40	7.37	1.93	31%	598	69%
FS-176	31	23.2	4.25	8.38	< 5.0	15.6	23.6	2.6	0.041	1.45	< 0.05		<.039					200	6.66	1.54	70%	1078	30%
FS-177					< 5.0	14.1	23.6	2.8	0.055	1.45	< 0.05		<.039					205	6.43	3.19	80%	2552	20%
FS-178	75.9	22.6	4.35	7.14	1560	18.3	21.2	3.2			< 0.05							820					
P-33	19.03	35.02	5.18	10.66	7.3	5.79	11.73	3.82	0.045	0.89		0.039	0.042	13.28	1.04	0.139	9.12						
P-8																							
FS-130	39	30.5	3.22	13.8	15	31.7	6.88	3.8	0.045	0.48	< 0.05		<.039					45	7.53	0.0738	24%	18	76%
P-45	35.51	26.53	2.86	12.26	199.7	10.24	8.13	3.76	0.031	0.52		0.007	0.016	8.65	2.39	0.223	7.94		6.6	0.087	72%	63	28%
FS-367	39	23.8	2.36	9.54	54.5	22.1	4.41	3.6	0.024	0.46	< 0.05		<.039				8.23	50	7.15	0.0447	43%	19	57%
P-46	35.51	26.53	2.86	12.26	199.7	10.24	8.13	3.76	0.031	0.52		0.007	0.016	8.65	2.39	0.223			6.71	0.026	67%	17	33%
FS-62	28	19.1	1.89	9.05	< 5.0	14	7.11	2.6	< 0.010	0.53	< 0.05		<.039					35	6.48	0.221	78%	172	22%
FS-61	27	17.7	1.72	8.36	< 5.0	12.5	6.71	2.6	0.017	0.57	< 0.05		<.039					53	6.63	0.332	71%	236	29%
FS-350	36	21.1	1.9	6.92	< 5.0	25.9	6.96	3	0.011	0.22	< 0.05		<.039				8.75	10	6.99	0.119	52%	62	48%
FS-132	38	22.1	2.14	7.01	< 5.0	26.4	6.94	3	< 0.010	0.24	< 0.05		<.039					15	6.75	0.042	65%	27	35%
FS-198	37	21.7	2.1	7.12	< 5.0	26.4	6.95	3	< 0.010	0.23	< 0.05		<.039					10	6.98	0.0751	52%	39	48%
FS-197	23	9.58	1.43	7.51	< 5.0	8.4	9.63	1.72	0.012	0.44	< 0.05		<.039					20	6.22	0.0936	86%	80	14%
FS-347	25	10.3	1.41	7.69	< 5.0	8.2	10.4	1.9	< 0.010	0.44	< 0.05		<.039				10.62	0	6.73	0.097	66%	64	34%
FS-59	38	18.1	2.32	10.8	< 5.0	29.6	11.3	2.6	0.015	0.68	< 0.05		<.039					45	7.37	0.126	31%	39	69%
FS-383	31	20.3	2.58	12.3	< 5.0	33.6	14.1	2.6	0.064	0.72	< 0.05		<.039				11.51	45	7.4	0.0399	29%	12	71%
FS-60	38	17.8	2.14	8.83	< 5.0	33.6	8.35	2.6	< 0.010	0.51	< 0.05		<.039					44		0.243			
FS-357	37	16.9	2.08	8.62	< 5.0	28.5	8.73	2.6	0.021	3.05	< 0.05		<.039				10.34	50	6.97	1.26	53%	668	47%
FS-216	24	10.6	1.52	3.6	< 5.0	7.78	1.92	1.84	< 0.010	0.62	< 0.05		<.039					25	6.35	0.145	82%	119	18%
FS-223	33	15.4	1.74	4	< 5.0	13.7	2.64	2.4	0.029	0.71	< 0.05		<.039					70	6.67	0.534	69%	368	31%
FS-219	34	24	2.71	8.97	< 5.0	38.6	8.19	2.8	0.041	0.47	< 0.05		<.039					35	6.55	0.117	75%	88	25%
FS-356	30	23.6	2.38	9.12	< 5.0	39.1	8.62	2.6	0.017	0.39	< 0.05		<.039				8.95	15	6.73	0.103	66%	68	34%
FS-353	50	31.7	2.76	6.81	< 5.0	68	5.58	3.8	< 0.010	0.28	< 0.05		<.039				7.98	10	6.49	0.583	77%	449	23%
FS-218	49	19.9	2.52	7.14	< 5.0	24.2	7.09	3.4	< 0.010	0.33	< 0.05		<.039					25	6.72	1.01	67%	677	33%
FS-134	36	10.6	1.71	5.3	9.4	1.01	4.11	2.6	< 0.010	0.91	< 0.05		0.101					55	7.58	0.0664	22%	15	78%
FS-75	26	16.4	5.78	2.95	< 5.0	< 0.5	4.39	2.6	< 0.010	1.95	< 0.05		<.039					12	6.85	0.103	60%	62	40%
FS-76	19	11.6	1.29	1.15	6.3	< 0.5	1.75	1.84	0.035	0.93	< 0.05		<.039					34	6.8	0.0687	62%	43	38%
P-42	87.65	31.68	3.61	7.03	70.5	16.51	17.12	4.1	0.034	1.31		0.78	0.074	6.58	2.56	0.174	5.43		6.52	0.042	76%	32	24%
FS-77	26	27.6	2.87	6.53	< 5.0	21.7	13.9	2.8	< 0.010	0.94	< 0.05		<.039					20	7.35	1.37	32%	438	68%
FS-379	40	35.7	2.76	7.63	< 5.0	34.6	15.3	3.8	0.02	1.35	< 0.05		<.039				3.54	25	6.99	0.242	52%	126	48%
FS-340	36	30.8	2.43	6.05	< 5.0	33.6	13	3.2	0.02	1.03	< 0.05		<.039				9.16	25	6.58	0.122	73%	89	27%
FS-313	46	26	3.13	5.4	13.2	34.7	12.2	3.4	0.014	1.03	< 0.05		0.078				7.97	32	6.97	0.0941	53%	50	47%
FS-50	30	34.9	7.3	6.27	< 5.0	11.7	16.1	3.8	< 0.010	1.15	< 0.05		<.039					30					
FS-52	24	28.5	3.51	4.26	< 5.0	0.62	4.86	3.4	0.022	0.91	< 0.05		<.039					42	6.85	0.078	60%	47	40%
FS-51	48	29.4	6.31	17.8	< 5.0	< 0.5	43.3	4	0.053	1.25	< 0.05		<.039					65	6.67	0.061	69%	42	31%
FS-183	29	27.8	2.98	6.99	< 5.0	16.8	15.4	3	< 0.010	0.56	< 0.05		<.039					4	6.66	0.15	70%	105	30%
P-57	31.87	26.9	3.24	7.01	8.3	6.42	15.19	3.27	0.017	0.56		0.01	0.024	7.69	1.19	0.093	8.94		6.86	0.065	59%	38	41%
P-57	31.87	26.9	3.24	7.01	8.3	6.42	15.19	3.27	0.017	0.56		0.01	0.024	7.69	1.19	0.093	8.94		6.86	0.286	59%	169	41%
P-57	31.87	26.9	3.24	7.01	8.3	6.42	15.19	3.27	0.017	0.56		0.01	0.024	7.69	1.19	0.093	8.94		6.86	0.065	59%	38	41%
P-57	31.87	26.9	3.24	7.01	8.3	6.42	15.19	3.27	0.017	0.56		0.01	0.024	7.69	1.19	0.093	8.94		6.86	0.065	59%	38	41%
P-18	9.2	2.99	0.54	2.98	80.7	1.43	2.32	0.63	0.015	0.3		0.005	0.007	7.91	2.59	0.211	7.33						
P-31	6.53	3.24	0.77	2.1	365.1	0.81	0.5	0.39	0.016	0.88		0.004	0.013	21.07	2.38	0.532	7.53		5.98	0.024	92%	22	8%
FS-79	22	107	18.3	76.8	< 5.0	330	31	5.19	0.037	1.65	< 0.05		<.039					35	7.33	1.63	33%	538	67%
FS-78	21	107	18.3	76.3	< 5.0	335	30.8	5	0.043	1.75	< 0.05		<.039					37	7.43	1.68	28%	470	72%
P-55	28.74	95.35	16.47	69.4	6.3	107.71	29.69	4.82	0.141	1.77		0.005	0.106	20.81	0.97	0.202	9.51		7.49	14.84	25%	3710	75%
FS-188	28	26.6	3.1	5.09	< 5.0	18.1	12.7	2.8	0.012	0.65	< 0.05		<.039					10	6.87	1.79	59%	1056	41%
FS-341	36	25.9	3.01	4.72	7.5	24.7	13.5	3.2	0.024	0.76	< 0.05		<.039				8.29	45	7.08	0.0884	47%	42	53%
P-30	37.33	25.25	2.89	7.02	6.7	7.59	12.77		0.028	0.78		0.009	0.06	8.49	1.71	0.146	6.13		5.94	0.08	92%	74	8%
FS-55	29	10.7	1.81	4.93	15.8	3.42	5.85	2	0.063	0.88	< 0.05		<.039					76	6.65	0.0522	70%	37	30%
FS-125	41	19.3	0.72	2.78	< 5.0	2.33	2.12	3.4	0.015	0.76	< 0.05		<.039					62	6.48	0.0768	78%	60	22%
FS-228	25	27.7	2.77	5.23	< 5.0	4.03	7.38	3.2	0.011	0.57	< 0.05		<.039					9	6.85	0.189	60%	113	40%
FS-126	18	22.9	1.55	2.19	< 5.0	1.65	7.15	2.4	0.014	0.72	< 0.05		<.039					35	6.62	0.072	72%	52	28%

