Abstracts - Pilot Fertilization

Pilot Fertilization of the Nechako River: A Test of Nutrient Deficiency and Periphyton Response to Nutrient Addition (RM88-3)
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Two experiments were conducted in the upper Nechako River to examine relationships between nutrient concentrations and periphyton production and establish chemical criteria for fertilization of the upper Nechako River for conservation of chinook salmon.
A side channel was fertilized with a N-P-K blend of 34-0-0 and 12-51-0 resulting in predicted concentrations of dissolved inorganic nitrogen (DIN) and soluble reactive phosphorus (SRP) of 40 µg • L-1 and 10 µg • L-1 respectively. Actual concentrations were highly variable due to the pulsing nature of nutrient input from the mechanical dispensers and plume dynamics which affected the dispersal of fertilizer across the channel width profile. Elevated N and P concentrations that were detectable up to 3.4 km downstream of the side channel were also related to incomplete mixing of the side channel and mainstem water. The addition of N and P resulted in a shift from a diatom-dominated periphyton community to one having equal proportions of diatoms and chlorophytes. The fertilizer addition increased peak periphyton biomass (PB) (the highest concentration measured) and sustainable biomass (SB) (the highest average concentration) in the side channel to 218 mg • m2 and 120 mg • m-2 of chlorophyll-a respectively; a 10 times increase over background levels. There was a corresponding increase in the rate of accrual (k) from 0.088 in the control to 0.44 in the fertilized reach. A concurrent bioassay experiment involving manipulation of nutrient concentrations in flow-through chambers established that periphyton production in the upper Nechako River was primarily limited by nitrogen but that phosphorus was co-limiting. By examining responses to various levels of nutrient addition, N and P-limited accrual saturated at not more than 20 µg • L-1and 5 µg • L-1 respectively. These concentrations were also important in limiting taxonomic shifts and were identified as being acceptable as target concentrations for future fertilization trials in the Nechako River.

Pilot Fertilization of the Nechako River II: Nitrogen-Limited Periphyton Production and Water Quality Studies during Treatment of the Upper Fraser (RM89-4)
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As a continuation of fertilization trials in the upper Nechako River for conservation of chinook salmon (Oncorhynchus tshawytscha), detailed monitoring of fertilization of the upper river was conducted coincidentally with an experiment designed to examine changes in periphyton biomass over a gradient of N additions at surplus P.

The fertilizer was a blend of 12-51-0 and 34-0-0. It was added continuously from six independently controlled dispensers located near the Swanson Creek confluence to increase inorganic N and P concentrations to 20 and 5 µg • L-1 respectively in the Nechako River mainstem. Chemical binders associated with the fertilizers also resulted in small additions of micronutrients.

Concentrations of nitrate (NO3), ammonium (NH4), and soluble reactive phosphorus (SRP) were mostly undetectable in weekly water samples collected at distances of 1 (T1), 5 (T5), 10 (T10), 20 (T20), and 50 km (T50) downstream of the fertilizer dispensers. A simple simulation model suggested that complete assimilation of the added N and P would be expected at all times within 5 km of the dispensers, and after the first month of treatment within the first kilometre.

The periphyton community downstream of the dispensers was dominated by diatoms and the biomass increased to a maximum of 133 mg chlorophyll a • m-2 from control levels of 15.6 mg chlorophyll a • m-2. The peak biomass (PB) was reached within a month at T1 and T5, but subsequently collapsed and then increased to a second peak of 68 mg chlorophyll a • m-2 before declining again at the end of the study period. Unlike these responses, areal biomass at T10 through T50 increased at a slower rate, not reaching PB until the end of the monitoring period in early July. The differences in areal biomass between sites was explained by the role of algal-bacteria relationships, downstream spiralling of added nutrients through mineralization processes, and the possibility of confounding nutrient inputs from allochthonous sources.

The increased levels of areal biomass had no impact on potential trihalomethane production at Fort Fraser or on dissolved oxygen concentrations in gravels at T1. There was also no evidence of accumulation of fertilizer-derived metals in periphyton tissue.

The N addition experiment indicated strong co-limitation of N and P, and by comparison with data from 1988 indicated that very small differences in P concentrations (less than detection limits in water), the presence of ammonium, and changes in current velocity may be important in bioassay procedures. Ammonium in particular may be a preferred N source for the periphyton since biomass responses were greater with ammonium present compared to those when only nitrate was present.

The response of areal biomass to changes in N concentration indicated that marginally lower responses could be achieved at half the concentrations used during the river fertilization. By comparison of the data with results from other experiments, it was also shown that the nutrient-limited biomass curve could be used as a generalized response curve for periphyton limited by a single resource. By combining resource-limitation curves from this and other experiments it was evident that 60-70% of PB in the Nechako River could be produced at N and P levels of 10 and 1 µg • L-1. The curves were also suitable for determining a biomass response relative to a maximum possible response at a gradient of N and P additions.

Pilot Fertilization of the Nechako River III: Factors Determining Production of Fish Food Organisms (RM90-4)
Prepared by C.J. Perrin, Limnotek Research and Development Inc. March 1996

A three phase experimental and monitoring project was completed in the Nechako River as part of ongoing pilot testing of fertilizer additions for enhancement of juvenile chinook growth and survival. First, an experiment was completed using flow-through mesocosms to quantify relationships between additions of limiting nutrients, periphyton response, and the abundance of aquatic insects. Monitoring of periphyton accrual and nutrient levels in the mainstem was also continued as part of a multiyear design to determine if the increase in algal biomass that was observed at distances up to 50 km downstream of fertilizer additions to the mainstem in 1989 was due to factors other than the intentional fertilizer addition. Finally, algal accrual responses to additions of N and P were examined using doses of N and P that were lower than those tested in previous experiments in 1988 and 1989.

