A summary of fine-scale water chemistry, chlorophyll, and periphyton responses to nutrient addition in the Kootenai River, Idaho, 2005-2010

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Abstract - *The Kootenai River in Idaho, Montana, and British Columbia has undergone cultural oligotrophication during the past century following diking, channelization, wetland drainage, and upstream impoundment. Following a replicated, in-river mesocosm experiment to assess small-scale response to nutrient addition, a multi-year whole-ecosystem nutrient enrichment experiment was performed to assess nutrient addition as an ecosystem restoration technique. The river was dosed with liquid agricultural-grade ammonium polyphosphate (10-34-0) from July through September 2005 to achieve an in-river concentration of to achieve an in-river TDP concentration of 1.5 $\mu g \cdot L^{-1}$, and from June through September 2006 through 2010 with an increased dose to achieve an in-river TDP concentration of 3.0 $\mu g \cdot L^{-1}$. A fine-scale monitoring program included 8 sites (two upstream reference sites, one injection site, and 5 downstream treatment sites). Nutrient addition increased nutrient concentration and primary production. Atomic N:P ratios were significantly lower at treatment sites than reference sites. Total chlorophyll accrual rates were significantly higher at treatment sites than at reference sites. Mean algal biomass and algal cell density were significantly higher at treatment versus reference sites. Downstream from nutrient addition, diatom density increased and blue-green algae density decreased.* Results confirmed nutrient addition as a useful ecosystem restoration technique for the Kootenai River.

Study sites - A total of eight sites were sampled, with untreated sites located 11 and 1 rkm upstream from the dosing site, and one site every 2 rkm, starting one rkm below the dosing site.

Water chemistry - Water chemistry was sampled weekly from June through September at each site, with three samples taken per site per sample date. Samples were collected from the right bank, mid-channel, and left bank sections at each site to measure ambient nutrient concentrations across the river channel. All samples were collected in 250 ml bottles pre-rinsed with de-ionized water, stored on ice, and shipped to Aquatic Research Incorporated Laboratory in Seattle, WA for analysis within 24 hours. Water samples were analyzed for soluble reactive phosphorous (SRP), total phosphorous (TP), total dissolved phosphorous (TDP), nitrite plus nitrate (NO_3+ NO_2), and ammonia (NH_4).

Atomic TN:TP ratios were calculated using mean TN and TP values. Atomic DIN:TDP ratios were calculated by adding the mean NO_3+NO_2 and the NH_4 concentrations and dividing by the mean TDP value. Atomic DIN:TDP ratios are more biologically accurate because the refractory N in TN measurements overrides any subtle shifts in NO_3+NO_2 and NH_4 (K. Ashley, UBC, pers. comm.). Atomic DIN:SRP ratios would have been preferred over the atomic DIN:TDP ratio, however, SRP measurements in the Kootenai River at the monitoring sites seldom exceeded laboratory detection limits (2.0 $\mu g \cdot L^{-1}$).

Chlorophyll biomass and accrual - Two 30-cm x 30-cm cement tiles with four sections of 2.5-cm thick Styrofoam glued to its surface were placed at each channel position site. Total chlorophyll (chlorophyll a + chlorophyll b) was sampled every two weeks by taking two styrofoam punch cores per tile per sample date. Each tile was sampled with a metal corer (3.8 cm-2), with the sample placed in a Whirl-Pak, stored in brown plastic bottles, frozen at 20°C, and shipped to the University of Idaho Analytical Lab in Moscow, ID for chlorophyll processing using the Winterman/DeMots method for extraction and analysis.

Periphyton taxonomy - Representative algal taxa and density were identified from a 645.2 mm^2 scrape sampled from a randomly selected rock monthly over the duration of the experiment, with one sample collected per site per sample date. Periphyton samples were preserved with Lugol's solution (1% by volume). Algae samples were sent to Aquatic Taxonomy Specialists (Malinta, OH.) for enumeration and identification. Soft-bodied periphyton cells were identified by viewing 300 cell-count wet mounts at 400X magnification. Diatom species were identified using sub-sample burn mounts magnified up to 1,000X. All algal taxa were identified to genus and some were identified to species. Algae were subsequently grouped as Cyanophyta (blue-greens), Chlorophyta (greens), Bacillariophyta (diatoms), and 'other' for analysis.