FS-221	Hay Creek Flowage	59	58-0005-00-202	9/17/12	2012	46.0894	-92.4104	1	59	58.8	97.7	97.7	no	33.8	0.5	78	7.05	17.8	258	30	11.6	0.69	7.62	30.8	1.95	13	2.2	0.029	0.48	< 0.05		<.039					75	6.36	0.119	82%	98	18%
FS-87	Bee	60	60-0192-00-202	8/23/12	2012	47.6527	-96.0504	1	60	18.8	39.8	39.8	yes	0	0.6	101	8.66	25.3	370	26	34.2	2.28	3.19	< 5.0	11	5.93	3.6	0.017	0.81	< 0.05		<.039					35	6.9	0.67	57%	382	43%
FS-86	Eighteen	61	60-0199-00-202	8/22/12	2012	47.6397	-96.0607		61	23.8	40.1	40.1	yes	20	0.7	73	8.62	24.8	395	36	29.9	3.21	2.98	< 5.0	4.29	5.54	4	0.023	0.7	< 0.05		<.039					55	6.84	0.164	60%	98	40%
FS-309	Eighteen	62	60-0199-00-203	6/13/13	2013	47.6369	-96.0599		62	0	0.0	0.0	yes	25	0.76	101	8.72	20.39	415	46	29.4	3.46	3.1	56.3	4.36	4.9	4.2	0.015	0.49	< 0.05		<.039				9.25	25	6.86	0.127	59%	75	41%
FS-328	Eighteen	62	60-0199-00-203	7/18/13	2013	47.6369	-96.0599		62	27.5	44.2	44.2	yes	2.8	0.7	101	8.21	25.75	368	32	29.6	2.58	3.05	10.3	3.34	4.64	3.8	0.02	0.58	< 0.05		<.039				5.88	30	6.79	0.25	63%	158	37%
FS-359	Eighteen	62	60-0199-00-203	8/20/13	2013	47.6367	-96.06	1	62	5.5	21.0	21.0	no	0	0.6	47	9.13	27.15	276	31	30.4	3.52	3.38	< 5.0	2.83	5.19	3.8	0.07	0.75	< 0.05		<.039				10.28	65	7.09	0.118	46%	54	54%
FS-346	Westport	63	61-0029-00-205	8/8/13	2013	45.7042	-95.203	1	63	4.5	6.7	6.7	yes	0	0.85	101	7.44	20.47	414	54	23.8	1.4	3.96	7.9	6.3	11.8	4.2	0.032	0.86	< 0.05		<.039				6.12	45	6.75	0.205	65%	133	35%
FS-186	Westport	63	61-0029-00-204	8/1/12	2012	45.6897	-95.217		63	0	0.0	0.0	yes	43.8	0.9	71	8.9	27.2	311	32	20.2	1.74	4.34	< 5.0	7.11	16.3	2.6	0.13	1.25	0.05		<.039					60	7.46	1.79	27%	483	73%
FS-207	Kelly Lake	64	66-0015-00-204	8/13/12	2012	44.3542	-93.3743	1	64	0	0.0	0.0	yes	76.3	1	101	8.79	27.7	248	29	10.6	3.16	7.6	< 5.0	1.92	18.4	1.9	0.011	0.76	< 0.05		<.039					20	6.11	0.0927	89%	83	11%
FS-182	Hunt	65	66-0047-00-208	7/27/12	2012	44.3275	-93.4443	1	65	0	0.0	0.0	yes	70	0.4	22	9.38	27.3	274	22	16.6	4.34	8.88	6.8	17.1	21.1	1.82	0.059	1.55	< 0.05		0.117					175	7.91	0.0729	11%	8	89%
FS-181	Rice	66	66-0048-00-203	7/27/12	2012	44.3332	-93.4734	1	66	0	0.0	0.0	yes	100	0.5	20	7.13	23.3	330	39	15.8	5.04	6.51	< 5.0	5.22	13.5	3	0.282	2.15	< 0.05		0.202					82	6.86	0.777	59%	458	41%
FS-89	Birch	67	69-0003-00-205	9/10/12	2012	47.7358	-91.943	1	67	26.3	33.1	33.1	yes	11	0.5	101	7	19	103.8	10	6.67	0.75	3.58	226	8.61	3.79	0.7	0.011	0.71	< 0.05		<.039					95	6.89	0.1	57%	57	43%
P-12	Birch	67	69-0003-00-205	8/30/11	2011	47.7357	-91.9428			30		68.6	yes	7.5		98	7.47	20.25	92	8.02	5.68	0.95	3.27	228.2	3.58	3.37	0.51	0.022	0.65		0.004	0.006	17.59	2.84	0.52	7.24		5.64	0.104	96%	100	4%
FS-224	Stone Lake	68	69-0046-00-201	9/19/12	2012	47.5039	-91.8857	1	68	6.3	21.0	21.0	yes	0	0.2	76	7.5	13	104.7	9.6	8.22	0.87	2.43	2830	3.26	0.45	0.9	< 0.010	2.05	< 0.05		0.778					375	6.31	0.0533	84%	45	16%
FS-68	Wolf	69	69-0143-00-101	9/6/12	2012	47.2564	-91.963	1	69	2.3	8.9	8.9	yes	1.3	0.6	92	6.79	20.7	56.7	7.5	3.47	0.52	1.59	1500	2.01	0.44	0.34	0.015	1.42	0.12		0.117					300	6.33	0.119	83%	99	17%
P-19	Wolf	69	69-0143-00-202	9/2/11	2011	47.2586	-91.9618			56.3		128.8	yes	0.5			6.54	20.84	18	6.81	3.66	0.63	2.51	702.5	1.54	1.42	0.22	0.029	1.45		0.014	0.096	28.2	3.77	1.121	5.74		5.76	0.139	95%	132	5%
P-36	Wild Rice Reservoir	70	69-0371-00-204	9/16/11	2011	46.9098	-92.1636		70	7.5		17.2	yes	0		101	8.12	12.86	111	10.58	4.49	0.87	5.73	61.2	1.13	10.6	0.7	0.024	0.72		0.004	0.014	12.15	2.33	0.288	8.67		5.49	0.023	97%	22	3%
FS-93	Turpela	71	69-0427-00-201	9/12/12	2012	47.4613	-92.2371	1	71	0.8	1.0	1.0	yes	12.5	0.2	59	7.67	18.8	176.4	21	9.66	1.95	4.63	1650	3.3	4.4	1.46	0.035	2.82	0.22		0.754					200	7.25	0.115	37%	43	63%
FS-63	Caribou	72	69-0489-00-206	9/3/12	2012	46.8913	-92.3135	1	72	0	0.0	0.0	yes	27	0.8	101	8.72	28.1	130.3	13	5.76	0.58	4.18	5.2	1.21	7.83	0.98	0.023	0.59	< 0.05		<.039					29	6.13	0.0938	89%	83	11%
P-32	Caribou	72	69-0489-00-205	9/15/11	2011	46.8991	-92.3217			0		0.0	no	0			8.73	18.17	120	12.79	6.28	0.79	4.76	145.5	0.63	9.18	0.92	0.024	0.64		0.004	0.002	11.94	1.85	0.234	8.35						
FS-333	Embarrass	73	69-0496-00-203	7/26/13	2013	47.5333	-92.2976	1		0	0.0	0.0	yes	9.3	0.55	93	6.96	21.55	173	16	9.96	1.38	7.01	681	18.2	5.31	1.12	0.02	0.86	< 0.05		<.039				8.76	50	7.62	0.0866	20%	17	80%
FS-95	Embarrass	73	69-0496-00-203	9/14/12	2012	47.5334	-92.2979		73	0	0.0	0.0	yes	21.3	0.7	91	8.04	17.1	196	20	12	1.7	6.72	733	18.8	4.92	1.36	0.015	1.02	< 0.05		0.054					175	7.82	0.0298	14%	4	86%
P-9	Embarrass	73	69-0496-00-202	8/29/11	2011	47.534	-92.3164			0		0.0	no	0			7.96	21.6	170	14.72	9.84	1.75	7.08	363.4	6.35	5.62	1.18	0.022	0.83		0.005	0.006	28.25	2.33	0.689	7.89						
P-39	Grand	74	69-0511-00-203	9/17/11	2011	46.8872	-92.3988			0		0.0	no	0		101	9.32	13.13	126	12.04	7.27	0.77	4.23	74.8	0.83	8.46	1.07	0.015	0.69		0.003	0.008	9.06	1.39	0.132	9.05						
FS-250	Little Rice	75	69-0612-00-201	9/20/12	2012	47.7086	-92.4389	1	75	8.8	29.3	29.3	no	0	0.2	70	6.7	11.3	49.9	6.6	2.82		1.45	642	1.03	0.35	0.34	< 0.010	0.91	< 0.05		<.039					150	5.97	0.0293	92%	27	8%
FS-381	Sandy-2	76	69-0730-00-204	9/17/13	2013	47.6187	-92.5931		76	0	0.0	0.0	yes	3	1.15	101	8.91	16	459	35	50.9	3.83	19.5	24.3	126	27.3	2.8	0.012	0.78	< 0.05		<.039				9.94	90	6.76	0.0342	65%	22	35%
FS-349	Sandy-3	76	69-0730-00-205	8/13/13	2013	47.6191	-92.5898		76	0	0.0	0.0	no	2.5	1.06	101	8.27	21.1	511	33	44.5	3.78	16.8	70.6	122	24.1	2.6	< 0.010	0.8	< 0.05		<.039				8.1	5	7.47	0.0697	26%	18	74%
FS-320	Sandy-2	76	69-0730-00-204	7/9/13	2013	47.6188	-92.5936			0	0.0	0.0	no	0	1.05	101	7.46	22.83	497	31	38.7	4.15	14.8	401	118	21.9	1.98	0.017	0.77	< 0.05		<.039				6.76	97	7.33	3.08	33%	1016	67%
FS-348	Sandy-2	76	69-0730-00-204	8/13/13	2013	47.6186	-92.5934	1	76	0	0.0	0.0	yes	0.8	1.02	101	8.34	19.5	525	33	45.3	3.81	17.1	45.6	123	24.4	2.6	< 0.010	0.77	< 0.05		<.039				8.11	87	7.46	0.305	27%	82	73%
FS-380	Sandy-2	76	69-0730-00-204	9/17/13	2013	47.6187	-92.5939		76	0.3	0.6	0.6	yes	12.5	0.98	101	9.08	14.9	469	35	50.9	3.83	19.5	24.3	126	27.3	2.8	0.012	0.78	< 0.05		<.039				10.38	80	7.38	0.0342	30%	10	70%
FS-305	Sandy-2	76	69-0730-00-204	6/11/13	2013	47.6187	-92.5937		76	0	0.0	0.0	yes	0	0.8	101	8.2	18.17	514	33	40.8	4.75	14.9	87.6	135	22.6	1.8	0.012	0.51	< 0.05		<.039				9.57	100	6.97	1.08	53%	572	47%
FS-321	Sandy-1	76	69-0730-00-203	7/9/13	2013	47.6255	-92.5885		76	0	0.0	0.0	no	23.8	0.65	101	7.96	24.89	275	32	40	4.17	15.2	291	122	22	2.2	0.018	0.79	< 0.05		<.039				8.3	92	7.19	0.189	40%	76	60%
FS-306	Sandy-1	76	69-0730-00-203	6/11/13	2013	47.6255	-92.5884		76	0	0.0	0.0	yes	0	0.47	101	7.89	19.38	191	11	6.23	1.81	5.38	880	11	8.72	0.64	< 0.010	0.42	< 0.05		<.039				8.77	100	6.78	0.0918	63%	58	37%
FS-251	Sandy-1	76	69-0730-00-203	9/21/12	2012	47.6254	-92.5886		76	1.3	3.8	3.8	yes	0	0.2	101	6.46	12	120.1	11	4.44	1.43	4.77	517	3.05	14.2	0.62	0.042	0.35	< 0.05		<.039					65	6.99	0.123	52%	64	48%
FS-382	Sandy-1	76	69-0730-00-203	9/17/13	2013	47.6255	-92.5885		76	0	0.0	0.0	yes	12.8	0.93	50	7.84	16.5	298	25	30.5	2.87	13.1	524	67.9	21	2	0.018	0.73	< 0.05		<.039				8.5	97	6.93	0.135	55%	74	45%
FS-322	Dark	77	69-0790-00-202	7/10/13	2013	47.6389	-92.7781		77	1.3	3.2	3.2	yes	40.3	0.45	101	8.49	25.08	682	42	61.1	4.29	14.5	23.6	175	20.6	3.2	0.016	0.7	< 0.05		<.039				9.06	60	6.56	0.131	74%	97	26%
FS-369	Dark	77	69-0790-00-202	9/5/13	2013	47.6389	-92.7781		77	12.8	11.8	11.8	yes	12.5	0.55	95	7.18	22.78	748	45	68.1	4.69	16.1	10.4	176	21.5	3.6	0.022	0.79	< 0.05		0.047				9.69	95	8.16	0.052	7%	4	93%
FS-352	Dark	77	69-0790-00-202	8/15/13	2013	47.6388	-92.7782	1	77	1.3	2.9	2.9	yes	22.5	0.2	72	8.49	25.4	638	43	63	4.22	15.1	27.9	173	20.6	3.4	0.018	0.68	< 0.05		<.039				13.55	70	7.13	0.136	44%	60	56%
FS-368	Dark	77	69-0790-00-202	9/5/13	2013	47.6387	-92.7782		77	6.3	11.1	11.1	yes	27.5	0.25	64	7.15	21.36	744	45	65.5	4.64	16	11.9	175	21.4	3.6	0.03	0.83	< 0.05		<.039				8.24	80	7.13	0.305	44%	134	56%
FS-195	Fisher	78	70-0087-00-201	8/31/12	2012	44.7942	-93.4061	1	78	25	20.7	20.7	no	30	0.2	57	8.3	28.5	564	39	29.9	2.55	34.9	88.8	6.85	77.1	3.4	0.28	1.23	< 0.25		<.039					60	6.53	0.136	76%	103	24%
FS-193	Big Mud	79	71-0085-00-201	8/30/12	2012	45.4529	-93.7418	1	79	4.3	14.3	14.3	yes	28.8	0.7	101	7.37	24.1	233	37	8.68		1.26	20.1	< 0.5	2.21	2.4	0.011	0.65	< 0.05		<.039					65	6.5	0.0308	77%	24	23%
FS-345	Rice	80	73-0196-00-216	8/7/13	2013	45.3865	-94.6313	1	80	0	0.0	0.0	yes	70	0.8	101	7.63	23.63	426	58	27.3	1.72	5.3	< 5.0	6.85	11.5	4.8	0.088	1.05	< 0.05		<.039				4.96	64	7.02	2.08	50%	1040	50%
FS-184	Rice	80	73-0196-00-216	7/30/12	2012	45.3864	-94.6309		80	0	0.0	0.0	yes	72.5	0.7	101	9.47	31.5	278	21	24.6	1.91	4.86	< 5.0	2.58	10.7	2.8	0.015	0.84	< 0.05		<.039					20	6.59	2.97	73%	2168	27%
FS-187	McCormic	81	73-0273-00-203	8/2/12	2012	45.722	-94.9121	1	81	1.3	8.9	8.9	yes	0	0.6	101	9.51	27.5	274	18	20.1	8.39	5.63	< 5.0	1.54	20.9	2.2	0.018	1.15	< 0.05		<.039					25	7.41	0.144	29%	42	71%
FS-344	Padua	82	73-0277-00-202	8/6/13	2013	45.6231	-95.0187		82	2.5	9.5	9.5	no	0	0.4	101	8.86	21.3	170	22	18.6	8.42	7.83	37.3	< 0.5	18.2	2.4	0.04	1.85	< 0.05		0.047				12.28	60	6.79	0.0806	63%	51	37%
P-29	Padua	82	73-0277-00-203	9/13/11	2011	45.6202	-95.0192		82	1.5		3.4	no	0		66	7.3	18.6	271	23.45	21.42	7.19	4.93	101.6	0.76	11.82	2.41	0.118	1.97		0.003	0.008	17.8	2.28	0.414	6.42		6.19	0.13	87%	113	13%
FS-220	Padua	82	73-0277-00-202	8/7/12	2012	45.623	-95.0186	1	82	0	0.0	0.0	no	0.5	0.4	13	9.16	25.3	314	25	25.2	14.9	9.87	17.2	0.86	27.1	3	0.162	2.65	< 0.05		0.047					325	6.4	0.23	81%	186	19%
P-28	Raymond	83	73-0285-00-203	9/12/11	2011	45.629	-95.0234		83	30		68.6	no	0		53	7.57	22.84	333	32.94	24.05	5.08	3.42	20.8	0.82	15.15	2.96	0.074	1.52		0.003	0.002	16.63	1.73	0.29	10.49		7.34	0.094	32%	30	68%
FS-343	Raymond	83	73-0285-00-203	8/6/13	2013	45.629	-95.0233	1	83	25	61.4	61.4	no	0	0.75	35	9.46	21.29	292	20	24.7	4.34	4.16	27.9	1.92	17.7	2.6	0.046	1.55	< 0.05		<.039				8.07	83	6.67	0.0903	69%	62	31%
FS-53	Raymond	83	73-0285-00-203	8/2/12	2012	45.6286	-95.0225		83	19	61.1	61.1	no	0	0.7	30		30.8	284	16	27	4.51	4.25	13.8	< 0.5	19.5	2.4	0.025	1.55	< 0.05		<.039					100	7	0.0787	51%	40	49%
FS-179	Rice	84	74-0001-00-201	7/25/12	2012	44.0842	-93.0737	1	84	0	0.0	0.0	yes	90.3	0.5	3	9.33	31	203.8	35	14.7	2.59	4.39	71.3	3.84	13.5	2.8	0.431	2.65	< 0.05		0.14					435	7.22	0.217	39%	85	61%
FS-185	Hoffs Slough	85	76-0103-00-201	8/1/12	2012	45.3255	-95.7059			0	0.0	0.0	no	11.3	0.7	101	7.79	21.2	1030	150	57.6	4.19	12.4	< 5.0	273	18.5	5.79	0.024	0.43	< 0.05		<.039					5	6.73	0.0343	66%	23	34%
FS-204	Big Swan	86	77-0023-00-207	8/10/12	2012	45.8795	-94.742	1	86	55	133.7	133.7	yes	21.3	0.7	101	7.49	23.9	362	35	22.5	3.35	8.85	< 5.0	5.49	15.3	3.2	0.013	0.7	< 0.05		<.039					25	6.4	0.0914	81%	74	19%
FS-205	Big Swan	86	77-0023-00-207	8/10/12	2012	45.8795	-94.7418		86	17.5	56.3	56.3	yes	13.3	0.7	101	7.65	27.1	357	35	22.5	3.31	8.88	< 5.0	5.47	15.3	3.4	0.012	0.7	< 0.05		<.039					30	6.56	0.0527	74%	39	26%
FS-54	Little Birch	87	77-0089-00-207	8/3/12	2012	45.7779	-94.7978	1	87	11.3	70.0	70.0	yes	3.8	0.3	101	8.63	26.5	312	28	22.5	3.03	6.97	< 5.0	7.4	11.6	2.8	< 0.010	0.62	< 0.05		<.039					13	6.68	0.0353	69%	24	31%
P-47	Little Birch	87	77-0089-00-101	9/21/11	2011	45.7747	-94.7996		87	11.3		25.9	yes	36.3		101	7.35	16.36	348	38.32	20.99	3.34	6.7	9.2	3.2	11.31	3.25	0.021	0.71			0.015	8.4	1.85	0.156	8.71		6.53	0.05	76%	38	24%
P-47	Little Birch	87	77-0089-00-101	9/21/11	2011	45.7747	-94.7996		87	11.3		25.9	yes	36.3		101	7.35	16.36	348	38.32	20.99	3.34	6.7	9.2	3.2	11.31	3.25	0.021	0.71			0.015	8.4	1.85	0.156	8.71		6.53	0.191	76%	145	24%
P-47	Little Birch	87	77-0089-00-101	9/21/11	2011	45.7747	-94.7996			11.3		25.9	yes	36.3		101	7.35	16.36	348	38.32	20.99	3.34	6.7	9.2	3.2	11.31	3.25	0.021	0.71			0.015	8.4	1.85	0.156	8.71		6.53	0.191	76%	145	24%
P-47	Little Birch	87	77-0089-00-101	9/21/11	2011	45.7747	-94.7996			11.3		25.9	yes	36.3		101	7.35	16.36	348	38.32	20.99	3.34	6.7	9.2	3.2	11.31	3.25	0.021	0.71			0.015	8.4	1.85	0.156	8.71		6.53	0.191	76%	145	24%
FS-175	Maloney	88	79-0001-00-201	7/23/12	2012	44.2251	-91.9321	1		0	0.0	0.0	yes	47.5	0.4	52	7.19	30.6	435	42	35.9	1.04	3.15	< 5.0	3.15	8.24	4.8	0.131	0.69	< 0.05		<.039					73	6.69	0.0608	68%	41	32%
P-63	Maloney	88	79-0001-00-201	9/29/11	2011	44.2243	-91.9328		88	65		148.7	no	0		39	7.28	17.08	617	59.75	38.77	7.62	9.57	127.8	1.83	18.54	5.1	0.279	0.81		0.003	0.024	6.6	1.96	0.14	6.13		6.37	0.01	82%	8	18%
P-64	Maloney	88	79-0001-00-201	9/29/11	2011	44.2243	-91.9328			0		0.0	no	0						59.47	38.72	7.56	9.49	117.9	1.83	17.33		0.183	0.42		0.005	0.025	6.52	2.01	0.141							
FS-336	Mississippi Pool 4/Robinson Lake	89	79-0005-02-201	7/30/13	2013	44.3613	-91.9901		89	30	46.5	46.5	yes	23.8	0.65	101	8.51	23	463	57	22.6	2.86	13.7	9.4	55.3	20.6	3.4	0.111	3.2	1.3		<.039				8.73	50	7.26	0.0602	37%	22	63%
FS-211	Mississippi Pool 4/Robinson Lake	89	79-0005-02-201	8/16/12	2012	44.3611	-91.9897		89	51.3	57.6	57.6	yes	100	0.6	101	7.21	22.2	310	41	15.8	2.17	12.4	8.2	17.7	16.8	2.6	0.267	0.77	< 0.05		<.039					65	6.98	0.0714	52%	37	48%
FS-210	Mississippi Pool 4/Robinson Lake	89	79-0005-02-202	8/16/12	2012	44.3593	-91.9881	1	89	21.3	35.3	35.3	yes	100	0.6	69	7.05	21.3	339	42	16.6	2.98	14.7	< 5.0	15.7	21.3	2.8	0.391	0.81	< 0.05		<.039					85	6.74	0.07	66%	46	34%
FS-180	Lily	90	81-0067-00-202	7/26/12	2012	44.1947	-93.647	1	90	18.8	38.2	38.2	yes	42.5	1	101	6.94	26.8	305	33	16.8	3.55	5.35	< 5.0	< 0.5	20.9	2.8	0.027	0.84	< 0.05		<.039					55	6.16	0.0295	88%	26	12%
P-61	Lily	90	81-0067-00-202	9/28/11	2011	44.194	-93.6469		90	22.5		51.5	yes	30		101	7.24	16.22	316	34.2	17.26	4.8	5.95	43	0.66	20.37	2.6	0.018	0.81		0.004	0.013	9.24	1.47	0.14	5.58		6.41	0.041	80%	33	20%
P-62	Lily	90	81-0067-00-202	9/28/11	2011	44.194	-93.6469			0		0.0	no	0						33.5	17.31	4.54	8.35	42.3	0.64	20.3		0.017	0.81		0.004	0.008	9.29	1.48	0.142							
FS-194	Gilchrist	91	86-0064-00-201	8/31/12	2012	45.2309	-93.824	1	91	0	0.0	0.0	yes	80	0.7	101	7.42	22.9	337	26	25.1	1.85	6.76	< 5.0	6.98	22.1	2.8	< 0.010	0.62	< 0.05		<.039					25	6.53	0.355	76%	270	24%
FS-129	Mink	92	86-0229-00-207	8/23/12	2012	45.2767	-94.0299		92	0	0.0	0.0	yes	97.5	0.5	45	7.54	23.1	267	26	13.7	6.22	7.94	< 5.0	1.22	28.9	1.76	0.088	1.75	< 0.05		0.086					71	6.27	0.182	85%	155	15%
FS-201	Mink	92	86-0229-00-206	8/8/12	2012	45.274	-94.0269	1	92	0	0.0	0.0	yes	52.5	0.7	22	9.62	24.9	262	25	12.8	6.31	7.7	26.4	1.31	29.5	1.78	0.122	1.45	< 0.05		<.039					100	6.96	0.0373	53%	20	47%
FS-139	Welby family farm	93	86-0231-00-202	9/21/12	2012	45.3592	-94.0782	1	93	2	17.2	17.2	yes	0.8	1.1	101	8.29	14.8	342	38	20.4	0.75	6.63	10.2	< 0.5	19.2	3	< 0.010	0.64	< 0.05		<.039					24	7.04	0.118	49%	58	51%
FS-200	Louisa	94	86-0282-00-205	8/8/12	2012	45.2998	-94.258	1	94	0	0.0	0.0	yes	46.3	0.5	42	7.57	22.3	427	50	26.1	3.22	6.09	11.7	7.04	14.7	4	0.103	0.95	< 0.05		<.039					83	6.63	0.192	71%	136	29%
FS-80	Mission	95	S001-646	8/6/12	2012	45.8623	-93.0011	1	95	52.3	87.5	87.5	no	57.5	0.7	84	7.09	21.9	239	30	11.5	0.85	5.39	673	0.62	7.6	2.2	0.113	0.9	< 0.05		<.039					100	6.77	0.0485	64%	31	36%
FS-189	Clearwater	96	S002-121	8/28/12	2012	47.9372	-95.6906	1	96	1.8	4.5	4.5	no	15.3	0.2	87	8.04	20.9	490	60	28.4	3.55	7.13	< 5.0	23.8	6.56	4.6	0.062	0.61	< 0.05		0.039					45	7.58	0.117	22%	26	78%
FS-314	Clearwater	96	S002-121	6/24/13	2013	47.9372	-95.6907		96	0.3	0.6	0.6	no	1.5	0.6	78	8.82	20.48	515	72	25.3	5.56	6.45	96.2	28	7.35	4.8	0.12	1.05	< 0.05		<.039				7.59	85	7.64	0.0664	19%	13	81%
FS-373	Clearwater	96	S002-121	9/9/13	2013	47.9372	-95.6909			5	3.2	3.2	no	36.3	0.25	50	7.83	19.6	362	62	27.2	3.62	7.02	76.8	34.4	7	4.4	0.075	1.01	0.11		0.078				7.26	57	7.58	0.0354	22%	8	78%
FS-327	Clearwater	96	S002-121	7/17/13	2013	47.9371	-95.6906			0.3	0.3	0.3	no	22.8	0.2	27	7.72	24.83	481	68	25.6	4.3	6.21	57.8	23.7	7	4.8	0.213	1.78	0.18		0.303				5.06	125	7.69	0.117	18%	21	82%
P-11	Sand	97	S003-249	8/30/11	2011	47.6348	-92.4235			6.3		14.4	no	1.3		95	6.47	19.59	228	17.53	16.95	1.8	9.89	1132.3	7.69	15.58	0.89	0.037	1.17		0.009	0.016	30.47	3.29	1.099	6.49		6.46	0.046	78%	36	22%
FS-90	Sand	97	S003-249	9/11/12	2012	47.6351	-92.4234	1	97	0.8	2.9	2.9	yes	2.8	0.2	53	7.74	15.7	322	24	22.5	2.7	12.1	1790	15.9	20.7	2.2	0.028	0.96	< 0.05		<.039					200	7.17	0.152	41%	62	59%
FS-88	Clearwater	98	S004-204	8/24/12	2012	47.5174	-95.3904	1	98	61.3	148.3	148.3	yes	44.8	0.6	101	7.26	21.2	515	61	29.1	2.34	5.55	< 5.0	2.04	5.52	5.19	0.054	0.46	< 0.05		<.039					40	7.18	0.0488	41%	20	59%
FS-337	Clearwater	98	S004-204	7/29/13	2013	47.5175	-95.3906		98	52.5	69.1	69.1	yes	3.3	0.5	101	7.35	20.04	495	67	24.4	1.27	5.44	235	0.95	6.3	5.19	0.047	0.52	< 0.05		<.039				4.85	67	6.84	0.0608	60%	36	40%
P-2	Mud	99	S004-735	8/23/11	2011	46.6266	-95.5751			0		0.0	no	0			8.38	24.1	350																	9.56						
FS-94	Sturgeon	100	S004-870	9/13/12	2012	47.656	-92.9315	1	100	13.8	37.9	37.9	yes	31.3	0.5	101	6.97	15	97.7	11	4.72	1.03	3.86	471	1.62	4.01	0.8	< 0.010	0.74	< 0.05		<.039					100	6.94	0.0659	55%	36	45%
FS-215	Popple	101	S006-188	9/11/12	2012	47.7254	-94.0817	1	101	11.8	36.3	36.3	no	58.8	0.5	32	7.78	19.3	258	38	12.5	1.27	3.02	< 5.0	< 0.5	2.52	2.6	0.062	1.75	< 0.05		0.124					85	6.68	0.0269	69%	19	31%
FS-199	Rice	102	S006-208	9/5/12	2012	47.6742	-93.6547	1	102	29	75.4	75.4	yes	0	0.6	101	7.5	19.1	247	39	10.2	1.57	3.38	12.3	1.57	0.8	2.8	< 0.010	0.38	< 0.05		<.039					15	7.33	0.0552	33%	18	67%
FS-355	Mississippi River below Clay Boswell	103	S006-923	8/13/13	2013	47.2553	-93.634	1	103	33.8	78.3	78.3	no	0	0.8	101	7.85	24.28	312	36	15.9	1.42	5.56	25.7	10.2	3.52	3	0.03	0.74	< 0.05		<.039				6.03	35	6.28	0.0819	85%	70	15%
FS-57	Mississippi River below Clay Boswell	103	S006-923	8/28/12	2012	47.2551	-93.6342		103	0	0.0	0.0	no	0	0.5	101	7.63	25.6	293	35	16.5	1.61	5.9	27.1	10.3	3.48	2.8	0.018	0.7	< 0.05		<.039					35	7.35	0.134	32%	43	68%
P-15	Mississippi River below Clay Boswell	103	S006-923	9/1/11	2011	47.2547	-93.6344			43.8		100.2	no	1.5			7.59	22.22	255	28.1	14.73	2.04	5.2	118.1	3.65	3.85	2.6	0.029	0.79		0.017	0.043	9.75	2.02	0.207	3.89		6.6	0.035	72%	25	28%
P-10	Pike	104	S006-927	8/30/11	2011	47.7325	-92.3468			18.8		43.0	yes	8.8		62	6.96	21.77	172	15.92	11.77	1.79	6.54	1218.9	8.31	9.82	0.97	0.038	0.97		0.005	0.013	21.5	3.14	0.779	7.11		6.59	0.063	73%	46	27%
FS-91	Pike	104	S006-927	9/11/12	2012	47.7327	-92.3473	1	104	23.8	3.5	3.5	yes	2.8	0.2	32	7.47	19.9	214.7	19	13.2	2.12	6.83	985	14.2	11.3	1.5	0.019	0.65	< 0.05		<.039					175	6.8	0.0656	62%	41	38%
FS-67	St. Louis Estuary Pokegama Bay	105	S006-928	9/5/12	2012	46.6859	-92.1606	1	105	0	0.0	0.0	yes	46.5	0.7	26	8.14	25.4	210.7	25	11.6	1.38	6.62	1200	9.97	6.07	1.76	0.085	0.89	< 0.05		<.039					320	6.87	0.112	59%	66	41%
P-41	St. Louis Estuary Pokegama Bay	105	S006-928	9/19/11	2011	46.6855	-92.1619			0		0.0	no	0		3	7.86	17.85	178	20.64	9.93	1.68	5.41	1645.6	2.33	6.32	1.48	0.173	1.34		0.091	0.049	30.35	4.1	1.384	6.68						
FS-70	St. Louis	106	S006-929	9/7/12	2012	47.4015	-92.3772			0	0.0	0.0	no	0	0.7	101	7.78	16.2	349	24.6	29.2	1.94	8.2	1210	73.8	5.1	1.84			< 0.05							275					
P-16	St. Louis	106	S006-929	9/1/11	2011	47.4015	-92.3773			0		0.0	no	0		101	6.67	19.75	343	22.39	28.28	2.31	9.31	358.1	24.5	6.38	1.32	0.018	0.59		0.007	0.012	16.09	2.88	0.493	7.91		6.9	0.025	57%	14	43%
P-25	Lower Rice	107	S006-985	9/8/11	2011	47.3793	-95.4834			50		114.4	no	0		101	7.15	18.09	323	42.28	18.62	0.58	2.8	75.3	1.02	1.16	3.08	0.042	0.94		0.003	0.005	23.49	2.2	0.524	7.36		7.16	0.097	42%	41	58%
FS-58	Mississippi River above Clay Boswell	108	S007-163	8/28/12	2012	47.2386	-93.7197		108	0	0.0	0.0	no	0	0.5	101	7.65	24.7	266	31	15.8	1.7	5.28	46.9	1.19	3.2	2.8	0.011	0.71	< 0.05		<.039					41	7.23	0.0806	38%	31	62%
FS-354	Mississippi River above Clay Boswell	108	S007-163	8/13/13	2013	47.2376	-93.7187	1	108	75	132.7	132.7	no	1.8	0.3	101	7.91	20.86	288	33	15.3	1.33	4.95	22.2	1.18	3.63	2.8	0.022	0.67	< 0.05		<.039				5.98	40	6.83	0.0532	61%	32	39%
P-14	Mississippi River above Clay Boswell	108	S007-163	9/1/11	2011	47.2379	-93.7196			71.3		163.2	no	7.5			7.77	21.26	251	26.72	14.71	1.9	5.19	94.8	1.09	3.7	2.67	0.029	0.46		0.03	0.067	10.01	1.88	0.196	5.09		6.61	0.053	72%	38	28%
P-26	Lower Rice	109	S007-164	9/8/11	2011	47.3817	-95.4926			52.5		120.1	no	0		101	6.82	19.02	325	44.74	18.8	0.41	2.56	81.1	0.55	0.99	2.7	0.05	1.36		0.004	0.006	27.44	1.89	0.526	6.83		6.76	0.07	65%	46	35%
FS-203	Long Prairie	110	S007-203	8/9/12	2012	45.9729	-95.1603		110	46.3	58.3	58.3	no	0.5	0.4	101	7.73	22.8	465	40	27.5	3.91	18.1	84.7	6.66	29.3	3.8	0.042	0.55	< 0.05		<.039					15	7.3	0.0391	34%	13	66%
FS-202	Long Prairie	110	S007-204	8/9/12	2012	46.0072	-95.2634	1	110	8.8	13.4	13.4	no	11.5	0.2	101	7.53	21.9	456	33	27.9	4.43	20.1	29.6	7.71	33	3.4	0.018	0.59	< 0.05		<.039					10	7.23	0.0793	38%	30	62%
FS-83	Mississippi Crow Wing	111	S007-205	8/8/12	2012	46.4386	-94.1251	1	111	0	0.0	0.0	yes	53.8	0.9	54	7.56	24.4	234	31	10.6	1.55	4.65	590	3.13	3.36	2.2	0.059	1.12	0.17		0.039					150	6.88	0.127	58%	74	42%
FS-66	St. Louis Estuary	112	S007-206	9/5/12	2012	46.6545	-92.2739	1	112	0	0.0	0.0	yes	13.3	0.3	64	8.05	21.9	226	22	13.7	1.42	7.33	587	16	6.62	1.74	0.018	0.73	< 0.05		<.039					150	7.34	0.0445	32%	14	68%
FS-131	Hinken	113	S007-207	9/5/12	2012	47.7271	-93.9923	1	113	18.8	46.8	46.8	yes	0.5	0.3	101	7.51	21.3	276	39	17.4	1.78	3.52	< 5.0	< 0.5	1.37	3.2	0.034	0.8	< 0.05		<.039					50	6.93	0.0876	55%	48	45%
P-17	St. Louis	114	S007-208	9/1/11	2011	47.4668	-91.9355			30		68.6	yes	11.3		101	6.43	19	11	4.93	4.43	0.38	1.6	1344.2	1.23	0.49	0.18	0.027	1.1		0.007	0.016	27.73	3.53	1.094	5.12		6.02	0.04	91%	36	9%
FS-69	St. Louis	114	S007-208	9/7/12	2012	47.4671	-91.9279	1	114	0	0.0	0.0	yes	93.5	0.6	75	6.91	17.7	75.4	8.8	6.58	0.51	1.72	3400	1.33	0.4	0.56	0.018	1.55	< 0.05		0.086					520	6.54	0.181	75%	136	25%
FS-196	Prairie	115	S007-209	9/3/12	2012	47.2519	-93.4884	1	115	16.3	44.6	44.6	yes	45	0.4	101	7.65	26.6	196.4	28	8.74	1.32	4.2	9.7	9.63	3.17	1.78	0.017	0.65	< 0.05		<.039					55	6.44	0.0709	79%	56	21%
FS-214	Bowstring	116	S007-219	9/11/12	2012	47.7024	-94.0608	1	116	27.5	69.7	69.7	yes	91.8	0.5	101	7.29	17.3	226	30	11	1.47	3.49	< 5.0	1.34	2.45	2.2	0.014	0.66	< 0.05		<.039					25	6.74	0.256	66%	169	34%
FS-303	Second	117	S007-220	5/30/13	2013	47.5204	-92.1925		117	0	0.0	0.0	no	0	1	101	8.25	17.5	969	37	99.7		21.3	870	303	14	4.2	0.011	0.48	< 0.05		<.039				8.59	80	6.5	0.0991	77%	76	23%
FS-323	Second	117	S007-220	7/11/13	2013	47.5204	-92.1925		117	45	76.4	76.4	yes	20	0.8	101	8.05	18.94	1162	38	143	6.65	20.1	610	405	5.79	5.19	0.018	0.73	0.06		<.039				8.28	150	6.92	0.067	56%	38	44%
FS-310	Second	117	S007-220	6/14/13	2013	47.5205	-92.1925		117	25	57.6	57.6	no	0	0.5	101	8.49	18.37	1105	43	122	9.36	28.2	252	316	18.7	5.59	< 0.010	0.44	< 0.05		<.039				9.04	62	7.71	0.0927	17%	16	83%
FS-384	Second	117	S007-220	9/19/13	2013	47.5204	-92.1925			15	27.7	27.7	no	0	0.2	101	8.19	16.6	1762											< 0.05						8.16	45	7.65	0.104	19%	20	81%
FS-351	Second	117	S007-220	8/15/13	2013	47.5205	-92.1925	1	117	52.5	66.8	66.8	no	43.8	0.12	101	8.44	16.5	1789	48	266	11.1	38.4	29	838	7.62	8.19	0.012	0.49	< 0.05		<.039				7.39	70	7.44	0.0447	28%	13	72%
FS-208	Mississippi Pool 8 at Genoa	118	S007-222	8/14/12	2012	43.5758	-91.2334	1	118	43.8	41.4	41.4	yes	76.3	1.2	101	8.12	27.6	342	38	16.2	2.15	10.6	< 5.0	18	15.2	2.6	0.118	1.29	0.34		<.039					65	7.05	0.176	48%	84	52%
FS-370	Mississippi Pool 8 at Genoa	118	S007-222	9/9/13	2013	43.5765	-91.2337		118	11.3	17.8	17.8	yes	47.5	1.1	101	7.23	26.41	428	42	22.1	2.78	13.8	< 5.0	33.3	20.5	3	0.129	1.56	0.36		0.093				6.47	40	6.97	0.062	53%	33	47%
FS-334	Mississippi Pool 8 at Genoa	118	S007-222	7/29/13	2013	43.5758	-91.2344		118	28.8	52.8	52.8	yes	12.5	0.7	101	8.38	24	436	56	22.2	2.78	11.2	7	44.2	17.7	3.4	0.098	4.3	1.9		<.039				8.11	35	7.34	0.102	32%	33	68%
FS-311	Mississippi Pool 8 at Genoa	118	S007-222	6/20/13	2013	43.5766	-91.2341		118	10	12.7	12.7	no	1	0.55	39	8.85	22.94	401	49	18.1	2.33	9.7	74.6	29.3	16.5	2.8	0.048	5.4	2.4		<.039				10.09	115	7.44	0.107	28%	30	72%
FS-365	Partridge	119	S007-443	9/3/13	2013	47.5212	-92.1901		119	31.3	76.7	76.7	yes	0	0.3	101	7.43	23.43	253	26	13.4	1.49	7.77	1850	34.1	5.51	1.54	0.015	1.28	0.18		0.047				9.11	350	7.63	0.0393	20%	8	80%
P-13	Partridge	119	S007-443	8/31/11	2011	47.5212	-92.1899			28.8		65.9	yes	3.3		101	6.38	19.37	191	21.15	11.14	1.72	7.31	781	10.39	7.99	0.66	0.016	0.82		0.04	0.012	36.2	2.09	0.824	6.8		6.6	0.075	72%	54	28%

FS-317	Partridge	119	S007-443	6/26/13	2013	47.5215	-92.1903			0	0.0	0.0	no	16.8	0.55	94	6.28	23.4	920	7.8	4.64	0.75	2.64	801	7.65	2.27	0.48	0.015	1.19	0.09		0.047				6.78	275					
FS-301	Partridge	119	S007-443	5/28/13	2013	47.5213	-92.1903		119	0	0.0	0.0	no	0	0.5	93	7.21	15.44	87	8.6	4.96	1.14	2.98	421	14.8	2.21	0.36	< 0.010	1.04	0.17		<.039				9.38	225	6.29	0.125	84%	105	16%
FS-366	Partridge	119	S007-443	9/3/13	2013	47.5213	-92.19		119	17.5	47.7	47.7	yes	0	0.3	70	7.42	22.88	254	26	13.6	1.44	7.87	1950	34.2	5.47	1.54	0.02	1.38	0.18		0.062				8.75	275	7.25	0.057	37%	21	63%
FS-92	Partridge	119	S007-443	9/12/12	2012	47.5207	-92.1909		119	1.5	4.1	4.1	yes	75	0.2	59	7.75	16	260	26	16.1	1.61	6.68	888	36.3	7.31	1.54	0.02	0.99	0.10		<.039					150	7.42	0.0741	28%	21	72%
FS-331	Partridge	119	S007-443	7/24/13	2013	47.5212	-92.1904	1	119	30	60.5	60.5	yes	5	0.45	52	7.72	23.19	151	17	9.03	1	4.81	2510	14.6	3.12	1.04	0.021	1.52	0.22		0.062				6.35	425	6.87	0.112	59%	66	41%
FS-363	St. Louis Estuary	120	S007-444	8/26/13	2013	46.6518	-92.2372			18.8	31.2	31.2	no	1.5	0.62	101	7.37	30.87	225											< 0.05						7.12	100	7.24				
FS-330	St. Louis Estuary	120	S007-444	7/22/13	2013	46.6518	-92.2372	1	120	8.8	11.8	11.8	yes	3.3	0.6	63	7.9	22.4	145	17	8.55	0.87	4.45	1020	6.71	3.64	1.22	0.036	0.93	< 0.05		<.039				8.87	325	6.6	0.0901	72%	65	28%
FS-300	St. Louis Estuary	120	S007-444	5/27/13	2013	46.6515	-92.2376		120	0	0.0	0.0	no	0	0.45	58	7.33	11.89	127	14	6.93	1.38	4.72	395	9.4	6.23	0.84	0.02	0.82	0.06		<.039				11.12	200	6.89	0.0713	57%	41	43%
FS-315	St. Louis Estuary	120	S007-444	6/24/13	2013	46.6516	-92.2373		120	0	0.0	0.0	no	0	0.5	30	6.65	19.6	149.2	17	7.8	1.17	4.89	497	8.1	5.66	1.1	0.051	0.85	< 0.05		<.039				7.86	360	6.65	0.147	70%	103	30%
P-40	St. Louis Estuary	120	S007-444	9/19/11	2011	46.6588	-92.2819			0		0.0	no	0		6	8.32	18.13	208	21.15	12.94	1.51	6.97	1165.2	4.9	8.28	1.76	0.046	1.01		0.116	0.033	24.56	3.79	1.03	8.85						
FS-302	Partridge	121	S007-513	5/30/13	2013	47.5153	-92.1894		121	0	0.0	0.0	no	0	0.65	101	7.99	18.86	190	12	14.9	1.69	4.9	380	43.1	3.48	0.78	< 0.010	0.92	0.16		<.039				8.08	235	6.93	0.0624	55%	34	45%
FS-364	Partridge	121	S007-513	8/30/13	2013	47.5138	-92.1894			57.5	105.7	105.7	no	0	0.32	101	7.33	26.17	588											< 0.05						6.94	375	7.39				
FS-316	Partridge	121	S007-513	6/28/13	2013	47.5137	-92.1899		121	0	0.0	0.0	no	0.8	0.72	85	7.06	21.3	108.8	9.9	10.7	1.01	3.29	1130	24.9	1.74	0.62	0.012	1.16	0.06		<.039				6.77	250		0.098			
FS-332	Partridge	121	S007-513	7/24/13	2013	47.5137	-92.1894	1	121	53.8	79.6	79.6	no	0	0.4	44	7.56	23.37	203	19	22.6	1.68	6.64	2370	54.4	3.89	1.52	0.019	1.38	0.18		<.039				6.81	400	7.25	0.102	37%	38	63%
FS-209	Mississippi Pool 8 at Reno Bottoms	122	S007-556	8/15/12	2012	43.6025	-91.2686	1	122	46.3	72.3	72.3	no	67	1.2	57	7.56	24.1	344	39	16.5	2.3	10.6	13.5	18.1	15.5	2.8	0.151	1.98	0.48		0.054					60	6.8	0.0711	62%	44	38%
FS-335	Mississippi Pool 5 / Spring	123	S007-660	7/30/13	2013	44.1953	-91.841		123	42.5	63.0	63.0	yes	2	1	101	8.57	22.4	425	52	20.7	2.81	12.4	21.9	47.7	18.6	3.2	0.119	3.8	1.6		<.039				9.12	55	7.29	0.0342	35%	12	65%
FS-212	Mississippi Pool 5 / Spring	123	S007-660	8/17/12	2012	44.1993	-91.8461	1	123	17.5	29.6	29.6	no	1	0.9	101	9.16	21.2	292	38	15.3	2.01	11.7	32.4	17.2	16.4	2.6	0.134	0.67	< 0.05		<.039					85	7.92	0.0224	11%	2	89%
FS-371	Mississippi Pool 5 / Spring	123	S007-660	9/10/13	2013	44.2016	-91.8443		123	26.3	39.8	39.8	no	47.5	0.75	101	7.25	24.77	402	39	20.3	2.77	15.2	13.6	34.4	21.3	2.6	0.102	1.04	0.18		0.117				6.9	45	6.85	0.069	60%	41	40%
FS-372	Mississippi Pool 5 / Spring	123	S007-660	9/10/13	2013	44.2016	-91.8443		123	13.8	26.7	26.7	yes	3.8	0.75	101	7.26	28.74	377	39	20.1	2.47	15.3	< 5.0	34.8	21.5	2.6	0.068	0.71	< 0.05		0.047				16.63	45	8	0.0536	9%	5	91%
FS-312	Mississippi Pool 5 / Spring	123	S007-660	6/21/13	2013	44.2018	-91.8444		123	23.8	35.7	35.7	yes	1.3	0.76	36	8.34	21.49	292	39	14.5	2.31	9.15	114	28.3	14.2	2.2	0.092	4.5	1.9		0.047				14.8	95	7.49	0.0844	25%	21	75%
FS-358	Turtle River, North Branch	124	S007-662	8/19/13	2013	47.9952	-97.6276	1	124	22.5	121.0	121.0	no	0	0.15	101	8.34	26.36	897	100	36.7	4.62	39.5	5.3	198	19.1	5	0.03	0.53	0.10		<.039				8.76	20		0.083			
FS-101	Rice paddy	125	WT00026	6/25/12		48.2161	-94.6188			4.3	8.3	8.3	no	1	0.4	43	7.22	23.7	229	32	11.6	5.34	3.03	428	11.3	6.84	1.58	0.724	3.25	< 0.05		0.109					383	5.41	0.298	98%	292	2%
FS-102	Rice paddy	126	WT00027	6/26/12		47.9265	-95.6313			39.3	93.6	93.6	no	0.8	0.5	101	6.44	21.37	897	130	43.5	11.5	6.75	412	1.61	14.3	9.19	1.58	3.65	< 0.05		0.249					230	6.19	0.677	87%	589	13%
FS-308	Rice paddy	127	WT00028	6/12/13		47.8056	-95.674			36.3	85.9	85.9	no	0.3	0.3	98	9.21	23.83	651	79	43.1	16.3	10.7	13.6	57.1	18.6	5.59	0.043	1.95	< 0.05		<.039				12.14	97	6.83	0.802	61%	489	39%
FS-326	Rice paddy	127	WT00028	7/17/13		47.8055	-95.6732			100	251.8	251.8	no	0	0.08	43	6.82	20.76	672	77	48.6	6.78	9.76	128	28.8	17.7	6.59	0.336	4.15	< 0.05		0.552				0.93	250	6.91	0.39	56%	218	44%
FS-103	Rice paddy	127	WT00028	6/26/12		47.8053	-95.6732			23.8	58.9	58.9	no	0	0.2	23	8.55	27.91	927	84	74.8	13.3	23.9	68.2	279	39.8	3.4	0.093	5.05	< 0.05		0.14					233	6.33	0.732	83%	608	17%
FS-361	Rice paddy	127	WT00028	8/21/13		47.8054	-95.6744			68.8	78.6	78.6	no	0																< 0.05												
FS-106	Rice paddy	128	WT00029	6/28/12		47.8523	-95.4732			25	50.6	50.6	no	0	0.2	68	7.76	22.11	434	49	25.8	2.95	5.49	32	7.14	5.72	4.2	0.043	0.69	< 0.05		<.039					67	5.93	0.169	92%	155	8%
FS-107	Rice paddy	129	WT00030	6/28/12		47.8521	-95.4953			80	134.3	134.3	no	0	0.3	84	7.24	24.16	489	51	31.3	5.44	7.49	147	9.46	9.6	4.6	0.092	3.05	< 0.05		0.319					160	6.18	0.194	87%	169	13%
FS-108	Rice paddy	130	WT00031	6/29/12		46.246	-94.2548			33.8	54.7	54.7	no	0	0.3	84	7.34	23.04	132	21	4.99		1.91	64.2	0.25	0.3	1.3	0.021	1.05	< 0.05		<.039					155	5.9	0.0313	93%	29	7%
FS-307	Rice paddy	131	WT00046	6/12/13		47.8482	-95.4865			4.3	8.3	8.3	no	0	0.2	73	9.46	20.95	423	64	20.8	7.6	4.82	9.3	16.6	4.77	4.2	0.09	1.25	< 0.05		<.039				10.47	92	7.26	0.039	37%	14	63%
FS-325	Rice paddy	131	WT00046	7/16/13		47.8481	-95.4865			51.3	79.6	79.6	no	1.3	0.05	29	8.26	24.33	467	82	30.3	1.88	3.62	362	0.46	1.03	5.99	1.15	3.65	< 0.05		0.093				5.75	350	7.69	0.115	18%	21	82%
FS-360	Rice paddy	131	WT00046	8/21/13		47.8479	-95.4866			33.8	66.5	66.5	no	0																< 0.05									0.0943			