Project Results Summary

Water Chemistry - Significant differences were observed between treatment and reference sites in all years for: NO_3+NO_2, TN:TP ratios, and DIN:TDP ratios, whereas no signidicant differences in TDP concentration were observed in all years except 2009.

Some spatial trends were also evident:

- Treated sites typically showed lower NO_3+NO_2 concentrations than reference sites.
- Treated sites showed elevated TDP concentrations compared to reference sites.
- Treated sites showed lower TN:TP and DIN:TDP ratios compared to reference sites, with a stronger treatment effect seen with TN:TP ratios (Figure 1).

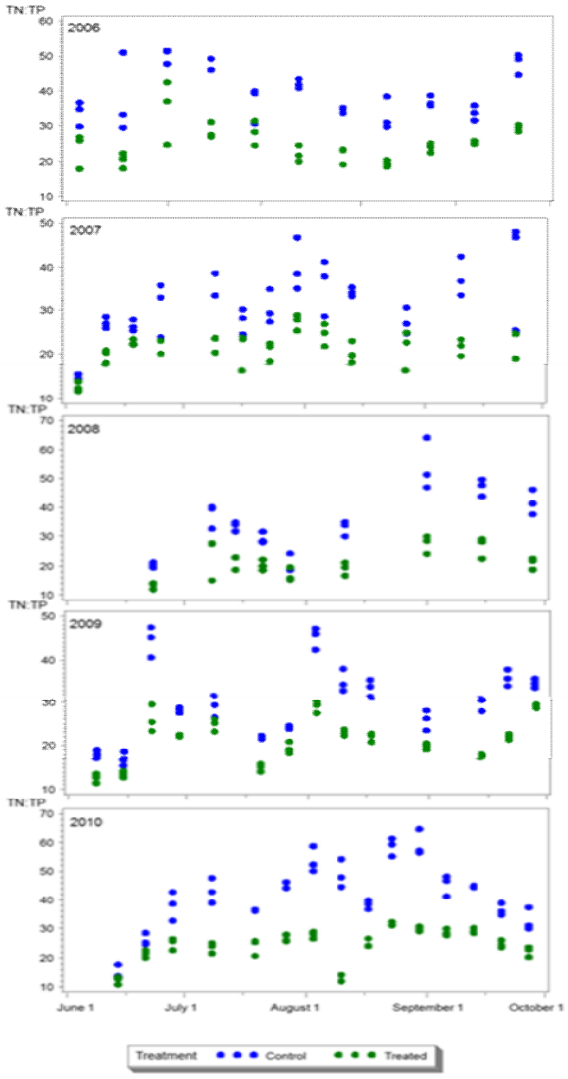

Figure 1. Mean atomic TN:TP ratios in the Kootenai River at the eight monitoring sites from June through October, 2006 through 2010.

Total chlorophyll accrual – Total chlorophyll accrual rate was significantly different between treatment and reference sites in all years for total chlorophyll, increasing significantly following treatment (Figure 2). All years showed an overall increase in total chlorophyll accrual rate response at the treated sites versus reference sites.