pore water Cl (mg/L)	pore water DOC (mg C/L)	pore water Ca (mg/L)	pore water Mg (mg/L)	pore water K (mg/L)	pore water Na (mg/L)	pore water Fe (µg/L)	pore water Mn (µg/L)	pore water TP (mg/L)	pore water TN (mg/L)	pore water NH4 (mg N/L)	pore water Si (mg/L)	Pore Water NO3 (mg N/L)	Pore Water NO2NO3 (mg N/L)	Pore Water Al (µg/L)	Pore Water Ba (µg/L)	Pore Water Sr (µg/L)	Pore Water Ag (µg/L)	Pore Water As (µg/L)	Pore Water Cd (µg/L)	Pore Water Co (µg/L)	Pore Water Cr (µg/L)	Pore Water Cu (µg/L)	Pore Water Ga (µg/L)	Pore Water Ni (µg/L)	Pore Water Pb (µg/L)	Pore Water Rb (µg/L)	Pore Water Se (µg/L)	Pore Water Zn (µg/L)	Sediment Water content (%)	Sediment organic (% LOI)	Sediment carbonate (% LOI)	Sediment inorganic (% LOI)	Sediment Fine organics (%)	Sediment Coarse organics (%)	Sediment Fine inorganics (%)	Sediment Coarse inorganics (%)	Sediment fine organics (g/g dry)	Sediment coarse organics (g/g dry)	Sediment fine inorganics (g/g dry)	Sediment coarse inorganics (g/g dry)	Sediment Total S (mg/g)	Sediment AVS (µg/g)	Sediment Ca (µg/g)	Sediment Mg (µg/g)	Sediment Fe (µg/g)
11.35	27.8	31.05	12.65	0.42	9.86	7906	458	0.23	1.35	0.1		0.02	0.02	44.92	31.19	122.45	0.06	0.82	0.03	0.47	0.56		6.47	2.1	0.04	0.57		25.55	78.4	39.5	5.1	55.4	88	13	54	47	0.348	0.024	0.327	0.284	2.88	27.3	9363	1955	5627
4.67	60.2	51.2	14.4	1.96	5.16	8630	1690	1.1	8.25	5.3	40.2		< 0.05					1.4		1.07		<10					<1	18.5	87.6	59.6	3.3	37.15	94	6	49	52	0.560	0.017	0.198	0.210	3.4	200	12689	1909	12470
13.15	52.2	36.1	13.1	0.75	4.34	16837	1166	1.15	3.94	1.89		0.03	0.03	127.81	30.65	119.32	0.03	1.01	0.03	0.5	0.75		6.33	0.97	0.02	2.76		275.29	81.1	42.3	5.2	52.5									3.15	16.9	11157	2445	4302
13.15	52.2	36.1	13.1	0.75	4.34	16837	1166	1.15	3.94	1.89		0.03	0.03	127.81	30.65	119.32	0.03	1.01	0.03	0.5	0.75		6.33	0.97	0.02	2.76		275.29	76.4	33.3	5.3	61.4									2.37	8.9	8227	2105	3706
13.15	52.2	36.1	13.1	0.75	4.34	16837	1166	1.15	3.94	1.89		0.03	0.03	127.81	30.65	119.32	0.03	1.01	0.03	0.5	0.75		6.33	0.97	0.02	2.76		275.29	81.4	40.5	5.3	54.2									3.43	27.9	10812	2472	4641
41.4	18.7	98.1	26.1	5.61	24.5	986	1370	2.48	18.05	18	58.4		< 0.05					<1		<1		<10					<1	<10	76.7	15.2	5.9	78.9	79	20	44	56	0.120	0.033	0.373	0.475	5.26	1380	9993	947	2159
13.6	35.4	83.6	12.7	1.77	8.25	28500	1630	1.18	4.45	3.4	35.9		< 0.05					15.6		<1		48.7					<1	12.6	74.8	25.8	2.1	72.17	92	7	47	53	0.237	0.011	0.349	0.394	0.98	260	9335	720	14736
																													77.9	32.3	3.2	64.5	90	10	29	71	0.291	0.023	0.196	0.481	2.61	254.2	9912	747	37965
4	22.3	120	40.9	9.16	10.9	13400	692	0.81	3.75	3.2	58.8		< 0.05					5.36		0.56		1.21					<1	9.68	69.2	8.1	8	83.92	39	61	26	74	0.032	0.059	0.239	0.680	0.69	98.8	25565	3258	2641
2.46	16.4	67	21	2.45	6.32	9160	268	0.63	2.85	1.8	26.2		< 0.05					27.7		<.5		1.86					<1	11.3	25.4	1.8	3.9	94.32	58	42	26	74	0.010	0.029	0.255	0.727		8.44	7786	1975	1349
1.32	14.6	78.1	23.1	< 0.5	1.61	6750	543	< 0.010	1.01	0.1	28.2		< 0.05					5.94		<1		<10					<1	<10	52.8	3.1	8	88.89	70	30	15	85	0.022	0.068	0.145	0.824	0.28	70	27441	3022	2112
1.2	14.5	83	25.8	< 0.5	2.54	8920	700	0.08	1.25	0.18	45.7		< 0.05					9.01		<.5		3.16					<1	15.5	27.1	1.4	5.5	93.06	28	72	25	75	0.004	0.041	0.246	0.739	0.31	25	18526	3530	1795
																													48.4	3.7	10.3	86.1	87	13	17	84	0.032	0.087	0.164	0.810	0.38	17.3	31262	2646	1298
																													95.8	63.4	12.4	24.3	87	13	48	51	0.552	0.063	0.176	0.187	2.13	24.5	51864	3513	7479
1.2	17.4	120	34	2.95	2.31	1480	883	0.13	5.35	4.6	56.8		< 0.05					1.76		0.55		1.02					<1	11	94.1	39.3	39.9	20.86	75	25	28	72	0.295	0.287	0.170	0.437	3.33	160	148678	4672	2018
																													93.4	40.9	31.5	27.6									2.02	97	116074	4302	1689
1.49	24	66	17.3	5.11	2.95	1520	609	0.6	4.05	3	19.9		< 0.05					1		<.5		0.59					<1	12.7	93.6	79.2	3.4	17.45	72	28	38	62	0.570	0.021	0.079	0.129	12.13	39.5	11641	2180	3579
0.27	25.9	126	31.9	< 0.5	0.9	3970	1350	0.5	3.65	2.5	54.5		< 0.05					<1		<1		<10					<1	10.7	92.7	50.3	17.5	32.21	55	45	47	53	0.277	0.093	0.234	0.263	8.6	110	64690	4222	3069
2.58	27.3	120	38.4	1.82	1.03	3280	1660	0.27	3.47	2	49.5		0.07					<1		0.7		1.49					<1	20.6	90.5	50.5	15.7	33.82	78	22	25	75	0.394	0.118	0.124	0.371	8.38	190	57080	3950	4447
4.73	29.4	87.2	60.2	8.53	6.03	50	332	2.33	8.45	12	60.7		< 0.05					1.3		<1		<10					<1	<10	83.2	24.6	10	65.46	77	23	84	16	0.189	0.016	0.634	0.121	10.49	390	26185	9926	1967
0.38	24.2	89.7	27.6	4.06	4.23	3070	1180	0.02	1.65	0.14	71.3		< 0.05					1.09		<1		<10					<1	<10	87.9	30.1	9.1	60.74	75	25	92	8	0.226	0.007	0.643	0.056	2.48	120	22354	10351	3527
																													62.2	9.5	7.2	83.3	75	25	28	71	0.071	0.051	0.253	0.643	1.41	31.5	15537	8455	1608
																													92.5	74.3	3.1	22.58	62	38	52	48	0.461	0.015	0.134	0.123	3.18		14158	2167	1776
																													89.6	66.3	3.9	29.8	89	10	47	53	0.590	0.021	0.158	0.179	4.32	23.2	15358	2261	2675
4.67	52.9	37.8	8.22	< 0.5	4.52	18500	1490	0.71	8.15	8.4	28.2		< 0.05					2.09		<1		<10					<1	15.4	91.7	54.5	6	39.55	79	20	68	32	0.431	0.019	0.310	0.146	5.47	210	6909	923	13650
0.53	43.2	27	8.38	0.55	3.11	12400	1590	0.52	3.45	2.1	19		< 0.05					4.44		<1		<10					<1	16.9	89.2	48.5	5.7	45.76	94	6	20	81	0.456	0.046	0.103	0.417	4.68	700	9364	1650	14387
4.91	28.4	26.69	11.12	0.33	2.32	16585	1306	0.1	2.06	0.83		0.02	0.02	54	33.47	102.94	0.03	3.33	0.01	0.27	0.92		6.87	0.96	0.03	0.76		18.2	90.7	37.4	8.8	53.8	98	2	75	25	0.367	0.022	0.470	0.157	3.47	133.3	8626	1558	9685
3.19	31.7	85.6	22.2	5.69	7.93	6830	788	1.08	10.05	6.6	62.5		< 0.05					9.14		<1		<10					<1	15.5	87.1	42.9	1.5	55.61	70	30	36	63	0.300	0.009	0.206	0.360	2.68	80	9332	1162	7065
																													91.5	78.6	3.1	18.4	90	21	39	61	0.707	0.019	0.084	0.131	3.24	7.2	15424	1700	5331
17	23.1	55.5	101	25.1	13.4	86	662	1.06	9.35	17	54.7		< 0.05					2		<1		<10					<1	<10	61.5	8.9	7.6	83.56	91	9	80	20	0.081	0.015	0.729	0.182	2.82	520	20863	7171	2948
1.56	15.8	102	23.6	4.32	15.8	15900	1120	0.08	2.45	1.7	59.4		< 0.05					1.73		3.9		<10					<1	<10	84.8	19.6	42.6	37.81	92	9	94	6	0.180	0.026	0.756	0.048	1.53	260	160013	7755	6334
																													79.3	20.8	39.4	39.9	73	27	50	50	0.152	0.197	0.397	0.397	1.93	120.5	146602	7765	8480
																													88	14.3	77.1	8.7	91	10	84	16	0.130	0.123	0.721	0.137	1.66	55.4	297257	6997	1355
0.56	17.6	123	23.3	0.87	2.37	7520	2030	0.27	7.75	6.9	64.1		< 0.05					1.87		<1		<10					<1	<10	62.7	6.4	8.2	85.44	75	25	14	86	0.048	0.071	0.131	0.805	0.76	170	20557	1317	1496
																													85.9	11.3	72.7	16.1	94	7	45	55	0.106	0.400	0.400	0.488	0.11	90.3	271804	7093	1650
1.88	29.8	81	17.8	2.24	4.21	887	956	1.52	11.05	10	60.2		< 0.05					3.99		<1		<10					<1	<10	94	63	5.2	31.83	80	18	82	18	0.504	0.009	0.304	0.067	7.48	80	18812	1945	2527
																													93	64.3	6.1	29.6	83	17	34	65	0.534	0.040	0.121	0.232	7.54	54.4	19343	1891	3813
0.33	44.8	156	53.5	7.99	11.9	4560	1770	0.54	6.45	4.4	73.9		< 0.05					1.9		1.82		<10					<1	<10	69.9	13.3	45.6	41.08	86	13	87	13	0.114	0.059	0.754	0.113	2.38	860	184942	11752	4477
3.54	24.9	52	9.79	2.51	3.49	38400	1010	0.77	4.05	3	33.5		< 0.05					33.5		<.5		2.12					<1	19.5	93.7	62.9	11.6	25.55	71	29	33	67	0.447	0.078	0.123	0.249	4.38	587	10409	1222	48287
9.5	25.5	36.73	7.8	0.6	1.99	28823	964	0.02	1.16	0.08		0.04	0.04	57.92	21.32	66.65	0.05	4.27	0.09	0.28	0.52		4.04	1.13	0.06	0.54		137.46	96	65.4	6.2	28.5									4.33	93.7	10634	1317	50389
2.74	40.3	84.1	15.3	1.29	2.14	84600	1750	0.32	7.25	0.16	46.4		< 0.05					24.2		<5		<50					<5	<50	94.6	60.9	5	34.11	87	13	71	30	0.530	0.015	0.278	0.117	2.55	190	10602	1284	83421
2	23.5	32	6.34	< 0.5	1.65	22900	562	0.08	0.29	0.06	29.6		< 0.05					15.3		<.5		2.11					<1	15.2	95.1	65.6	6.6	27.86	74	26	37	63	0.485	0.042	0.128	0.217	8.73	272	8601	1019	44704
2.72	27.2	44	8.87	< 0.5	1.33	35500	742	0.04	1.15	0.11	42.8		< 0.05					14.4		<.5		1.62					<1	9.14	94.9	66.4	6.6	27.07	76	24	27	73	0.505	0.048	0.091	0.246	3.63	181	9222	1354	65261
3.95	15.5	89.4	35.4	2.78	7.33	937	471	0.06	1.65	0.15	52.2		< 0.05					<1		<1		<10					<1	25.7	83.6	22.5	5.1	72.35	91	9	92	8	0.205	0.004	0.713	0.062	11.75	2120	21507	3730	10903
8.94	6.7	94.3	22.7	1.14	9.82	5870	1350	0.2	1.25	0.92	31		< 0.05					3.9		<1		<10					<1	<10	82.2	16.5	11.1	72.46	74	26	39	62	0.122	0.069	0.326	0.518	45.38	9170	57702	1401	18746
10.3	5.5	83	20	2.18	9.96	4540	1540	0.1	0.89	0.41	32.1		< 0.05					3.84		<.5		0.56					<1	9.26	86.1	21.8	8.2	69.98	63	37	32	68	0.137	0.056	0.250	0.532	29.5	8270	52668	1458	16540
0.19	41.3	51	12.7	< 0.5	< 0.5	18700	2270	0.15	1.65	0.12	33.6		< 0.05					8.25		0.89		0.72					<1	9.74	93	54.2	7.9	37.92	76	24	40	60	0.412	0.047	0.183	0.275	10.75	194	9536	1319	12151
8.57	12.1	101	26.8	1.08	1.94	2780	796	1.09	9.85	9.9	56.9		< 0.05					1.51		<1		<10					<1	<10	65.6	7.7	26.2	66.06	82	18	44	56	0.063	0.147	0.406	0.517	1.02	1300	103637	4389	3969
8.81	11.7	111	28.6	5.97	3.51	4080	950	0.19	1.15	0.16	40.4		< 0.05					1.66		<1		<10					<1	11.2	76.7	13.3	33.6	53.19	84	16	38	62	0.112	0.208	0.330	0.538	1.93	1420	138865	3850	5143
5.61	99.8	129	59.3	14.1	4.91	14800	650	0.32	2.75	< 0.5	40.9		< 0.05					2.24		<1		<10					<1	<10	42.5	5.4	10.3	84.32	69	30	2	99	0.037	0.102	0.019	0.937	0.82	150	20322	9184	2624
9.05	11.5	78.3	33.6	3.82	6.43	8760	2440	0.03	0.8	0.19	39.1		< 0.05					1.98		<1		<10					<1	<10	34.4	2.6	12.4	85.03	35	65	34	67	0.009	0.083	0.331	0.653	2.29	230	27366	6365	1833
11	24.5	97.8	63.4	10.6	13.9	189	813	0.47	16.05	9.33	75.9		< 0.05																91.8	50.3	9.2	40.58	86	14	56	44	0.433	0.040	0.279	0.219	11.4	226	35337	5090	1498
22.53	19	50.94	39.23	5.28	6.86	289	464	0.28	14.63	16.15		0	0	30.95	43.64	262.83	0.03	0.64	0.02	0.53	11.62		8.08	5.29	0.05	2.58		21.13	91	44.3	10.2	45.5	69	31	43	57	0.306	0.058	0.240	0.317	12.52	37.9	32123	5903	1485
22.18	22	33.14	26.04	2.93	5.06	193	253	0.45	11.36	10.59		0.02	0.02	34.14	36.92	178.73	0.03	0.56	0.01	0.32	5.83		6.81	2.79	0.04	1.63		80.37	92.1	39.2	10.2	50.7	68	32	51	50	0.267	0.051	0.311	0.305	9.37	106	33765	4860	2170
7.64	17.9	106	48.4	6.05	24.2	2330	531	0.19	8.45	8.6	73.7		< 0.05					<1		<1		<10					<1	<10	85	17.7	30.8	51.49	90	10	89	11	0.159	0.034	0.732	0.091	6.42	660	121780	8098	2216
6.41	17.6	81	53.2	7.31	12.8	< 10	311	0.62	9.95	8.6	60.4		< 0.05					1.01		0.93		1					<1	3.75	81	20.6	23.1	56.32	66	34	27	73	0.136	0.169	0.214	0.580	2.4	302	85011	7910	1741
24.2	15.8	87.3	30.8	6.49	8.16	< 10	610	0.38	8.15	9.2	65.7		< 0.05					1.37		<1		<10					<1	<10	90.3	25.2	38.1	36.66	96	4	75	25	0.242	0.095	0.561	0.187	6.59	240	157017	5598	2212
27.8	16.5					< 10	788	2.07	14.05	16	69.2		< 0.05					1.56		1.26		<10					<1	<10	92.5	30.9	29.3	39.85	96	4	96	3	0.297	0.009	0.664	0.021	8.12	310	117725	4940	1618
0.6	26.5	90.4	47.7	< 0.5	11.4	16600	14100	1.03	2.65	1.4	56		< 0.05					2.75		1.35		<10					<1	16.2	70	10.4	4.3	85.36	91	9	97	3	0.095	0.001	0.870	0.027	3.73	2420	8249	4225	13154
27.89	28.9	75.86	44.03	1.92	11.49	35586	16725	2.56	4.87	3.93		0.04	0.04	58.61	39.4	229.63	0.04	1.59	0.02	1.61	1.29		7.91	0.92	0.11	3.05		26.25	64.6	9.2	4.6	86.2	91	9	47	53	0.084	0.024	0.427	0.481	4.27	1596.6	7779	3953	12403
2.92	26.5	100	55.3	< 0.5	4.28	31400	16300	0.95	1.25	0.16	48.4		< 0.05					3.66		0.7		0.83					<1	6.35	66.9	9.4	4.1	86.47	74	26	34	66	0.070	0.027	0.308	0.598	2.78	3500	8495	3821	15436
25.44	22.1	44.3	25.08	1.77	9.12	13402	7511	1.8	6.03	5.68		0.03	0.03	36.23	64.17	131.52	0.03	0.77	0.02	0.53	0.58		13.82	0.7	0.05	1.83		27.92	85.8	17.7	6.8	75.6	78	21	77	23	0.138	0.016	0.634	0.190	7.81	4017.5	8223	3954	16139
7.64	19	95.2	27.6	3.68	10	3860	5170	2.5	8.15	8.2	64.7		< 0.05					<1		<1		<10					<1	<10	92.3	41.2	6.8	52	60	40	17	84	0.247	0.057	0.100	0.494	15.95	370	12166	2034	4821
6.49	21.9	88.7	29.5	5.4	9.93	3840	4820	3.16	10.05	13	74.5		< 0.05					<1		1.01		<10					<1	<10	92.6	43.9	6.7	49.41	81	20	88	12	0.356	0.008	0.494	0.067	11.93	390	11442	2058	5827
3.79	10.1	100	14.2	4.63	4.9	1870	2110	0.17	2.35	1.9	50.6		< 0.05					<1		<.5		0.58					<1	8.57	87.2	36.9	31.5	31.62	63	37	34	66	0.232	0.208	0.215	0.417	5.95	689	126758	3429	3889
1.17	32	91.4	17.2	4.98	5.96	20900	1120	0.04	1.04	0.25	49.5		< 0.05					<1		<1		<10					<1	12.2	85.3	27.6	5.4	67.07	84	16	90	10	0.232	0.005	0.652	0.072	9.93	2030	18812	2786	14936
5.46	18	117	17.3	3.61	6.39	9730	1190	0.14	1.65	1.1	49.4		< 0.05					<1		<1		<10					<1	<10	87.5	43.2	6.1	50.75	75	26	89	10	0.324	0.006	0.506	0.057	17.64	2360	14606	2150	8743
6.42	34.5	139	35.1	6.34	14.9	19100	4260	0.09	1.55	0.2	34.5		< 0.05					<1		1.19		<10					<1	11.6	59.2	12.3	2.5	85.14	76	24	51	49	0.093	0.012	0.447	0.429	9.13	530	4615	890	4213
9.93	10.4	59	12.5	2.77	6.82	6650	4400	0.02	0.65	0.07	33.3		< 0.05					1.76		<.5		0.51					<1	13	25.6	1.3	0.7	98.04	93	7	24	76	0.012	0.005	0.237	0.750	1.52	87.4	391	178	1136
13.7	14.7	69.6	26.4	4.44	11.7	6470	2290	0.26	1.65	1	22.7		< 0.05					1.5		<1		<10					<1	<10	24.1	1.1	0.7	98.24	82	17	13	87	0.009	0.006	0.129	0.861	1.23	60	1158	306	895
11.9	41.2	99	31.2	8.84	11	62900	1820	1.13	8.3	7.9	46.9		< 0.5					3.2		0.51		2.02					<1	6.31	63.2	8.6	7.4	84.01	65	35	28	72	0.056	0.053	0.256	0.658	1.52	3170	27396	826	19148
6.88	15.1	122	30.8	6.85	10.8	5300	2780	0.16	1.95	1	70.3		< 0.05					<1		<1		<10					<1	<10	89.5	29	5.5	65.48	52	48	97	3	0.151	0.002	0.689	0.021	44.34	2780	25410	2373	8048
3.57	12.4	97	27.8	2	11.8	763	1670	0.07	1.35	0.29	29.8		< 0.05					1		<.5		1.09					<1	4.44	51.6	5.4	2.7	91.96	60	40	24	76	0.032	0.021	0.227	0.719	5.61	559	10954	875	2347
2.1	22.2	69.9	19.8	3.22	4.88	3140	1430	0.02	1.05	0.18	40.7		< 0.05					<1		<1		<10					<1	<10	85.1	45.4	2	52.59	36	64	33	67	0.163	0.013	0.180	0.366	6.59	203	9245	1504	3559
1.75	17.3	44	17.3	5.81	6.35	542	1870	0.31	0.91	0.18	48		< 0.05					<1		<1		<10					<1	<10	86.5	30	6.1	63.89	84	16	56	45	0.252	0.027	0.392	0.315	28.19	1300	8764	2325	6297
10.1	15.3	133	34.6	8.68	11.4	18400	1650	2.62	15.05	15	53.4		< 0.05					<1		1.1		<10					<1	<10	84.2	21.3	13.1	65.65	65	34	76	23	0.138	0.030	0.599	0.181	6.12	4900	42060	2852	12535
12.8	14.7	110	29	3.6	9.86	12800	1140	1.93	8.65	9.4	55.8		< 0.05					<1		0.68		0.57					<1	3.23	85.8	27.9	8.6	63.49	58	42	33	67	0.162	0.058	0.238	0.483	14.24	5060	22613	2550	11992
3.61	13.7	74	27.7	2.71	6.64	31	776	0.01	1.35	0.12	35.5		< 0.05					<1		<.5		0.93					<1	5.16	94.3	61.9	9	29.09	73	27	39	61	0.452	0.055	0.149	0.232	34.62	510	13596	2459	5094
3.41	6.5	124	23.9	< 0.5	6.18	132	1830	< 0.010	0.49	0.19	36.5		< 0.05					<1		<1		<10					<1	<10	93.9	55.1	12.9	32.08	66	34	71	29	0.364	0.037	0.319	0.130	10.28	790	53905	2748	3035
4.36	18.7	74.7	15.7	3.14	5.66	2800	998	4.53	30.05	26	47.8		< 0.05					<1		<1		<10					<1	<10	93.5	51.1	5.9	43.02	74	26	42	57	0.378	0.034	0.205	0.279	7.82	144	12809	2907	3740
4.57	22.5	104	24.1	13.5	3.32	13600	1620	2.08	11.05	11	77.8		< 0.05					2.9		1.19		<10					<1	<10	90.3	23.7	21.9	54.4	97	3	23	77	0.230	0.169	0.175	0.588	1.9	360	96015	6576	9071
2.27	17.5	62.5	15.6	3.58	1.54	12700	2720	2.08	8.15	9	35.3		< 0.05					3		<1		<10					<1	<10	80.8	18.8	7.1	74.07	89	11	83	16	0.167	0.011	0.674	0.130	2.11	190	20459	7022	7586
13.01	14.1	59.2	20.16	1.25	3.77	13295	654	1.27	4.11	7.01		0.03	0.03	43.11	197.36	196.82	0.04	2.17	0.03	0.21	4.98		37.6	2.61	0.08	1.04		83.49	87.8	29.9	31.8	38.3	85	15	45	56	0.254	0.178	0.315	0.393	1.76	3962.7	126271	4751	46471
11.5	19	58.8	36.6	3.85	7.06	59	315	0.04	3.05	2	43.4		< 0.05					<1		<1		<10					<1	<10	91.3	35.2	28.3	36.48	70	30	59	41	0.246	0.116	0.382	0.266	9.83	1290	118737	5832	4953
14.6	19.2	130	52.2	< 0.5	2.33	2740	2020	0.12	2.65	1.7	62.3		< 0.05					<1		0.6		0.88					<1	11	92.8	50.2	13.8	35.95	68	32	31	69	0.341	0.095	0.154	0.343	0.36	1530	63482	4848	5436
14.9	28.1	130	55.9	2.09	3.99	6660	2990	0.8	10.05	8.6	64.3		< 0.05					1.01		1.46		0.98					<1	6.19	93.8	42.6	15	42.35	71	29	39	61	0.302	0.092	0.224	0.350	14.22	1690	59822	4551	5530
11.2	15.2	120	42.5	4.93	18.9	5760	1330	1.19	8.55	2	48.4		< 0.05					<1		0.54		0.62					<1	5.3	89.5	37.4	13.7	48.97	58	42	24	76	0.217	0.104	0.150	0.476	9.02	1290	49998	4050	6028
													< 0.05																																
3.57	23.7	128	40.8	0.99	2.46	4220	2420	0.02	2.05	0.09	69.8		< 0.05					2.16		<1		<10					<1	<10	84.1	19.7	54	26.28	88	12	68	33	0.173	0.178	0.546	0.265	2.75	630	201124	10216	3517
48.2	33.9	136	53.7	15.8	15.7	31800	3130	1.46	6.75	4.4	52.9		< 0.05					2.63		1.95		<10					<1	<10	65.3	7.1	9.5	83.42	83	17	41	59	0.059	0.056	0.381	0.548	0.71	590	55756	25745	7983
12.4	27.3	110	40.7	1.48	6.69	428	326	< 0.010	4.85	1.4	67.4		< 0.05					1.06		<1		<10					<1	<10	68.5	12.4	58.2	29.35	94	7	89	11	0.117	0.064	0.779	0.096	0.92	170	221357	10676	2157
32.22	22.8	49.36	17.85	2.79	3.86	123	269	0.28	11.78	15.84		0.02	0.02	23.94	62.17	126.44	0.04	0.71	0.02	0.33	0.34		11.8	3.21	0.04	1.62		10.86	85.3	18.1	47.6	34.3									0.37	230.4	168456	9489	1946
23.64	14.2	75.47	27.53	2.07	3.08	1581	341	0.51	10.15	11.83		0.02	0.02	32.86	122.74	203.03	0.03	0.71	0.02	0.77	0.53		24.38	0.68	0.04	1.5		47.2	81.4	15.2	42.7	42.1	76	24	42	58	0.116	0.248	0.356	0.492	0.49	249.9	164486	9672	2311
32.22	22.8	49.36	17.85	2.79	3.86	123	269	0.28	11.78	15.84		0.02	0.02	23.94	62.17	126.44	0.04	0.71	0.02	0.33	0.34		11.8	3.21	0.04	1.62		10.86	88.6	19.4	49.6	31.1									5.25	475.3	177054	9802	2193
32.22	22.8	49.36	17.85	2.79	3.86	123	269	0.28	11.78	15.84		0.02	0.02	23.94	62.17	126.44	0.04	0.71	0.02	0.33	0.34		11.8	3.21	0.04	1.62		10.86	82.8	15.6	45.2	39.2									4.8	253.5	153500	8966	1689
6.42	19.2	24.54	8.29	0.34	0.64	17831	913	0.02	0.96	0.11		0.03	0.03	86.36	45.65	94.72	0.05	1.43	0.02	0.28	0.95		9.13	1.25	0.09	0.21		34.67	67.4	13.4	2.8	83.9	92	7	46	53	0.123	0.015	0.399	0.460	1.27	11.3	2899	807	4252
34.2	26.5	58.5	113	21.9	105	1320	697	0.77	5.35	3.8	91.4		< 0.05					41.7		<1		<10					1.14	<10	27.2	4	12.7	83.27	89	11	40	59	0.036	0.075	0.384	0.566	1.4	430	28692	8698	3314
32.6	35.6	69.4	116	24.8	97.5	81	536	1.61	13.05	13	83.7		< 0.05					2.57		1.31		<10					1.43	<10	41.5	3.4	8.7	87.92	74	26	34	62	0.025	0.054	0.329	0.599	1.6	790	22964	6033	2719
34.16	28.5	64.17	134.38	26.68	92.01	638	1166	1.23	8.56	6.9		0.03	0.03	40.12	192	511.32	0.05	4.03	0.04	0.64	0.93		39.15	6.57	0.16	3.08		35.5	36.8	3.2	12.5	84.3	81	19	28	72	0.026	0.090	0.271	0.697	3.45	454.7	44183	16232	2814
14.8	13.1	84.9	30.4	9.16	5.27	270	1300	0.44	21.05	21	46.2		< 0.05					1.17		<1		<10					<1	<10	51.7	4.3	22	73.77	79	21	70	30	0.034	0.066	0.670	0.287	1.45	200	73744	4152	1257
11.1	11.4	110	28.4	6.84	10.7	5240	717	0.21	5.65	5.6	54.9		< 0.05					1.66		<.5		0.6					<1	6.87	36.1	2.9	12	85.08	23	77	26	74	0.007	0.089	0.252	0.718		529	31206	6440	1786
24.06	18	79.88	30.45	5.06	5.07	2971	1082	0.23	7.75	7.31		0.02	0.02	44.91	113.31	236.29	0.04	2.19	0.02	0.27	14.23		23.46	8.8	0.25	1.48		65.78					49	52	92	8					1.49	246.7	40683	5223	2159
8.28	24.8	95.8	18.5	3.44	6.24	34300	9550	3.23	16.05	11	71.3		< 0.05					6.18		<1		<10					<1	<10	88.6	31.7	6.6	61.66	81	19	58	43	0.257	0.028	0.396	0.294	5.55	2090	31785	1788	30642
4.25	16.8	113	31.2	4.03	3.65	18900	1510	0.66	8.05	8.1	68.7		< 0.05					4.28		<1		<10					<1	<10	89.5	36.2	34.5	29.35	85	15	74	26	0.308	0.090	0.472	0.166	3.59	670	134089	4137	21908
8.71	15.5	170	60.1	15.6	8.13	5380	800	1.22	7.45	7.1	75.6		< 0.05					1.52		1.21		<10					<1	<10	87.1	33.4	9.6	57.02	81	19	91	9	0.271	0.009	0.606	0.060	7.13	240	48663	4096	3108
2.91	10	67	22.5	2.53	2.63	1740	1030	0.15	5.25	4.8	50.1		< 0.05					<1		<1		<10					<1	<10	89.2	45.9	29.4	24.67	79	22	80	20	0.363	0.059	0.433	0.108	4.47	360	119303	4389	3937



												< 0.05																											
3.93	18.6	31	12.6	1.43	5.13	17100	1510	0.04	2.15	1.1	22.4	< 0.05		9.78		0.82		1.46	<1			6.21	60.4	12.4	2.5	85.05	44	56	25	75	0.055	0.019	0.219	0.657	1.68	768	1705	663	9491
4.36	9.8	34	14.5	1.14	5.23	5430	1320	0.04	0.74	0.15	28.7	< 0.05	<1			0.52	<.5		<1			6.98	39.9	4.8	1.7	93.53	62	38	25	75	0.030	0.013	0.238	0.714	1.36	487	1490	830	7671
6.23	20.8	27.4	15	0.91	5.69	29800	1090	0.06	2.85	2	37.6	< 0.05		2.94	<1		<10		<1		<10		79.1	16	3.8	80.16	66	33	70	29	0.106	0.011	0.588	0.243	3.91	3370	3776	1318	29463
4.3	15.2	41	16.7	1.51	6.56	12000	1820	0.09	1.25	0.69	33	< 0.05		8.56	<.5			0.55	<1			6.55	42	4.6	1.6	93.78	42	58	25	75	0.019	0.012	0.238	0.715	0.55	365	1329	712	10082
												< 0.05											38.1	5.1	1.6	93.26	25	75	31	69	0.013	0.011	0.294	0.655		200	1900	1802	4761
8.13	30.4	48	24.7	4.17	11.2	8860	2160	0.71	3.46	2.6	32	< 0.05		2.75	<.5			1.17	<1			12	37.6	4.6	1.8	93.56	56	44	32	68	0.026	0.012	0.305	0.648	0.27	270	2822	2329	5817
9.7	22.3	49	23.3	2.01	11.4	15000	2920	0.28	2.85	1.6	18.5	< 0.05		2.94	<.5			1.25	<1			6.21	32.7	4.3	1.6	94.13	28	72	26	74	0.012	0.012	0.249	0.708	0.69	143	1825	1633	4499
8.68	30	50	22.3	3.52	12.4	13900	3020	0.43	3.05	2	21.7	< 0.05		4.29		0.5		1.22	<1			12.5	37.5	4.6	2.2	93.25	51	49	26	74	0.023	0.016	0.248	0.706	0.43	220	2828	2270	6056
6.41	18.5	23	18.5	2.58	6.75	19200	2470	0.36	2.68	1.8	21.2	0.08		17.7	<.5			1.92	<1			21.2	68.1	17.7	5.4	76.92	56	44	30	70	0.099	0.038	0.247	0.576	3.52	4050	2829	1472	24784
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4.98	11.6	30	15.2	2.55	4.74	11300	1210	0.07	1.66	0.93	24.5	0.06		4.96		1.01		0.75	<1			10.4	47.9	7.4	2	90.67	50	50	26	74	0.037	0.015	0.241	0.686	0.67		1719	945	6291
3.85	28.3	37	34.3	2.36	6.21	18600	9320	0.37	1.75	0.86	38.4	< 0.05		10.9	<.5			0.75	<1			13.6	68.7	19.2	3.7	77.17									4.76	989	3552	1751	20512
15.6	20.1	53.4	19.4	2.74	11.1	4870	2600	4.11	2.35	1	50.2	< 0.05		24.6	<1		<10		<1			10.8	58.6	6	8.3	85.72	97	3	97	2	0.058	0.002	0.912	0.019	0.47	470	25738	4708	9187
18.1	12.7	68	19.8	3.4	9.43	10500	4890	1.74	2.25	1.6	44.4	< 0.05		7.94	<.5			1.07	<1			7.09	29.2	1.6	2	96.39	53	47	26	74	0.008	0.015	0.256	0.728	0.43	281	3217	848	4362
15.7	18.9	80.8	20.6	< 0.5	3.15	11800	7340	1.78	1.25	0.15	39.5	< 0.05		6.38	<1		<10		<1			16.6	26.6	1.2	1.9	96.91	94	6	37	63	0.011	0.012	0.366	0.623	0.26	250	8214	899	3674
25.1	15.4	96	26.1	3.01	12.5	13800	6010	1.42	1.35	0.54	42.9	< 0.05		3.76	<.5			0.95	<1			7.54	28.5	1.5	1.6	96.9	30	70	26	74	0.005	0.012	0.256	0.729	0.4	403	3555	861	3582
25.2	15.4	100	29	2.43	13.3	14200	5670	1.81	1.65	0.86	54.8	< 0.05		3.29	<.5			0.97	<1			6.93	25.7	1.3	1.3	97.43	42	58	25	75	0.005	0.010	0.247	0.740	0.38	286	2866	707	3330
14.4	12.8	46	13.7	4.64	9.83	4180	2400	1.14	3.05	2	29.2	< 0.05		4.21	<.5			1.07	<1			12	31.9	1.6	1.5	96.89	50	50	26	74	0.008	0.011	0.256	0.728	0.25	239	2285	678	3563
20.8	8.1	110	45.3	4.15	51.2	2790	2000	0.6	0.94	0.1	37.7	0.13		17	<.5			0.71	<1			4.84	12.5	2.1	9.1	88.76	85	15	24	76	0.018	0.069	0.235	0.744	0.2	79.2	17611	6711	4262
7.68	129	40.3	11.8	16.1	3.11	1600	529	5.62	11.05	5	16.8	< 0.05		5.85		1.23		10.7	<1			37.1	83.9	81.1	4.3	14.67	81	19	71	29	0.657	0.012	0.135	0.055	3.52	70	26495	3250	3284
21.6	118	363	106	16.2	7.63	2820	2330	4.43	8.95	1.6	56.9	< 0.05		35.1		3.09	<10			3.39	<10		79.4	59.3	7.7	33.01	92	7	74	27	0.546	0.021	0.301	0.110	8.17	300	34512	5578	4932
45.9	83.3	280	127	24.6	21.7	825	201	0.91	17.05	18	60.4	< 0.05		37.7		1.8		2.51		1.68		9.12	70.8	38.2	29.5	32.32	73	27	26	74	0.279	0.218	0.161	0.457	1.8	460	118726	7411	2779
19.8	86.5	320	141	9.22	15.9	2220	269	0.31	6.05	0.09	60.8	< 0.05		11.3		2.4		1.72		2.14		10.7	68.2	39.1	30.5	30.42	74	26	24	76	0.289	0.232	0.146	0.463	5.61	73.2	117167	7239	2842
30.8	90.4	203	89.3	21.4	19.3	1120	194	1.01	13.05	6.5	71.6	< 0.05		9.25		2.14	<10			2.08		12.3	68	35.3	35.4	29.27	95	5	83	17	0.335	0.060	0.537	0.110	3.17	210	149585	8132	3367
												< 0.05											45.5	26.5	29	44.52	68	32	26	74	0.180	0.215	0.191	0.544	2.69	73.1	120647	9487	3089
	68.8	267	76.5	11.8	10.4	1060	1410	0.91	4.65	0.46	44.3	< 0.05		66.5		4.7	<10			2.14	<10		46.9	16.1	5.3	78.6	96	4	58	42	0.155	0.022	0.487	0.352	1.99	50	14441	2759	3242
13.8	67.1	397	115	7.7	11.9	1650	2090	2.68	4.05	0.19	42.7	< 0.05		54		3.25	<10			1.79	<10		77.5	52.2	8.5	39.26	97	3	91	10	0.506	0.009	0.435	0.048	3.77	160	41101	5775	5647
18.5	73.4	260	55.7	11.8	11.5	2500	3840	0.48	6.45	2.8	32.4	< 0.05		25.3		2.95	<10			1.89		22.6	82.7	71.7	5.8	22.54	80	20	79	21	0.574	0.012	0.224	0.060	5.06	60	36269	2757	7874
45.2	92.7	310	86.1	29.2	15.2	1140	1310	1.67	11.05		50.1	< 0.05		83.3		3.09		7.92		1.75		25.5	67.6	43	7.4	49.61	72	28	22	78	0.310	0.058	0.125	0.445	6.1	98.8	28935	5493	4292
18.5	117	370	99.2	29.5	12.9	4300	1840	4.87	8.15	4.3	75	< 0.05		63.2		3.77		1.94		2.69		11.7	68.7	41.9	8.1	50.08	72	28	21	79	0.302	0.064	0.122	0.460	7.07	109	31227	6085	4673
		780	226	7.39	45.7	1590	2110					< 0.05		11.5		4.07		8.09		2.32		18	49.2	33.8	5.8	60.41	75	25	19	81	0.254	0.047	0.126	0.536	5.66	128	30953	8142	4221

Sediment Al (µg/g)	Sediment Mn (µg/g)	Sediment Zn (µg/g)	Sediment Ni (µg/g)	Sediment Cr (µg/g)	Sediment As (µg/g)	Sediment Cu (µg/g)	Sediment Total-P (mg P/g)	Sediment Exchangea ble-P (mg P/g)	Sediment NAI-P (mg P/g)	Sediment Apatite-P (mg P/g)	Sediment Org-P (mg P/g)	Sediment Total-N (mg/g)	Sediment TIC (%)	Sediment TOC (%)	Sediment Se (µg/g)
3026	226	39.46	12.47	1.91	1	10.16	0.846	0.01	0.084	0.052	0.701	17.2	0	20.1	
4477	691	86.25	13.52	5.58	3.08	11.96	1.37	0.04	0.21	0.07	1.06	24.8	0	32.34	1.37
3924	157	33.82	11.42	3.03	1.24	11.3	0.919	0.009	0.064	0.055	0.791	18.5	0.01	21.79	
3401	124	31.59	11.18	2.7	0.76	9.38	0.642	0.011	0.071	0.076	0.485	13.6	0.01	16.52	
3474	165	48.18	11.68	3.29	1.46	8.31	0.852	0.003	0.062	0.07	0.718	16.4	0	18.1	
500	177	26.91	1.49	0.97	0.84	3.74	0.57	0.05	0.1	0.16	0.27	8.1	0.26	7.98	0.34
2388	380	25.34	5.28	1.78	2.63	3.98	0.87	0.04	0.34	0.17	0.32	10.3	0	12.51	0.88
2383	634	67.07	9.41	2.36	11.3	5.87	1.49	0.012	1.199	0.226	0.053	14.65	0.14	16.51	
482	104	12.28	1.37	0.43	1.82	0.93	0.34	0.04	0.06	0.16	0.08	4.79	0.77	4.58	
304	32	3.4	0.54	0.24	0.44	0.85	0.34	0.04	0.05	0.15	0.1	0.75	0.22	1.13	
421	95	3.54	1.15	0.89	0.99	0.82	0.14	0.04	0.03	0.19	< 0.01	1.5	0.99	1.32	0.78
489	80	3.66	1.73	1.63	0.48	0.94	0.15	0.04	0.02	0.1	< 0.01	0.53	0.49	0.86	
203	93	5.41	0.76	0.55	1.04	0.68	0.204	0.009	0.017	0.119	0.059	1.9	1.19	1.76	
824	293	36.44	2.46	1.71	3.65	4.73	1.399	0.027	0.241	0.091	1.039	32.2	1.27	33.13	
778	511	19.63	2.44	0.7	2.05	4.3	0.97	0.11	0.17	0.12	0.57	18	4.65	14.8	
686	418	26.51	2.2	0.89	2.17	4.48	0.806	0.08	0.125	0.096	0.505	22.5	3.59	20.91	
711	371	34.85	3.05	0.09	2.25	4.6	0.96	0.07	0.1	0.06	0.72	29.33	0.01	39.84	
1293	455	31.49	3.38	1.41	2.12	5.27	1	0.07	0.08	0.14	0.71	25.4	1.73	27.48	0.99
1344	486	29.95	3.38	0.91	2.91	4.08	0.82	0.04	0.12	0.14	0.52	24.28	1.49	25.16	
1685	126	26.96	6.4	2.44	1.38	7.75	0.78	0.07	0.12	0.22	0.38	9.9	1.06	11.85	1.25
1711	268	41.48	4.29	2.8	1.53	7.96	0.75	0.04	0.07	0.2	0.44	15.1	0.9	16.01	1.61
611	118	15.18	2.47	1.47	0.71	3.57	0.406	0.008	0.026	0.188	0.184	3.8	0.79	5.08	
1321	45	42.08	2.66	1.31	0.86	7.87	0.16	0.05	0.06	0.06	< 0.01	30.2	0	36.87	1.08
2173	82	43.53	4	2.38	1.11	6.5	0.381	0.017	0.034	0.058	0.272	24.4	0	27.4	
2896	749	128.57	3.77	2.22	4.82	7.35	0.89	0.03	0.13	0	0.73	21.9	0	28.82	1.15
4637	688	166.54	6.8	3.05	7.03	11.43	1.19	0.04	0.28	0.09	0.78	17.2	0	22.4	1.15
3799	511	103.98	4.97	2	3.19	7.37	0.718	0.006	0.075	0.093	0.544	16.7	0	16.6	
1073	116	13.82	2.83	1.88	2.08	2.94	0.58	0.04	0.13	0.09	0.31	18	0	23.99	0.43
943	975	19.57	2.74	1.18	3.98	4.6	0.559	0.02	0.066	0.04	0.432	31.1	0.03	30.37	
2722	160	16.51	6.33	3.49	1.71	7.02	0.55	0.03	0.06	0.12	0.34	2.8	0.82	2.85	0.8
994	454	18.62	2.74	1.96	2.53	6.36	0.75	0.04	0.11	0.17	0.43	9	4.94	10.07	1.01
873	405	29.02	2.9	2.1	2.41	4.36	0.669	0.011	0.169	0.191	0.299	7.4	5.06	10.24	
276	1016	25.41	1.3	1.27	3.29	1.66	0.427	0.028	0.024	0.087	0.288	8.2	9.1	7.4	
595	140	6.49	1.18	1.32	0.82	1.51	0.13	0.03	0.18	0.15	< 0.01	1.8	0.66	2.23	0.46
291	1161	23.96	1.16	1.1	2.37	2.42	0.501	0.027	0.045	0.098	0.332	6.55	8.34	6.01	
663	480	35.68	2.37	0.71	2.61	3.97	0.76	0.1	0.11	0.04	0.51	32.1	0	33.3	0.94
725	1154	41.8	2.45	0.76	2.78	4.56	0.861	0.051	0.086	0.051	0.672	29.4	0.03	25.67	
1323	1198	21.66	4.36	2.3	4.08	4.47	0.75	0.07	0.12	0.3	0.26	6.2	5.6	7.08	1.08
1512	520	64.55	2.63	1.36	22.37	6.02	1.76	0.04	0.76	0.14	0.81	32.47	0.12	33.61	
2372	505	88.29	3.82	3.5	11.92	7.19	1.095	0.01	0.186	0.083	0.815	34.2	0.05	35.55	
2731	605	85.28	3.47	4.63	18.94	6.39	1.23	0.04	0.33	0.12	0.74	27	0	31.88	0.83
2115	380	77.75	3.22	2.26	14.83	6.02	1.22	0.05	0.27	0.09	0.8	31.69	0.05	33.18	
2788	507	92.6	3.1	4.01	19.28	6.63	1.12	0.05	0.31	0.13	0.63	29.87	0.06	33.36	
3703	288	66.43	12.3	7.79	2.77	22.13	0.81	0.04	0.12	0.27	0.37	11.1	0.43	11.79	1.42
844	11941	11.7	3.18	1.61	11.4	4.7	0.9	0.04	0.23	0.34	0.29	6.9	2.04	7.7	0.96
1046	10833	14.78	3.02	1.42	9.8	5.38	0.96	0.05	0.21	0.22	0.49	6.84	1.43	7.47	
4744	719	140	10.74	3.04	8.89	9.88	1.24	0.05	0.19	0.09	0.92	23.15	0	26.57	
1103	300	13.13	3.73	2.14	1.86	3.63	0.17	0.04	0.15	0.1	< 0.01	3.6	3.26	3.14	1.12
1856	476	21.22	3.57	2.72	2.61	4.78	0.38	0.04	0.1	0.08	0.16	7.2	4.08	7.86	0.86
671	160	9.2	2.55	1.9	1.08	1.96	0.15	0.04	0.05	0.15	< 0.01	1.6	1.3	1.77	0.58
656	149	6.42	1.87	1.59	0.64	1.4	0.15	0.03	0.03	0.24	< 0.01	1.3	1.59	0.83	0.43
1069	230	22.31	2.22	1.45	1.3	6.18	1.04	0.12	0.104	0.13	0.69	2.06	1.26	22.85	
1583	206	34.97	3.43	2.59	1.59	4.86	0.721	0.073	0.09	0.119	0.439	18.9	0.53	23.57	
1713	195	35.01	5.83	2.31	2.39	7.49	0.87	0.069	0.059	0.082	0.659	14.8	0.96	14.84	
863	617	18.01	2	1.28	2.94	3.31	0.8	0.09	0.16	0.2	0.35	9.6	3.85	9.09	1.04
1605	242	26.23	3.31	1.6	1.57	4.51	0.51	0.04	0.06	0.17	0.23	9.83	2.45	8.96	
2432	488	35.78	4.61	2.65	2.04	8.6	0.94	0.07	0.15	0.19	0.53	14.7	4.54	13.45	1.53
2088	406	34.81	3.76	1.96	1.98	7.8	1.03	0.15	0.09	0.2	0.6	18	3.09	16.71	1.23
5247	2148	69.84	10.27	12.16	2.1	10.46	0.73	0.04	0.24	0.31	0.14	5.8	0.3	5.79	1.19
4318	2080	61.51	10.32	11.02	2.03	10.62	0.584	0.005	0.108	0.294	0.177	3.7	0.15	4.36	
4903	2678	53.59	9.38	13.77	1.67	9.96	0.77	0.05	0.25	0.35	0.12	3.08	0.19	3.44	
4494	3815	72.97	10.95	10.8	3.22	12.88	0.816	0.006	0.123	0.198	0.489	7.1	0.29	7.69	
2291	938	45.3	5.7	3.5	2.37	16.11	1.04	0.03	0.31	0	0.7	18.6	0	22.53	1.29
2469	913	46.31	6.92	3.27	2.12	15.75	0.93	0.04	0.17	0.07	0.66	18.3	0	22.71	2.45
2371	845	37.94	6.61	1.62	1.43	10.06	0.48	0.04	0.07	0.06	0.3	9.01	2.94	12.12	
3820	311	66.67	9.37	9.14	2.46	17.99	0.75	0.04	0.1	0.15	0.46	9.8	0.42	14.43	1.33
2612	281	47.93	6.77	4.88	2.18	12.51	0.74	0.05	0.09	0.09	0.51	15	0	24.51	1.52
1648	215	21.6	3.72	3.81	0.87	4.64	0.37	0.04	0.05	0.11	0.17	3.3	0	6	0.87
631	75	11.59	1.38	1.19	0.2	1.06	0.15	0.05	0.02	0.12	< 0.01	0.89	0	1.19	
541	39	4.44	1.31	1.32	0.61	1.61	0.13	0.03	0.03	0	0.06	0.4	0.03	0.43	0.3
389	484	13.55	1.44	1.03	1.06	3.16	0.46	0.05	0.22	0.08	0.11	3.26	1.01	2.86	
2037	566	23.68	6.37	5.39	3.42	8.59	1.24	0.04	0.2	0.17	0.83	13.2	0.57	14.12	1.97
1009	208	6.5	2.1	1.56	0.74	1.19	0.36	0.05	0.11	0.29	< 0.01	2.71	0.29	2.42	
1513	470	21.44	3.89	2.19	0.62	4.95	0.61	0.03	0.06	0.27	0.24	14.8	0	21.45	0.95
3666	742	55.81	9.59	6.93	3.63	12.75	0.84	0.04	0.17	0.59	0.04	13.3	0	16.56	2.05
2327	241	256.16	6.65	4.73	10.51	25.69	0.87	0.04	0.26	0	0.57	9.9	1.21	15	0.8
2530	203	222.75	6.55	4.08	11.6	35.16	0.97	0.04	0.26	0.2	0.45	10.04	0.44	12.59	
2324	322	49.27	6.98	2.24	1.78	7.19	0.55	0.04	0.09	0.07	0.35	27.38	0.01	30.6	
3006	575	44.57	7.94	3.27	1.38	7.9	0.91	0.04	0.11	0.05	0.71	22	1.25	29.74	1.43
2441	222	41.38	5.77	4.17	2.38	10.15	0.8	0.07	0.12	0.1	0.51	22.3	0.11	26.12	1.03
3499	395	56.04	9.52	5.48	2.31	19.23	1.21	0.04	0.2	0.2	0.77	14	2.62	12.09	1.75
2864	480	32.65	7.7	3.87	1.33	15.5	0.85	0.04	0.15	0.24	0.42	8.5	0.68	8.68	1.67
877	3535	45.11	3.75	1.44	10.88	6.12	1.1	0.007	0.617	0.205	0.27	13.1	4.04	14.76	
2113	364	37.14	5.48	4	2.85	5.42	0.93	0.06	0.11	0.17	0.59	16.4	3.26	18.66	1.05
1620	603	32.93	2.7	1.27	1.94	4.26	1.05	0.05	0.17	0.11	0.73	0.38	1.56	26.42	
1495	732	50.95	2.49	0.79	1.8	3.56	0.87	0.11	0.25	0.15	0.35	21.61	1.6	22.1	
1433	526	30.22	2.91	1.21	1.79	4.78	0.98	0.04	0.17	0.13	0.64	17.33	1.37	19.44	
1099	1949	22.45	3.03	1.46	3.29	5.54	0.49	0.03	0.06	0.17	0.22	9.3	6.79	9.33	1.26
2250	504	140.89	7.41	3.57	2.76	6.9	0.72	0.04	0.15	0.21	0.31	2.7	1.04	3.01	1.3
867	336	11.28	3.4	1.44	1.95	3.48	0.36	0.04	0.04	0.14	0.14	5.1	7.2	5.61	0.53
723	438	28.08	2.41	1.89	1.63	5.15	0.525	0.036	0.041	0.168	0.281	7.5		13.8	
993	412	31.27	2.88	2.15	2.05	5.31	0.555	0.033	0.043	0.288	0.191	6.8	5.82	6.48	
627	518	28.55	2.75	1.88	2.3	5.66	0.588	0.036	0.071	0.145	0.338	8.7	6.48	8.1	
685	385	25.24	2.11	1.37	1.62	4.19	0.477	0.037	0.037	0.207	0.197	6.8		12.6	
2359	81	40.78	3.13	2.17	0.92	5.42	0.477	0.008	0.032	0.35	0.087	5	0	6.58	
1441	285	16.94	7.44	2.61	1.86	5.23	0.45	0.03	0.05	0.18	0.19	1.7	1.27	1.85	0.83
1495	177	16.34	4.6	2.38	1.31	3.29	0.57	0.06	0.07	0.25	0.18	1.2	0.95	1.66	0.74
1235	315	17.74	5.55	2.41	1.39	4.35	0.441	0.032	0.045	0.241	0.123	1.3	0.89	2.09	
587	346	10.15	1.73	1.2	0.78	1.2	0.44	0.03	0.03	0.32	0.06	2.2	2.47	2.34	0.6
732	130	18.13	2.53	2.06	0.79	1.29	0.25	0.04	0.05	0.22	< 0.01	0.99	1.03	1.35	
838	199	24.97	2.36	2.08	1.15	2.1	0.38	0.012	0.029	0.248	0.09	1.5		2.88	
2656	2637	93.21	7.67	5.18	7.17	9.68	2.18	0.04	1.39	0.16	0.59	14.4	0.61	17.32	1.07
1202	817	23.36	1.83	1.19	5.56	3.84	0.79	0.03	0.19	0	0.58	15.6	4.19	18.41	1.11
1389	177	26.9	2.92	1.53	3.6	5.73	0.53	0.03	0.08	0	0.42	14.8	1.07	17.37	0.59
907	1103	21.94	1.83	1.13	1.21	7	0.91	0.07	0.17	0.14	0.52	18.4	3.8	21.95	0.63