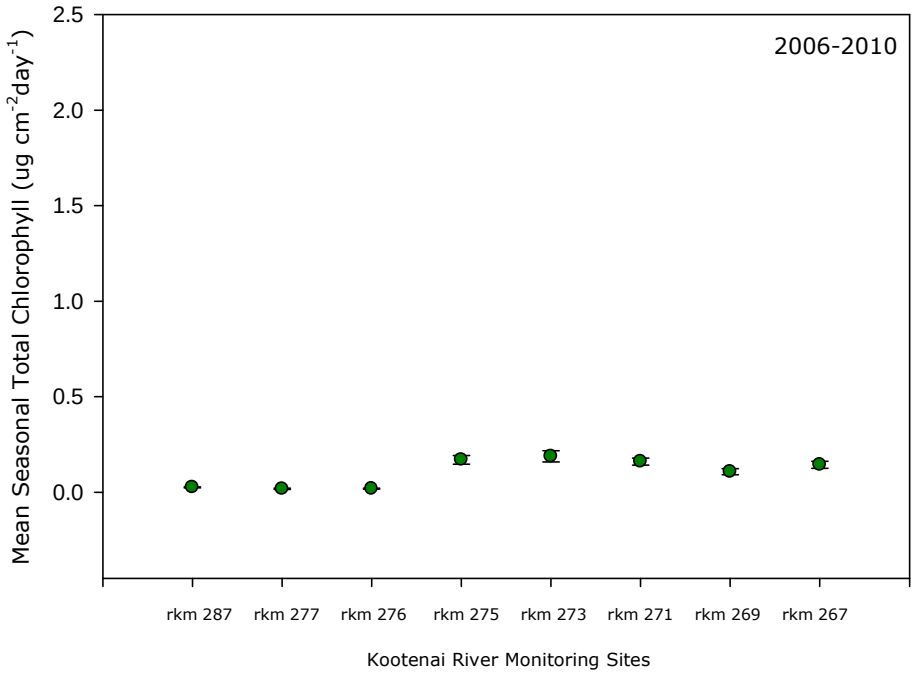

Figure 2. Mean algal biomass (µg·cm^{-2}·day^{-1}), measured as total chlorophyll, at the nutrient monitoring sites in the Kootenai River, Idaho, from June through October, 2006 through 2010.

Periphyton Taxonomy - Four taxa groups were defined: Bacillariophyta (diatom), Chlorophyta (green), Cyanobacteria (blue-green), and "Other". Treated sites had significantly higher diatom numbers compared to the reference sites ($p < 0.05$). Blue-green algae numbers were higher in the reference sites. Green algae numbers were low in both the treatment and reference sites, but slightly elevated at the treated sites (Figure 3).

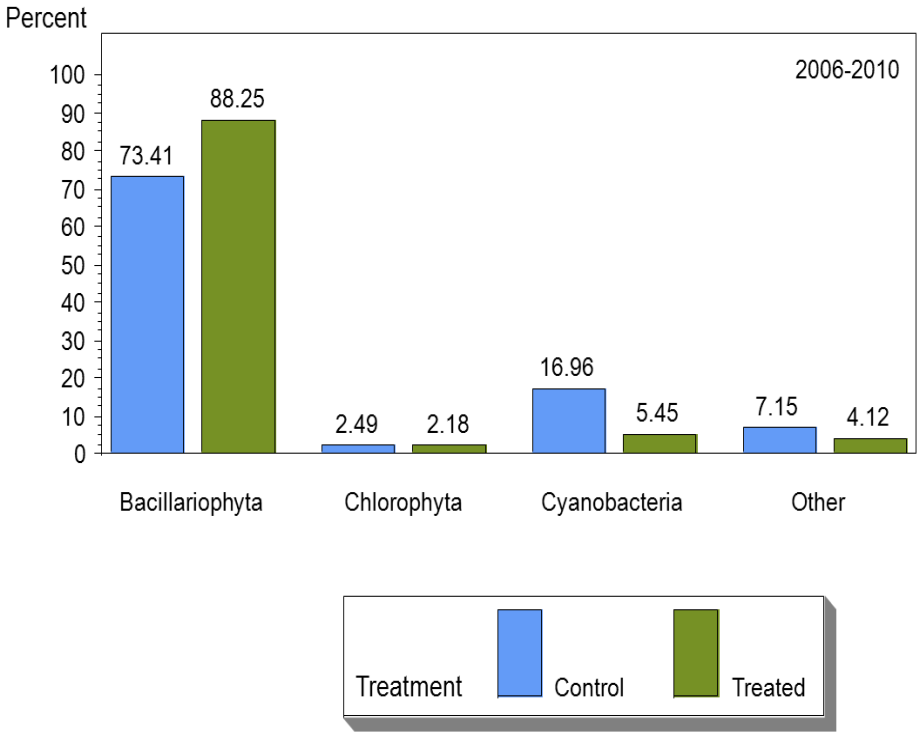

Figure 3. Percent composition of algal orders sampled in the Kootenai River before and after nutrient addition, 2006 through 2010.

Conclusions **-** In conclusion, this project, as measured by the fine-scale water chemistry, chlorophyll, and periphyton metrics, maintained desirable N:P ratios, while partially compensating for cultural de-nutrufication. Increased chlorophyll production following nutrient addition and a favorable relationship between nutrient addition and algal taxonomic composition were also observed. Algal taxonomic composition analyses revealed increased diatom production and suppressed blue-green algal abundance. Overall, multi-trophic responses confirmed nutrient addition as a useful ecosystem restoration technique for the Kootenai River in Idaho.