5831	865	108.88	11.72	5.13	2.12	20.06	1.31	0.04	0.25	0.08	0.94	17.2	0	22.05	1.82
938	995	17.96	2.07	1.11	2.68	5.08	1.15	0.11	0.18	0.1	0.77	15.8	5.2	13.62	0.85
824	160	34.28	2.59	1.44	0.93	2.98	0.49	0.03	0.04	0.28	0.14	2.3	0.94	3.1	0.49
1410	418	29.48	3.06	0.96	2.15	4.56	0.82	0.04	0.11	0.12	0.54	14.05	0.69	16.52	
1572	421	38.73	4.41	1.86	3.08	6.35	1.03	0.04	0.13	0.12	0.75	19.1	0.7	24.65	
1394	536	40.58	3.38	1.06	2.84	5.21	1.14	0.1	0.24	0.12	0.68	26.12	0.52	30.88	
1387	398	20.99	2.98	1.38	0.95	2.25	0.99	0.07	0.13	0.37	0.42	16.29	1.41	19.66	
1577	522	30.34	3	1.62	1.72	12.05	1.7	0.07	0.19	0.17	1.27	21.1	3.25	20.15	1.34
2130	629	47.82	8.05	2.29	1.86	9.84	0.48	0.04	0.13	0.08	0.24	26	0	27.33	2.34
1008	194	10.29	4.14	2.4	0.82	3.31	0.2	0.03	0.04	0.27	< 0.01	0.4	0.7	1.21	1
2750	1259	55.07	12.37	4.42	1.32	13.38	1.22	0.05	0.16	0.09	0.92	20	0.18	21.67	2.71
5220	1248	63.41	19.48	4.08	3.52	20.25	0.83	0.05	0.15	0.03	0.6	15.4	0	31.2	2.01
5163	795	50.88	16.05	4.05	2.22	18.74	0.821	0.007	0.113	0.045	0.655	15.6	0.02	26.8	
3516	99	61.66	9.48	3.05	1.94	10.81	1.13	0.06	0.21	0.04	0.82	18	0.36	18.87	1.87
6367	148	58.35	12.48	6.81	1.95	18.14	0.88	0.03	0.18	0	0.66	10.1	0	17.19	0.94
4455	172	49.39	8.8	3.55	2.31	14.98	0.674	0.008	0.074	0.039	0.552	10.8	0	25.1	
2662	146	26.86	6.65	3.41	0.54	18.13	0.623	0.015	0.085	0.337	0.186	3	0	3.75	
4279	194	81.93	7.25	3.88	3.53	8.08	1.26	0.03	0.2	0	1.03	24.3	0	31.08	1.13
5386	1249	155.96	10.31	3.97	4.76	16.39	0.85	0.04	0.15	0.04	0.62	12.7	0	29.44	2.18
2048	2028	15.84	6.15	5.78	1.17	15.41	0.17	0.05	0.04	0.13	< 0.01	2.11	0.07	0.47	
2179	5950	23.31	9.17	6.88	1.76	13.57	0.36	0.04	0.07	0.15	0.1	1.6	0.3	1.89	1.18
4871	433	88.77	7.39	2.31	3.57	7.31	0.89	0.04	0.13	0.03	0.69	18.2	0	26.45	1.52
1844	84	41.11	2.93	5.62	1.98	1.99	0.39	0.05	0.16	0.11	0.07	10	0	11.67	
2965	430	57.51	5.26	3.05	4.37	5.02	0.32	0.04	0.12	0.09	0.07	11.78	0.06	20.46	
2684	201	48.33	2.07	3.23	2.91	3.36	0.55	0.04	0.19	0.13	0.19	12.63	0.05	15.43	
1882	106	33.81	2.78	4.03	2.2	2.27	0.47	0.05	0.16	0.17	0.09	8.03	0.03	8.23	
2700	200	42.89	4.49	5.53	2.62	5.64	0.32	0.05	0.2	0.08	< 0.01	19.31	-0.01	22.7	
3113	322	51.74	2.41	2.62	3	4.55	0.88	0.04	0.26	0.09	0.5	18.06	0.08	22.23	
2079	530	68.42	5.93	3.32	7.04	6.63	0.79	0.04	0.32	0.09	0.34	20.26	0.06	29.51	
2005	578	60.22	6.2	2.6	6.57	6.28	0.68	0.04	0.37	0.11	0.16	20.02	0.06	28.53	
2071	657	56.98	6.76	4.03	7.23	5.83	0.95	0.04	0.35	0.08	0.47	16.7	0	33.08	0.99
1828	373	50.4	6.05	3.05	5.9	5.54	0.55	0.04	0.21	0.07	0.22	21.21	0.03	32.28	
1140	64	10.55	1.82	3.39	0.21	5.22	0.34	0.04	0.03	0.14	0.12	1.25	0	1.48	
991	51	7.73	3.05	3.27	0.07	2.52	0.21	0.04	0.03	0.13	< 0.01	0.69	0.02	0.82	
2039	211	27.5	4.14	9.11	0.85	5.18	0.45	0.04	0.11	0.26	0.04	3.72	0.01	3.61	
1667	149	22.25	5.06	7.76	0.89	4.05	0.4	0.04	0.04	0.14	0.18	1.77	0.03	1.94	
3348	846	49.5	15.38	5.45	4.66	17.67	1.06	0.04	0.38	0.28	0.36	5.2	2.03	5.76	1.91
979	510	16.72	1.59	1.37	1.34	11.51	0.49	0.04	0.1	0.12	0.23	15.2	2.87	18.63	0.87
1015	742	19.53	3.22	1.72	1.49	4.49	0.62	0.1	0.13	0.25	0.14	18.22	5.09	14.83	
1506	659	24.25	3.48	1.66	1.42	4.75	0.69	0.06	0.1	0.18	0.36	14.4	4.61	15.03	1.24
694	58	7.19	1.56	2.04	0.27	5.45	0.13	0.03	0.03	0.12	< 0.01	1.2	0.15	1.1	0.46
1495	621	21.6	4.05	1.73	1.17	4.74	0.82	0.06	0.16	0.25	0.36	13.64	1.19	12.61	
1908	673	36.74	4.64	2.52	1.94	7.1	1.069	0.033	0.135	0.164	0.737	19.8	1.75	20.15	
939	259	11.5	2.14	1.51	0.58	2.96	0.66	0.04	0.08	0.2	0.32	8.9	0.86	9.77	0.72
1911	268	50.64	5.42	2.96	1.34	8.25	0.621	0.01	0.054	0.138	0.419	10.1	0.14	10.06	
1645	171	23.12	3.72	1.99	0.96	4.54	0.44	0.05	0.06	0.17	0.17	7.56	0.03	7.59	
947	123	14.33	2.33	1.5	0.88	3.74	0.47	0.03	0.04	0.2	0.21	4.4	0.13	4.79	1.03
2679	299	43.91	5.9	3.18	1.79	9.95	1.01	0.09	0.09	0.15	0.69	18.6	1.51	19.07	1.19
523	1224	6.5	2.55	1.38	5.48	4.15	0.33	0.04	0.11	0.16	0.02		1.42	0.75	1.34
418	874	4.13	1.15	0.98	1.17	2.13	0.35	0.04	0.03	0.09	0.19	5.3	8.72	5.94	1.01
382	841	3.2	0.96	0.7	1.15	1.71	0.29	0.04	0.03	0.07	0.15	4.2	9.05	4.81	1.07
581	576	9.85	1.89	1.26	1.37	2.22	0.39	0.04	0.02	0.09	0.24	4.5	6.07	6.02	0.52
1144	528	23.4	4.92	3.81	2.01	6.96	0.455	0.016	0.057	0.153	0.229	3.6	3.19	4.46	
646	163	9.27	3.01	2.13	1.02	3.27	0.294	0.011	0.029	0.126	0.128	1.2	1.2	1.75	
876	412	20.19	3.48	2.77	1.68	5.38	0.424	0.021	0.04	0.124	0.238	3.8	3.42	5.11	
664	342	18.71	2.58	2.1	1.35	3.42	0.511	0.018	0.027	0.12	0.346	4.4	3.53	8.37	
4502	1672	41.15	12.5	7.31	3.99	13.57	1.05	0.04	0.6	0.14	0.27	3.9	1.25	4.57	2.14
2726	1292	34.78	11.06	4.55	3.01	12.47	0.97	0.016	0.5	0.124	0.329	3.9	0.88	4.24	
2740	1394	34.93	10.36	4.8	2.77	12.88	0.839	0.012	0.456	0.14	0.231	3.6	1.12	4.05	
2533	626	29.31	8.89	4.46	0.81	6.71	0.44	0.04	0.13	0.1	0.16	1.36	0.2	1.41	
3190	829	32.04	10.85	5.89	1.78	9.31	0.39	0.04	0.15	0.13	0.08	1.4	0.2	1.55	1.35
2462	513	22.61	7.82	4.87	0.95	6.35	0.29	0.04	0.09	0.12	0.05	1	0.1	1.16	1.05
2402	478	48.17	8.48	2.8	2.47	12.29	0.95	0.05	0.14	0.06	0.71	29.9	0.2	28.07	1.03
2693	520	50.91	10.38	4.06	2.33	11.62	0.731	0.01	0.1	0.111	0.509	14.4	0.14	14.06	
1947	512	42.16	10.83	3.06	1.83	10.41	0.787	0.006	0.094	0.146	0.542	13.2	0.31	13.39	
1830	705	34.58	4.11	2.61	1.7	4.67	0.71	0.03	0.07	0.12	0.5	18.1	1.8	20.81	1.08
2425	269	37.18	9.2	3.23	1.63	26.83	0.75	0.03	0.15	0.07	0.49	13.8	0.1	13.63	1.49
827	77	10.32	3.19	1.53	0.3	2.68	0.16	0.04	0.05	0.11	< 0.01	0.4	0.29	1.53	0.95
1384	1328	38.1	2.42	1.43	1.83	4.67	0.79	0.03	0.1	0	0.66	28.3	2.03	30.76	0.86
2291	1252	26.09	7.64	3.86	2.54	8.56	1.01	0.06	0.22	0.25	0.48	7.9	2.84	8.76	1.28
3708	214	62.56	8.55	6.31	1.75	10.54	0.77	0.04	0.24	0.23	0.26	3.3	0.08	4.83	1.45
556	338	8.6	2.55	1.54	1.81	1.77	0.36	0.04	0.1	0.2	0.02	0.6	1.8	1.27	0.71
768	378	11.21	2.53	1.5	1.36	2.66	0.43	0.04	0.07	0.3	0.01	1.59	1.74	2.68	
944	456	12.28	3.49	4.71	1.96	2.97	0.54	0.04	0.11	0.27	0.12	1.79	0.58	3.33	
619	309	11.83	1.92	1.05	1.43	1.94	0.31	0.04	0.04	0.25	< 0.01	1.76	0.42	1.82	
3721	838	73.34	7.65	7.54	3.15	7.97	0.78	0.008	0.219	0.143	0.41	9.4	0.01	17.49	
1880	188	33.49	3.94	4.23	1.17	3.98	0.51	0.04	0.09	0.24	0.15	5.6	0	9.68	0.83
1143	2250	38.01	4.09	1.91	6.16	5.07	0.93	0.04	0.15	0.16	0.59	13.6	3.34	22.17	0.98
1227	2301	57.9	5.19	1.5	4.72	7.28	1.12	0.05	0.28	0.16	0.64	20.08	2.45	24.58	
780	152	10.75	2.03	2.37	0.44	1.36	0.24	0.04	0.03	0.12	0.05	0.7	0	0.65	0.36
1174	240	28.77	2.69	1.89	1.54	3.64	0.5	0.04	0.05	0.14	0.27	11.4	0	14.42	0.9
1496	254	23.07	4.53	2.08	2.4	5.16	0.61	0.04	0.09	0.24	0.24	6.7	0.57	10.88	0.9
2883	1089	57.43	10.52	4.99	5.09	44.91	1	0.05	0.21	0.26	0.48	7.52	0.12	8.98	
1880	246	19.92	4.45	4.13	1.19	9.64	0.51	0.03	0.16	0.29	0.02	1	0.04	1.2	0.9
2005	720	40.29	8.32	4.71	3.12	22.65	0.667	0.009	0.084	0.338	0.237	4.9	0.65	6.07	
4470	730	79.66	11.11	11.26	2.28	9.21	0.567	0.011	0.107	0.276	0.173	7	0	10.9	
3007	360	51.6	6.43	6.11	1.67	3.6	0.46	0.04	0.06	0.23	0.14	2.8	0	4.72	0.78
9042	382	62.78	19.48	16.66	1.84	28.96	0.75	0.04	0.15	0.3	0.26	2.8	0.27	3.66	2.34
427	46	4.92	1.11	1.17	0.44	0.69	0.28	0.017	0.022	0.312	< 0.01	0.1	0	0.1	
539	431	27.41	1.42	0.63	2.46	2.96	0.66	0.031	0.041	0.182	0.406	18.1	4.64	17.76	
2101	434	33.45	5.99	4.33	2.21	6.6	0.77	0.04	0.12	0.38	0.23	6.9	0.92	9.08	1.53
1738	507	30.33	4.65	3.57	1.85	4.89	0.6	0.04	0.08	0.29	0.18	4.28	0.25	5.76	
1758	561	27.19	6.15	4.67	2.04	6.47	0.728	0.01	0.08	0.402	0.235	5.2	1.01	6.43	
554	249	17.21	2.49	1.17	1.84	2.87	0.476	0.032	0.034	0.196	0.214	8.5	4.44	6.76	
697	441	7.24	2.45	1.94	1.48	1.49	0.29	0.04	0.13	0.1	0.02	3.9	0.66	4.35	0.69
780	192	11.72	2.79	1.54	1.52	3	0.44	0.03	0.08	0.27	0.07	1.9	0.35	2.85	0.74
4706	683	57.46	14.01	12.1	2.49	17.68	0.85	0.05	0.18	0.4	0.23	3.1	1.07	3.88	1.33
3000	387	26.8	8.35	5.82	1.41	12.75	0.6	0.04	0.06	0.43	0.07	0.9	0.24	1.73	1.42
1218	498	15.22	3.38	2.27	0.86	4.9	0.37	0.04	0.05	0.18	0.11	3.6	0.09	4.53	0.69
4124	601	65.91	12.87	2.02	1.71	9.37	0.659	0.012	0.085	0.077	0.485	15.8	0	30.4	
5529	522	89.47	16.15	5.19	2.33	10.96	0.94	0.04	0.13	0.07	0.69	15	0	27.16	1.35
4309	957	76.69	10.83	9.67	2.55	13.16	0.88	0.04	0.16	0.27	0.4	0.8		10.51	1.7
1544	179	42.51	2.85	1.85	2.79	5.45	0.59	0.03	0.05	0.09	0.42	20.9	0	24.34	0.97
2073	3512	53.77	6.88	4.23	7.85	4.4	0.44	0.04	0.1	0.3	0.01	1.72	0.13	2.2	
2458	1863	45.72	6.47	4.22	4.32	3.89	0.34	0.05	0.05	0.21	0.04	1.85	0.11	2.91	
2267	13954	66.38	8.96	4.45	10.41	8.76	0.72	0.05	0.23	0.3	0.15	3.7	0.32	4.22	
2671	7104	79.07	9.26	5.07	9.18	6.45	0.51	0.04	0.13	0.26	0.08	2.78	0.11	3.42	
2550	485	51.81	6.82	4.98	2.77	5.11	0.42	0.04	0.03	0.25	0.09	1.28	0	1.84	
912	109	9.96	2.68	1.93	0.64	1.86	0.25	0.04	0.04	0.05	0.12	0.5	0.19	0.41	0.43
2516	490	24.33	7.04	4.99	1.39	6.31	0.39	0.04	0.1	0.13	0.11	1.09	0.13	1.43	
885	102	9.11	2.47	1.41	0.47	1.52	0.18	0.04	0.04	0.1	< 0.01	0.42	0.13	0.4	
706	68	7.51	2.09	1.59	0.27	1.56	0.12	0.04	0.04	0.1	< 0.01	0.37	0.11	0.62	
3058	532	41.98	11.15	3.41	1.17	10.29	0.4	0.05	0.08	0.27	0.01	2.91	0	2.5	
2110	322	37.28	9.07	2.75	1.65	9.99	0.398	0.017	0.072	0.224	0.085	1	0	1.44	

3827	250	56.76	9.87	3.04	2.69	14.67	0.42	0.04	0.16	0.32	< 0.01	2.39	0	3.94	
3535	308	44.4	11.89	2.93	0.91	9.36	0.41	0.04	0.07	0.34	< 0.01	1.11	0	1.79	
6594	1366	109.53	27.33	6.45	6.54	33.48	0.7	0.04	0.36	0.22	0.08	3.7	0.09	5.87	1.34
3263	552	47.42	11.01	3.45	1.8	10.51	0.36	0.04	0.08	0.22	0.02	1.11	-0.01	1.68	
2771	116	39.91	7.59	4.73	0.61	8.86	0.46	0.04	0.05	0.36	0.01	0.89	0.01	1.4	
3242	168	38.42	8.43	6.45	0.85	10.51	0.47	0.04	0.05	0.37	< 0.01	0.97	0	1.55	
2378	134	30.53	6.8	4.04	0.85	7.2	0.36	0.04	0.13	0.31	< 0.01	0.77	0.01	1.26	
2806	263	33.04	6.71	5.17	1.3	10.74	0.48	0.04	0.07	0.35	0.02	1.13	0.05	1.68	
5542	1238	105.19	20.31	5.79	6.34	30.58	0.69	0.05	0.24	0.32	0.08	4.43	0	6.27	
5066	11250	91.15	46.15	5.93	8.58	29.21	0.68	0.04	0.19	0.25	0.2	4.73	0.15	8.19	
3426	174	39.18	8.9	4.3	1.9	12.13	0.48	0.04	0.07	0.24	0.12	1.77	-0.01	2.6	
4537	4748	83.96	29	5.8	6.01	24.13	0.62	0.05	0.15	0.28	0.14	4.89	0.11	8.34	
3445	591	39.45	9.4	7.27	2.02	10.4	0.71	0.03	0.29	0.15	0.24	2.2	0.9	2.29	1.62
1260	218	13.07	3.78	2.85	0.73	3.01	0.28	0.04	0.1	0.11	0.02	0.63	0.42	0.25	
1061	200	13.65	3.95	3	0.63	2.7	0.33	0.04	0.05	0.07	0.17	0.4	0.23	0.22	0.75
1144	133	11.85	3.87	2.5	0.62	2.76	0.28	0.05	0.07	0.1	0.06	0.49	0.4	0.11	
1090	134	12.37	3.5	2.49	0.38	2.93	0.24	0.05	0.07	0.12	< 0.01	0.37	0.06	0.33	
980	170	12.63	2.94	1.84	0.35	3.25	0.27	0.04	0.11	0.14	< 0.01	0.63	0.04	0.67	
1243	850	23.05	5.74	0.78	4.58	1.98	0.86	0.04	0.17	0.77	< 0.01	0.36	0.27	1.52	
2059	384	43.02	2.48	0.41	0.67	2.45	0.34	0.03	0.06	0.01	0.24	18.5	0	44.21	0.53
1814	389	31.44	7.58	2.16	3.42	6.15	0.76	0.08	0.26	0.11	0.31	23.6	0.56	31.82	0.87
1315	223	21.99	2.64	1.08	1.95	6.82	0.66	0.07	0.09	0.19	0.31	17.09	3.47	17.1	
1222	218	21.33	3.2	1.31	2.38	6.57	0.54	0.06	0.06	0.17	0.24	17.25	3.39	18.37	
1568	264	24.28	4.72	1.99	2.41	5.33	0.65	0.1	0.09	0.16	0.3	16.3	4.04	19.01	0.43
1548	273	23.62	3.9	1.65	2.13	6.22	0.65	0.05	0.07	0.22	0.31	12.11	3.3	12.46	
2407	106	10.79	11.54	5.72	2.8	6.57	0.45	0.03	0.04	0.1	0.28	7.6	0.33	9.75	1.07
2561	381	17.46	11.93	2.86	4.36	11.79	0.84	0.05	0.1	0.11	0.58	20.7	0.68	28.09	0.81
2467	1106	35.44	8.61	0.92	2.64	5.91	1.11	0.04	0.21	0.04	0.83	19.6	0	37.88	0.84
1763	235	13.86	7.25	1.94	4.06	9.86	0.53	0.07	0.11	0.17	0.17	18.72	0.16	22.33	
1932	249	13.92	8.26	2.13	3.52	9.84	0.75	0.06	0.1	0.18	0.41	16.19	0.34	19.28	
1938	222	14.69	7.12	1.86	3.37	8.79	0.9	0.04	0.09	0.23	0.54	12.38	0.23	14.94	

Field Comments
"dense, harvested stand"
pH probe would not stabilize after 10 minutes, in a 3x rinsed Nalgene water sample bottle, pH stabilized after 30 sec and recorded value. Paddled to two small bays north of boat launch, no wild rice, went to main body of water by boat launch.
"dense rice, 100% harvested"
"dense rice, 100% harvested"
"dense rice, 100% harvested"
Airboat airport at lake. Very flocculent water sample because the lake was so choked with coontail. Routine.
NA
Took cores & completed plant survey with 2 canoes strapped together
None
Photos taken on Amanda's phone.
The rhizon for the sulfide bottle was leaking for the first few minutes of sipping but then Sean fixed it and it was bubble free. We measured pore water pH using the Quanta because the Hach meter was broken. We calibrated the pH probe on the Quanta before we took a measurement. We accessed the site from a National Wildlife Refuge laun
Water became so shallow ~150m from 2011 core location (and main body of rice bed) that we had to paddle the MPCA boat to reach the rice. Sandy sediment led to some lost water in cores during on shore processing. Pore water pH was taken in extra core and some water had been lost.

much of the vegetation looks like rice from afar but is not - bulrushes
Lots of rice, hardly any visible open water; sediment unconsolidated, sediment water interface doesn't really exist; most coring attempts came out with loose mixed sediment swirling throughout, even with pushing the corer in

NA
accessed lake via Jim Ziegler's property. he has mowed a trail out to access the lake. cores consisted of ~ 20 cm of organic plant material with very high water content. fine sand sediment starting around 30 cm.
pH probe reads very high. Begins ~ 11.00 and falls, stabilizing multiple times at high pHs. I took readings until I got same pH 3 times in a row. Water samples very flocculent due to plant mat near water surface.

repeat sampling event from last year's rice bed, no repository core taken this year.
spent a lot of time looking for rice
Difficulty coring due to woody debris from other emergent plants, tried to move boat after only getting 2 cores. Lots of algae - tough to avoid when sampling water. We cored the same "bed" as last year's crew but, it was really shallow for rice and we could not positively identify any wild rice on this lake. Lots of stuff looked like rice, some was
Few wild rice plants mixed with dense emergent vegetation

NA

NA

covered with rice at medium density. Tons of lily pads
Very sandy near shore where beds of cattails and bulrush are. Could not core here, so we cored in bed of submerged sago pondweed. Water sampling bottles forgotten on shore. Returned to core site and water samples taken ~ canoe length north of core site.

NA
Deep water
Sippers drew down sediment a lot. Air was probably introduced into sulfide vial. Moved a boat length for seventh and repository core.
sparse rice-mixed
lake is low this year. Last year's core area is too shallow tried to core what we thought is the same bed. Very warm water at coring spot.
Clumpy rice patches over whole lake, thicker on south side, lots of coontail, lake bottom extremely soft
Water was extremely clear in lack, sample pulled plant material into nalgene bottles causing lower t-tube values than expected.
Sediment was very unconsolidated and gassy, so we collected cores by dropping corer gently into sediment. We didn't collect a repository core because the sediment was too unconsolidated. After several futile attempts, were only able to calibrate Hach 1 to pH 4. It did not recognize pH 7, but the readings seemed reasonable for the pH 7 and p
Abundant wild rice! Water deeper than usual, used piston coring method.
Tried pushing corer way down with paddle and could not get cores. dropped corer without pushing and voilà! cores! Very loose/unconsolidated. Repository core would probably become Zorbitrol soup, so no repository sample was taken. No open water near dock so tools and equipment were washed with drinking water.
Strong iron smell present. Composite cores were 5 cm short of our goal of 30 cm. Composite cores were: 10 cm, 7 cm, and 8 cm.
NA

Thermal stick at 1.1 m at water surface. pH probe had some trouble calibrating at pH 7.0 today. Sediment smells like sulfur. Some air got into the sulfide bottle, septum was very slow to close.

Met 2 ricers at boat launch. Met another man at boat launch (duck hunter) who said he hasn't seen ducks out when he normally would have and that the outlet on the w side of the lake used to be dammed but isn't now.
Ran out of Rhizon tubing so we re-used those from the first Mill Pond site. Shook out old water and stored in cooler between sites. Couldn't get one Rhizon to unscrew at bottom (large opening just above filter), so it wasn't sealed there with Teflon tape. Did NOT use this sipper for sulfide. Noticed an air bubble in the sulfide sipper (inside bottle
pH meter still isn't stabilizing well during water sampling. Easy coring. Had to be careful not to push too hard. One core was a bit sandy at depth, but not the others. Secchi disk nearly disappeared at 100 cm.
No pore pH taken--hardly any water in cores and very sandy. One of the composite sediment cores had dewatered significantly by the time we got to it. Only 2 sippers produced samples--sulfide & one other ~50 mL bottle. Sandy sediment just didn't have much pore fluid. The 2 other cores were muddier. Revisited this location (~2 boat lengths
pH reading would not stabilize, even after 20 min in water (no problems with calibration at 7.0 & 4.0). Came back to shore, processed samples & re-calibrated hydrolab, this time at pH 10.0, also. Went back out for water pH measurement in rice bed. Still did not finish stabilizing but there was very little drift in the reading. Temp was also taken a
Water sample coordinates: 46.07703, -95.72967, waypoint 042. Gas in sediment smelled like sulfur.
sparse rice along reedy shoreline
1 rice plant along dense reedy shoreline
High water content in sediment.
NA
Talked to a local at launch who said that rice had been planted in the lake during previous years. Also said water level is up because of dam. We saw two MPCA monitoring stations. Sediment and water smelled like asphalt.
Zinc acetate added 7/26/12. Samples were out of freezer for 3.5 hours to thaw and add zinc acetate.
Zinc acetate added 7/26/12. Samples were out of freezer for 3.5 hours to thaw and add zinc acetate.
No cores taken for processing. Site treated as recon.
NA
Water clarity varies; no rice
Took photos of beaver dams on W, N, and E sides of lake (in that order).
near Hay Creek inlet
Kevin Menken, from Barr Engineering joined us to help us access the site with an ATV.
we are just SE of Hay Creek

Used Hach 13- Quanta not working.
One rhizon connection (glued) snapped during assembly. First sulfide sipper appeared to be letting in air. Two sulfide samples taken from two separate cores. First sulfide bottle- 107.23, second sulfide bottle- 107.36.
Some cores smell like vomit. Variable coring substrate, iron oxide sandy clay, peaty material.

used Hach 13 b/c quanta froze up

Some parts of the lake were so clayey that we couldn't get cores. Tried 5 locations before we found a muddier spot where we could push the corer in.
H2S smell very strong. Top 3-5 cm of sediment is organic, and the rest in medium grained sand with shells and pebbles.

Landowners say lots of dust from mine tracks blows into the lake.

Water and sediment smells like iron and hydrogen sulfide.
We forgot the hula hoop, so we used two paddles and the side of a boat to form a plant ring "triangle." There is a strip of tape in one of the paddles that has a .5 m long piece of duct tape on it.
sulfate supper pulled a lot of gas, but we think it was all from within the core (cores stunk of hydrogen sulfide)

Many shells in sediment. All sippers lost air pressure. This may mean that a connection on the Rhizons isn't airtight. We put Teflon tape on both ends of the flexible connection tubes & had this problem. One outrigger foam didn't fit (too big) so we could only float on one side. AVS subsample didn't freeze overnight. Low on dry ice. **Rhizon prc
Lots of sediment in water column at core site. Can't see any submergent plants there other than those that have floated to the surface. Saw during watercolor test that there are tons of green spicular things in the water.

Stopped and probed ~10 sites with denser rice but water was too deep and we couldn't get cores. Accidentally left a drive rod in at the third spot, so we had to core with one drive rod and 1 outrigger, which caused the canoe to rotate over the corer a few times. :(

Sediment very soft and unconsolidated so coring was difficult. Used new Hach for pore water pH.
Membrane came off the Hydrolab DO sensor. Replaced onshore before we launched.
Unable to core in most lily stands due to large layer of unconsolidated sediment. Water depth also an issue. Tried coring 6 different sites. Consolidated sed was too deep to push corer into.
Second repository core taken because sediment-water interface was disturbed on first core (19.3 cm total length, 13.7 cm sediment length). Low lake levels made it necessary to use waders to load canoe through muck. Used 3rd sipper core for pH. One Rhizon snapped when I was reassembling it & then it sucked a lot of air (tossed it).
one ring stand base broke in the truck. Big drop from shore to water (difficulty > 2 for access). Farming on hillside. Possible outlet at S end of site near hwy, deputy in area did not know, suggested it might be clogged. Flocculent water sample. Pebble layer may be from when they needed to blast sed out through the culvert about a year ago bec
8/3/2012 - JS added photos to transfers.
NA
NA
NA
NA
NA
rice is mostly absent of seed
Drive rod went into the drink as we were coring. This boat sits too high! Had to get out and fetch drive rod, then moved two boat lengths NW after first 2 cores. Sitting atop a boulder field so we often set the corer down on rock and had to re-try nearby.
Same "bed" where we took water samples earlier this week, and where 2011 team sampled. Tough to get under cores with this MPCA boat because its profile is so high.
no lilies, no rice
No rice at 2011 core site. Eurasian water milfoil present according to sign at boat launch.
Sandy sediment a little tricky to core and extrude. Hard to ID pondweed. Plant ring 4 photo not taken.
wild rice at SW part of lake
very gassy sediment
Access very difficult; what appears to be a small trail through cattails near culvert quickly becomes dense. We had to exit canoe to pull through vegetation. We cored in a small pool between dense cattail/Phragmites stands. We forgot repository core polycarbonate at car, no repository core. One seal was cracked. N tank ran out while cores wer
Waypoint 24 for cores. No repository core or 8th "back-up" core. Thunderclouds rolled in. Needed to get off lake. One composite core was 0.5 cm short. Bent propellor a bit when we drove too close to shore. Suburban got stuck in sand on boat ramp. May be possible to put a canoe in from the road nearer to core site instead of motoring across
Multiple cores lost due to loose sediment. Moved ~2 boat lengths over to shallower water. Seems that it is necessary to core deep enough to penetrate a grayish clay layer that helps act as a plug. Retook orientation photos, secchi depths, and plant rings.

Shotgun shell found deep in core used for sipping. Massive dragonfly hatch taking place during sampling.

Took 15 min to get pH probe to stabilize.

Moved to different location for cores due to subsurface objects, rocks and logs. Kept thermal stick in place. Went back to sub for iPad since camera died.
variable stand of wild rice
surface water has reddish color. rain fell heavily during shore processing, but we managed to mostly keep the cores covered.
tea stained water air may have been introduced into sulfide bottle.
dense rice, tough coring due to lots of dead trees in all shallow areas
rice beside shore is mixed in with cattails
Unloaded on side of highway, re-parked at gravel road on south side of lake. 2x4s on trail to lake, not possible to access lake without them.
Very hard plant mat- difficult to core through. Some air was introduced into sulfide bottle when I pulled the needle. I think we misidentified the milfoil last year as Eurasian, but it is actually northern milfoil.
NA
Past Coordinates: 47.53339, -92.29790

NA
NA
lake is surrounded by a sphagnum bog, dense and spongy.

Used Hch 13- Quanta not working.

Used Hach 13

Sediment was extremely gassy at this site.
Went smoothly. No peepers at this site yet. Plants seemed pretty behind- lillies were not even out yet. Ran out of dry ice, and picked up some in Grand Rapids. AVS sample was chilled on block ice, but remained unfrozen for ~ 2 hours.
thermal stick submerged to 65cm. Top two sensor buttons out of the water.

Because we didn't have the correct size glass jars for AVS, we used Ziploc glass containers with plastic lids.
Porewater started to leak out of two cores during compositing
iPad used for field photos. surface water pH never truly stabilized. sulfide bottle weight was not readable on bottle.

toured entire lake by canoe, and did not observe any rice growing along shoreline, inlet or outlet.
Boat moved forward drifting 1 m while coring. 8/3/2012 - JS uploaded photos t
For composite mud sample, one core had sand stuck in piston, could not move on extruder pas 2.5 cm; measured to 10 cm depth from top, scooped appropriate level with spatula. Edges of lake dominated by cattails and reed canary; cornfield to SE; most of lake bottom covered with pondweed spp. Extruding cores was difficult due to high sar
large blooms of algae covering nearly entire lake
Man duck hunting at site, 11 stalks of wild rice
rhizons soaked in non q&c container. sediment was coarse organics with fine silt particles and sand/gravel.
Sparse wild rice, but evident on the S,SE edge of lake, easily visible from road

Water surface not covered by WR is covered by algae. Lake is eutrophic and dark green in color. Forgot to take pore water pH, so we went back out and got another core at same location.
Zinc acetate added 7/26/12. Samples were out of freezer for 3.5 hours to thaw and add zinc acetate.
pore water pH not possible from composite cores due to water draining out during the trip back to shore. We pulled pore water pH from a sipped core. Paddled 30 min one-way into Danvers WMA, did not see any rice, turned around, cored under tree for shade since entire ditch had same channel bottom everywhere (sandy and shallow), very
rice patches along east and west shorelines. rice growing in separate stands, some dense.

It helps to use 3 drive rods with the boat. Took some extra photos for plant ID (chara & Eurasian water milfoil). Water level much lower than LY.
cabins, houses, private tennis courts with lighting
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cabins, houses, private tennis courts with lighting
I believe we forgot to label these samples as AIS. Our outboard was easily fouled by extremely dense vegetation, and navigating the site was very difficult. Zinc acetate added 7/26/12. Samples were out of freezer for 3.5 hours to thaw and add zinc acetate.
HUGE rice plants
duplicate: wild rice present

dead bird head in water
NA
Water very deep in original core site; took three cores and couldn't pull any more. Moved a canoe length over to finsih coring. Gas in cores smells like sulfur.
Lots of algae/particulate matter in water. Eurasian water milfoil present according to DNR 2012 Fishing Regulations guide.
Lake is full of shoreline vegetation. Water is heavily colored green by phytoplankton. Blue-green algae present as well.

surveyed south western arm of Louisa, where DNR map showed emergent vegetation. extensive and varied aquatic plants, but no rice visible.
RHIZONS SOAKED IN UN-QC'D MILLI-Q WATER. First location with GPS coordinates for 4 cores, moved to two locations, one upstream of original location, and one downstream of original location by one boat length. Channel bottom extremely soft and used up locations around boat to retrieve core.
very coarse sand layers, pebbles greater than 3cm diameter. Difficulty inserting rhizons because of coarse sand layer.
Sediment notes: 0-10 cm: fine brown silt 10-15 cm: abrupt transition to very coarse, gray sand below 15 cm: coarse sand and gravel with 1-3 cm pebbles Not very much vegetation in river, most of the growth was on the southern bank.

Camera battery died during plant ring photos. Sean used his cellphone camera to take pictures. Sediment was very sandy with pea sized gravel mixed in.
super thick mats at sediment surface
water very shallow

Using new Hach for the first time. Photos taken with Amanda's phone.
The conductivity was lower than desired thus no samples were taken from the lake

We used thermal stick C. Curly leaf pondweed present in Mississippi, according to sign on shore. Repository core collected, but length is unknown.
AIS curly leaf pondweed difficult coring--very sandy, slow sippers Rhizons had been soaking since yesterday afternoon in Milli-Q because we expected to get a 2nd site but didn't.
dense stand of rice cattails and bulrush near shore
shallow, no submergent plants, wide channel with rice on both sides

camera battery died. used my own camera. some shallow areas around the mouth of the bay--must be careful not to run the motor aground. sippers are painfully slow left them overnight to drip. tea stained water marked as AIS because Superior has invasives
NA
All cores dewatered by the time we got to shore. Tried plugging with 2nd piston, but that created a gap of air that moved up, mixing the core. Did not sip cores because this would not be a representative pore water sample. Couldn't push up cores on extruder for composite. Treated site as Recon--only processed water samples.
shallow water, steep banks about 2 m high
Wild rice so thick we couldn't push into it, hence, our survey numbers are low, most abundant site on this trip.
This site should be done prior to Cohasset #4 because #4 has an invasive species (curly leaf pondweed). Marked these samples as AIS also.
Sulfide vial weight is smudged and hard to read. A sign on shore says curly leaf pondweed, and aquatic invasive species, is present in the Mississippi.
small dense stand of rice, near stand of cattails
Wild rice very ripe, easily fell off stalk, very tall, 4-5 feet above water.
sandy sediments led to slow sipping. sippers were bringing up a lot of bubbles, and the 70 ml sipper would not finish.n
AIS zebra mussels

it rained while we were processing samples
Moved downstream 2 canoe lengths for final 5 cores and 2 plant rings. Very narrow (~1m) area on E side of creek that is rice habitat. Can only core on this shallow side, other (W)side is much deeper w/hard sediment and no rice.
Large outer bend of river, had to go upstream a ways from landing do that water was shallow enough for good cores

What we disregarded as water celery during our last visit (May 30, 2013) turned out to be wild rice. This observation was made after, Amanda, Nate and I pulled a few specimens and found several to still be attached to the germinated seed.
pistons may contain some red clay from upper panasa (FS-382) but will only be in lower part of core. should not make it into bulk sediment.

coring was not possible at first site. Water was too deep, and clay was too thick. we moved further up river and deeper into the rice bed. coring coordinates 43.57590, -91.23418 (w/n 500 ft of water sample).
Deep water at site made coring difficult. Sediment was mostly clay with some shells and woody debris.

2cm of sediment dropped to ground and was recovered during extruding. carp fisherman (commercial) predicted 80%reduction of rice this year based on current observations.

rocky (boulders), very flat, low flow rate

The very fibrous plant material at this location made it impossible to core at this site. a suggestion is to have serrated HTH tubes for this site. Also, we saw Nate from Duluth who was sampling at Second Creek and mentioned that water levels here had significantly risen in the past few weeks.
many dead plants from last year's season present, deep mats of plant matter on river bottom made coring difficult, had to core at the edge of stand. No repository core taken during this visit.
The pore water started to leak out while we were extruding the cores for compositing.

Hard paddle upstream to coring spot. Hach meter (pH probe) read but did not calibrate (new one has been ordered).
NA
N E S W boat photos were taken before the picture of the side ID data sheet.

partial tank of nitrogen we received from other field crew was empty. got water sipping for samples but no AVS or composited core sample. GPS finicky, couldn't store waypoint need to tape DO meter every ten cm intervals mike said he planted WR but we didn't see any.
coordinates 47.51398, -92.18950.

One core used for pore water sampling was extruded to 1 cm below sed surface, so pore water sample will be from 1-11 cm. Another core was too short, so some air may have been introduced. Sulfide vial is ok, though. We couldn't extrude one of the cores for compositing, so we siphoned off the surface water and scooped the top 10 cm out
DO values seem unusually high, but sensor looks fine. The boat moved a lot during coring because the drive rods were difficult to put in. Two of the cores used for compositing had pore water leaking out. The cores used for pore water sampling were not leaking.
Very windy on the river. We had difficulties getting our drive-rods into sediment deep enough to hold our position, and were forced to pull anchor, and swing the boat around so we had our bow facing windward.
Very coarse sand and gravel makes insterting pistons difficult. We were having problems with pore water leaking out, so we moved locations for get cores. Pore water leaked out during extrusion, and Rhizons wouldn't sip. We collected surface water and sed samples on 8/19. Came back on morning of 8/20 to collect pore water directly from a s
Took pH from a composite core. Each of us did a water color reading, then we averaged the 3 values. Used MilliQ as control. No repository core at this site. Calibrated pH only.
pore water pH taken with Quanta probe inserted into composite core.
Wind picked up while we were out, so we had to use the anchor to stay in place. The anchor dug into the sediment and disturbed the rice plants.
Water is shallow at a depth of 8 cm. We pushed the canoe in by walking behind it in waders.
Due to shallow water depth, we had to add water on most cores. Took water sample from another spot about 14m to South. Core 3 fell over; saved it but lost a bit (maybe ~2 mL). Used for composite. Core 5 too short. Core 6 was ~0.5 cm too short when extruded.
Paddy has been drained so the soil is dry without standing water. Ed sent an email on 8/16 with instructions of how to sample dry paddies, so we referred to that. for the pore water, we dug an 8 cm hole to remove the dry topsoil. Then, we covered the hole with plastic wrap, inserted Rhizon, and let sip for 1.5 hours. We didn't get the desired a
VERY hard sediment. Wind blew our canoe sideways while we were working so our work area sprawled out a bit (front end swung northwards). Repositioned boat to get nose towards wind again.

Suburban had become stuck in the mud on a berm between paddies. Recent heavy rain had flooded the paddies and roads.
Black bear observed ambling across the rice paddy as we sampled on shore.

Paddy has been drained so the soil is dry without standing water. Ed sent an email on 8/16 with instructions of how to sample dry paddies, so we referred to that. for the pore water, we dug a 6-8 cm hole to remove the dry topsoil. then, we covered the hole with plastic wrap, inserted Rhizon, and let sip for 2 hours. We didn't get the desired am

Record notes	Quaternary_Geo_Major_Class	Geo_Abbrv	Ecoregion Level 3	County
	Des Moines Lobe	DML	NLF	Aitkin
	Des Moines Lobe	DML	NLF	Aitkin
The field site P-52 is associated with 3 different IDs in Sediment Table (P-52, P-54, P-68) because the site was duplicated at the same location AND three cores were not composited for the duplicate site. Labs ran the three cores separately instead of all together, like the other sites, to see the differences in sediment chemistry from cores collect	Des Moines Lobe	DML	NLF	Aitkin
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	Outwash	OUTW	NCHF	Anoka
no cores collected; no wild rice present	Outwash	OUTW	NCHF	Anoka
	Outwash	OUTW	NCHF	Anoka
Pore water and sediment duplicate data exists.	Outwash	OUTW	NCHF	Anoka
	Wadena Lobe	WADL	NLF	Becker
ch on the N end of the lake.	Wadena Lobe	WADL	NLF	Becker
	Wadena Lobe	WADL	NLF	Becker
	Wadena Lobe	WADL	NLF	Becker
pore water only collected for sulfide. Sediment and surface water duplicate data exists	Wadena Lobe	WADL	NLF	Becker
pore water only collected for sulfide	Outwash	OUTW	NLF	Becker
	Wadena Lobe	WADL	NCHF	Becker
pore water only collected for sulfide, sulfide data generated from TN sample, a result of changing sampling protocol (added a serum bottle at some point after visiting this site early in the season)	Wadena Lobe	WADL	NCHF	Becker
	Wadena Lobe	WADL	NCHF	Becker
	Wadena Lobe	WADL	NCHF	Becker
	Wadena Lobe	WADL	NCHF	Becker
	Des Moines Lobe	DML	NCHF	Becker
	Des Moines Lobe	DML	NLF	Beltrami
pore water only collected for sulfide	Des Moines Lobe	DML	NLF	Beltrami
sn't, some maybe?? Ed and Sean traveled back out to the site and could not locate any rice either. NO SIPPERS at this site.	Des Moines Lobe	DML	NLF	Beltrami
pore water only collected for sulfide	Des Moines Lobe	DML	NLF	Beltrami
	Peat	PEAT	NLF	Carlton
no cores collected; no wild rice present	Peat	PEAT	NLF	Carlton
	Outwash	OUTW	NLF	Carlton
Sediment duplicate data exists	Outwash	OUTW	NLF	Carlton
	Outwash	OUTW	NLF	Cass
pore water only collected for sulfide. Sediment duplicate data exists	Outwash	OUTW	NLF	Cass
	Des Moines Lobe	DML	RRV	Clay
	Outwash	OUTW	NLF	Clearwater
pore water only collected for sulfide	Outwash	OUTW	NLF	Clearwater
pore water only collected for sulfide	Outwash	OUTW	NLF	Clearwater
	Outwash	OUTW	NLF	Clearwater
pore water only collected for sulfide	Outwash	OUTW	NLF	Clearwater
	Peat	PEAT	NMW	Clearwater
pore water only collected for sulfide	Peat	PEAT	NMW	Clearwater
	Des Moines Lobe	DML	NCHF	Clearwater
›H 10 solutions so we decided to use the measurements.	Des Moines Lobe	DML	NLF	Crow Wing
visited the same GPS site twice; could not core the first time, came back with Griffith corer to do sediment sampling	Des Moines Lobe	DML	NLF	Crow Wing
	Des Moines Lobe	DML	NLF	Crow Wing
	Des Moines Lobe	DML	NLF	Crow Wing
Water too deep to core; only took a water sample	Des Moines Lobe	DML	NLF	Crow Wing
	Des Moines Lobe	DML	NLF	Crow Wing
	Des Moines Lobe	DML	NLF	Crow Wing
	Mine Pits And Dumps	MPAD	NLF	Crow Wing
	Mine Pits And Dumps	MPAD	NLF	Crow Wing
	Outwash	OUTW	NLF	Crow Wing
) just before I pulled the needle out. Not sure if the sipper began sucking air, but I think it was gas in the sediment.	Outwash	OUTW	NCHF	Douglas
	Outwash	OUTW	NCHF	Douglas
west) on 8/14/2012 to get 4 more cores for sippers & pore water pH.	Outwash	OUTW	NCHF	Douglas
at this time: 15:05.	Des Moines Lobe	DML	NCHF	Douglas
	Wadena Lobe	WADL	NCHF	Douglas
Surface water and sediment duplicate data exists.	Wadena Lobe	WADL	NCHF	Douglas
Surface water from 3rd surface water only site on Anka from same day. Sediment duplicate data exists	Wadena Lobe	WADL	NCHF	Douglas
	Wadena Lobe	WADL	NCHF	Douglas
no cores collected; no wild rice present. Surface water duplicate data exists	Wadena Lobe	WADL	NCHF	Douglas
	Wadena Lobe	WADL	NCHF	Douglas
	Des Moines Lobe	DML	WCBP	Freeborn
	Des Moines Lobe	DML	WCBP	Freeborn
This site was not cored, surface water samples only. Treated as recon site.	Des Moines Lobe	DML	WCBP	Freeborn
no cores collected; no wild rice present	Wadena Lobe	WADL	NCHF	Grant
Field crew only took observations at the lake on the first visit, no GPS coordinates, did take note of plants present on the lake.	Wadena Lobe	WADL	NCHF	Grant
	Rainy Lobe	RNYL	NLF	Itasca
Grain size duplicate data exists	Rainy Lobe	RNYL	NLF	Itasca
	Rainy Lobe	RNYL	NLF	Itasca
no surface water sample taken at P-46, assumed to be the same as P-45 from same day.	Rainy Lobe	RNYL	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
Combined with FS-140. Same site	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Rainy Lobe	RNYL	NLF	Itasca
	Rainy Lobe	RNYL	NLF	Itasca
	Sand and Gravel	SAG	NLF	Itasca
	Sand and Gravel	SAG	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
›blem means that sulfide vial probably contains air**	Wadena Lobe	WADL	NCHF	Kandiyohi
	Wadena Lobe	WADL	NCHF	Kandiyohi
	Outwash	OUTW	NCHF	Kandiyohi
	Outwash	OUTW	NCHF	Kandiyohi
	Outwash	OUTW	NCHF	Kandiyohi
	Outwash	OUTW	NCHF	Kandiyohi
	Outwash	OUTW	NCHF	Kandiyohi
No sediment sample, field crew unable to core this site	Wadena Lobe	WADL	NCHF	Kandiyohi
	Wadena Lobe	WADL	NCHF	Kandiyohi
ause fields on the south side flooded ~5 ft higher. Site also called "Haugen Slough"	Wadena Lobe	WADL	NCHF	Kandiyohi
	Des Moines Lobe	DML	NCHF	Kandiyohi
The field site P-57 is associated with two different IDs in Porewater Table (P-57, P-58) because pore water was duplicated at the same location. P-57 is associated with 4 different IDs in Sediment Table (P-57, P-58, P-59, P-60) because the site was duplicated at the same location AND three cores were not composited for the duplicate site. Labs r	Des Moines Lobe	DML	NCHF	Kandiyohi
The field site P-57 is associated with two different IDs in Porewater Table (P-57, P-58) because pore water was duplicated at the same location. P-57 is associated with 4 different IDs in Sediment Table (P-57, P-58, P-59, P-60) because the site was duplicated at the same location AND three cores were not composited for the duplicate site. Labs r	Des Moines Lobe	DML	NCHF	Kandiyohi
The field site P-57 is associated with two different IDs in Porewater Table (P-57, P-58) because pore water was duplicated at the same location. P-57 is associated with 4 different IDs in Sediment Table (P-57, P-58, P-59, P-60) because the site was duplicated at the same location AND three cores were not composited for the duplicate site. Labs r	Des Moines Lobe	DML	NCHF	Kandiyohi
The field site P-57 is associated with two different IDs in Porewater Table (P-57, P-58) because pore water was duplicated at the same location. P-57 is associated with 4 different IDs in Sediment Table (P-57, P-58, P-59, P-60) because the site was duplicated at the same location AND three cores were not composited for the duplicate site. Labs r	Des Moines Lobe	DML	NCHF	Kandiyohi
no cores collected; no wild rice present	Superior Lobe	SUPL	NLF	Lake
Sediment duplicate data exists	Superior Lobe	SUPL	NLF	Lake
	Des Moines Lobe	DML	WCBP	Lyon
	Des Moines Lobe	DML	WCBP	Lyon
	Des Moines Lobe	DML	WCBP	Lyon
	Outwash	OUTW	NCHF	Meeker
	Outwash	OUTW	NCHF	Meeker
Sediment duplicate data exists	Outwash	OUTW	NCHF	Meeker
	Outwash	OUTW	NCHF	Morrison
·e being composited, no N input for ~30 min. Regulator switched and glove bag flushed. Local said there is rice on Gourd Lake.	Outwash	OUTW	NCHF	Otter Tail
s from west end of lake.	Outwash	OUTW	NCHF	Otter Tail
	Outwash	OUTW	NCHF	Otter Tail

	Superior Lobe	SUPL	NLF	Pine
	Des Moines Lobe	DML	RRV	Polk
	Des Moines Lobe	DML	RRV	Polk
	Des Moines Lobe	DML	RRV	Polk
	Des Moines Lobe	DML	RRV	Polk
	Des Moines Lobe	DML	RRV	Polk
	Outwash	OUTW	NCHF	Pope
	Outwash	OUTW	NCHF	Pope
	Des Moines Lobe	DML	NCHF	Rice
	Des Moines Lobe	DML	NCHF	Rice
	Des Moines Lobe	DML	NCHF	Rice
	Rainy Lobe	RNYL	NLF	St. Louis
pore water only collected for sulfide. Sediment duplicate data exists.	Rainy Lobe	RNYL	NLF	St. Louis
	Rainy Lobe	RNYL	NLF	St. Louis
	Rainy Lobe	RNYL	NLF	St. Louis
pore water only collected for sulfide	Rainy Lobe	RNYL	NLF	St. Louis
Sediment duplicate data exists	Superior Lobe	SUPL	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Superior Lobe	SUPL	NLF	St. Louis
no cores collected; no wild rice present	Superior Lobe	SUPL	NLF	St. Louis
	Sand and Gravel	SAG	NLF	St. Louis
	Sand and Gravel	SAG	NLF	St. Louis
no cores collected; no wild rice present	Sand and Gravel	SAG	NLF	St. Louis
no cores collected; no wild rice present	Superior Lobe	SUPL	NLF	St. Louis
	Rainy Lobe	RNYL	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Peat	PEAT	NLF	St. Louis
	Outwash	OUTW	NLF	St. Louis
	Outwash	OUTW	NLF	St. Louis
	Outwash	OUTW	NLF	St. Louis
	Outwash	OUTW	NLF	St. Louis
	Alluvium	ALLU	NCHF	Scott
	Outwash	OUTW	NCHF	Sherburne
	Des Moines Lobe	DML	NCHF	Stearns
	Des Moines Lobe	DML	NCHF	Stearns
nd content. Sand prevented piston from moving up; entire polycarb was pushed up instead. One composite core had to be measured and scooped into beaker.	Des Moines Lobe	DML	NCHF	Stearns
	Des Moines Lobe	DML	NCHF	Stearns
	Des Moines Lobe	DML	NCHF	Stearns
	Des Moines Lobe	DML	NCHF	Stearns
	Des Moines Lobe	DML	NCHF	Stearns
	Des Moines Lobe	DML	NCHF	Stearns
	Des Moines Lobe	DML	NCHF	Stearns
	Des Moines Lobe	DML	WCBP	Steele
difficult to obtain cores and sand made the piston get stuck in polycarb. Cores lost water on way back to van, could not get pore water pH since sediment was too dry.	Sand and Gravel	SAG	NGP	Swift
	Outwash	OUTW	NCHF	Todd
	Outwash	OUTW	NCHF	Todd
	Rainy Lobe	RNYL	NCHF	Todd
The field site P-47 is associated with two different IDs in Porewater Table (P-47, P-48) because pore water was duplicated at the same location. P-47 is associated with 4 different IDs in Sediment Table (P-47, P-48, P-49, P-50) because the site was duplicated at the same location AND three cores were not composited for the duplicate site. Labs r	Rainy Lobe	RNYL	NCHF	Todd
The field site P-47 is associated with two different IDs in Porewater Table (P-47, P-48) and 4 different IDs in Sediment Table (P-47, P-48, P-49, P-50) because the site was duplicated at the same location AND three cores were not composited for the duplicate site. Labs ran sediment from the three cores separately instead of all together, like the	Rainy Lobe	RNYL	NCHF	Todd
The field site P-47 is associated with two different IDs in Porewater Table (P-47, P-48) and 4 different IDs in Sediment Table (P-47, P-48, P-49, P-50) because the site was duplicated at the same location AND three cores were not composited for the duplicate site. Labs ran sediment from the three cores separately instead of all together, like the	Rainy Lobe	RNYL	NCHF	Todd
The field site P-47 is associated with two different IDs in Porewater Table (P-47, P-48) and 4 different IDs in Sediment Table (P-47, P-48, P-49, P-50) because the site was duplicated at the same location AND three cores were not composited for the duplicate site. Labs ran sediment from the three cores separately instead of all together, like the	Rainy Lobe	RNYL	NCHF	Todd
	Alluvium	ALLU	DA	Wabasha
	Alluvium	ALLU	DA	Wabasha
wild rice present, took a duplicate sediment site (no water sample), but no pore water.	Alluvium	ALLU	DA	Wabasha
	Alluvium	ALLU	DA	Wabasha
	Alluvium	ALLU	DA	Wabasha
	Alluvium	ALLU	DA	Wabasha
	Des Moines Lobe	DML	NCHF	Waseca
Ran full site protocol at Lily on second visit (this one). Sediment duplicate data exists	Des Moines Lobe	DML	NCHF	Waseca
Could not core at original site as the water was too deep in the rice bed. Field, sediment data only (This note comes from unknown source, probably Chris Schodt). The likely scenario is P-62 is a field duplicate (surface water and sediment) of P-61. No coordinates exist for P-62, but it is assumed that samples were taken in generally the same sit	Des Moines Lobe	DML	NCHF	Waseca
	Des Moines Lobe	DML	NCHF	Wright
	Des Moines Lobe	DML	NCHF	Wright
	Des Moines Lobe	DML	NCHF	Wright
	Outwash	OUTW	NCHF	Wright
	Outwash	OUTW	NCHF	Wright
	Clay And Clayey Silt	CACS	NCHF	Pine
	Peat	PEAT	RRV	Pennington
	Peat	PEAT	RRV	Pennington
	Peat	PEAT	RRV	Pennington
	Peat	PEAT	RRV	Pennington
pore water only collected for sulfide	Outwash	OUTW	NLF	St. Louis
	Outwash	OUTW	NLF	St. Louis
	Peat	PEAT	NLF	Clearwater
	Peat	PEAT	NLF	Clearwater
sonde data only; did not meet conductivity threshold	Outwash	OUTW	NCHF	Otter Tail
	Rainy Lobe	RNYL	NLF	St. Louis
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Outwash	OUTW	NLF	Itasca
	Outwash	OUTW	NLF	Itasca
pore water only collected for sulfide	Outwash	OUTW	NLF	Itasca
pore water only collected for sulfide. Sediment duplicate data exists	Rainy Lobe	RNYL	NLF	St. Louis
	Rainy Lobe	RNYL	NLF	St. Louis
	Clay And Clayey Silt	CACS	NLF	Douglas, WI
no cores collected; no wild rice present	Clay And Clayey Silt	CACS	NLF	Douglas, WI
	Sand and Gravel	SAG	NLF	St. Louis
no pore water collected, sulfide data from in surface water TN sample	Sand and Gravel	SAG	NLF	St. Louis
pore water only collected for sulfide	Peat	PEAT	NLF	Clearwater
	Outwash	OUTW	NLF	Itasca
	Outwash	OUTW	NLF	Itasca
pore water only collected for sulfide	Outwash	OUTW	NLF	Itasca
pore water only collected for sulfide. Sediment duplicate data exists.	Peat	PEAT	NLF	Clearwater
	Outwash	OUTW	NCHF	Douglas
	Outwash	OUTW	NCHF	Douglas
	Outwash	OUTW	NLF	Crow Wing
	Clay And Clayey Silt	CACS	NLF	St. Louis
	Peat	PEAT	NMW	Itasca
pore water only collected for sulfide. Sediment duplicate data exists.	Rainy Lobe	RNYL	NLF	St. Louis
	Rainy Lobe	RNYL	NLF	St. Louis
	Outwash	OUTW	NLF	Itasca
	Des Moines Lobe	DML	NLF	Itasca
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Alluvium	ALLU	DA	Houston
	Alluvium	ALLU	DA	Houston
	Alluvium	ALLU	DA	Houston
	Alluvium	ALLU	DA	Houston
	Des Moines Lobe	DML	NLF	St. Louis
pore water only collected for sulfide	Des Moines Lobe	DML	NLF	St. Louis

	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Clay And Clayey Silt	CACS	NLF	St. Louis
	Clay And Clayey Silt	CACS	NLF	St. Louis
	Clay And Clayey Silt	CACS	NLF	St. Louis
	Clay And Clayey Silt	CACS	NLF	St. Louis
no cores collected; no wild rice present	Clay And Clayey Silt	CACS	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Des Moines Lobe	DML	NLF	St. Louis
	Alluvium	ALLU	DA	Houston
	Alluvium	ALLU	DA	Buffalo, WI
	Alluvium	ALLU	DA	Buffalo, WI
with a spatula.	Alluvium	ALLU	DA	Buffalo, WI
	Alluvium	ALLU	DA	Buffalo, WI
	Alluvium	ALLU	DA	Buffalo, WI
iandbar adjacent to our 8/19 site with WR growing. We dug down ~3 cm until we saw water in the hole. Then we put in Rhizons in - they sipped very quickly, and water level in hole did not change during sipping.	<Null>	<Null>	<Null>	Grand Forks, ND
	Peat	PEAT	NMW	Beltrami
	Peat	PEAT	RRV	Polk
	Peat	PEAT	RRV	Polk
	Peat	PEAT	RRV	Polk
	Peat	PEAT	RRV	Polk
mount, but air intake was a problem, so we decided to stop them. For compositing, we marked 10 cm on the bottom of an HTH tube, stuck the tube into the soil, pulled up and extruded the core into compositing container using a trowel and spatula. The soil was too dry to measure pore water pH, and there was not water in the ditches around	Peat	PEAT	RRV	Polk
	Des Moines Lobe	DML	RRV	Clearwater
	Peat	PEAT	RRV	Clearwater
	Rainy Lobe	RNYL	NLF	Crow Wing
	Peat	PEAT	RRV	Clearwater
	Peat	PEAT	RRV	Clearwater
ount, but air intake was a problem, so we decided to stop them. For compositing, we marked 10 cm on the bottom of an HTH tube, stuck the tube into the soil, pulled up and extruded the core into compositing container using a trowel and spatula. The soil was too dry to measure pore water pH, and there was not water in the ditches around t	Peat	PEAT	RRV	Clearwater