Mainstem nutrient concentrations were low in 1990. Ammonium concentrations were always <5 µg N • L-1 . Nitrate-N levels were <5 µg • L-1 in May but increased to 23 µg • L-1 at Fort Fraser by mid-June. At the end of June NO3 levels at all sites were <15 µg • L-1. Soluble P concentrations were <5 µg • L-1 at upstream sites but increased near Fort Fraser.

There were three reach-specific course changes in periphyton accrual. Peak biomass (PB) measured as chlorophyll a never exceeded 7 mg • m-2 at km 29 through 40. Possible phosphorus enrichment from volcanic parent material in the canyon between km 9.5 and 13 resulted in PB levels up to 26.3 mg • m-2. At distances >56 km from the Kenney Dam, mean PB levels reached 32 mg • m-2, almost five times lower than the level reached during fertilization of the mainstem in 1989. Comparison of these PB values and net rates of accrual analyzed by analysis of covariance (ANCOVAR) to correct for different measurement periods between years indicated that the high biomass levels measured at km 56 and 93.8 in 1989 was related to the fertilization at km 30. This conclusion was confounded by a forced spill of water from the Skins Lake Spillway that may have caused greater scouring by bedload, thus introducing a physical limitation to periphyton accrual that was not present in 1989. Continued monitoring of periphyton accrual in another non-treatment year when a forced spill does not occur will help to resolve the effects of fertilizer addition in reach 1 or 2 on periphyton accrual at sites near the community of Fort Fraser.

Tests of additions of a gradient of N and P additions to periphyton growing in flow-through chambers confirmed earlier findings that periphyton growth in the upper Nechako River is co-limited by N and P. Relative peak biomass responses were combined with similar data from 1988 and 1989 and with relevant data from P manipulation studies in the Thompson River to produce a model for each of N-limited and P-limited growth of periphyton growth in the Nechako River. Each model displayed curvilinear growth kinetics, indicating that changes in periphyton biomass from nutrient addition was due to actual change in growth of attached cells. Linear responses having lower relative PB values was found when dual nutrient limitation occurred. When both N and P were added but over a gradient in which the maximum level added produced <50% of a maximum PB response, curvilinear growth kinetics did not occur, also indicating limitation by more than one nutrient or factor. The growth models indicated that N and P-limited periphyton growth can be almost saturated at concentrations of 40 and 5 µg • L-1 respectively.

Nutrient additions to the mesocosms reduced algal periphyton responses that again indicated co-limitation by N and P. N was found to be more deficient than P compared to findings at the periphyton bioassay site, 6 km downstream. The difference was attributed to higher upstream P concentrations.

N and N plus P additions to the mesocosms significantly increased the abundance of aquatic insects. Emergence increased by 60% from N added alone and by 46% with additions of N plus P. There were no significant differences in emergence between the N alone and N plus P treatments. Benthos increased by 54% due to N added alone and by 73% with both N and P added. Despite this difference in response between N added alone and in combination with P, statistical contrasts between treatments showed that responses from the additions of P were not significant. Per capita drift rates did not change from the nutrient additions but absolute numbers of individuals in the drift did increase due to N and N plus P additions, mainly due to the greater benthos achieved from nutrient addition. Multiple lines of evidence including greater emergence, increases in numbers of pupae, and higher benthos and emigration at constant immigration are presented to show that the insect response was due to an increase in larval survival, not simply an effect of differences in residence time of individuals.

Results from this study demonstrate "bottom up" control of trophic production in the Nechako River. Addition of limiting nutrients can increase the availability of fish food organisms for juvenile chinook.

Pilot Fertilization of the Nechako River IV: Monitoring to Improve Precision (RM91-4)
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A project was completed in the Nechako basin to address two uncertainties remaining from the previous three years of pilot testing of fertilization in the Nechako River. Dissolved nutrients and periphyton growth and biomass was monitored in the river between Cheslatta Falls and Fort Fraser using the same sampling design from previous years. Measurements were also made of a range of chemical parameters which indicate potential change in nutrient concentrations with shifting the water supply for the river from the Murray-Cheslatta Lake system to a controlled discharge from the Kenney Dam cold water release facility at Knewstubb Arm as part of the Kemano Completion Project (KCP).

Spring flows were lower in 1991 compared to those in 1990, although a small forced spill in April increased flows from the baseflow of 60 m3 • s-1 to 90 m3 • s-1. Flows had returned to base conditions in the last week of May. River temperatures were typical of those measured in previous years; about 4° C in April, and rising to 17° C prior to the annual July spill. NH4+-N and NO3- -N concentrations were always near the analytical detection limit of 5µg • L-1. Soluble reactive P levels were <1µg • L-1. Concentrations were slightly higher in the spring. Explanations for lower nutrient levels in 1991 compared to 1990 involve hyporheic processes. Effects of nutrient discharge from cattle grazing areas were ruled out as being important since grazing activity did not change between years, but there was inter-year variation in nutrient levels in the river. Periphyton growth rates and biomass was not significantly different from the measurements of 1990. Peak biomass was near 10 mg • m-2 in reaches 1 through 3, but in Reach 4 it reached 22 mg • m-2. The periphyton community was dominated by diatoms, as was typical of previous years. A statistical comparison of periphyton accrual between years indicated that the large increase in algal biomass that occurred up to 50 km downstream of fertilizer additions in 1989 was due to the fertilizer additions. This analysis was supported with evidence that periphyton accrual rates were similar between 1990 and 1991 despite the higher flows from the forced spill in 1990. All evidence points to limiting nutrients as being the primary factor controlling periphyton growth, accrual, and biomass in the Nechako River.

Despite differences in morphology, there were many similarities between Murray Lake and Knewstubb Arm. Both were well-oxidized systems, both had atomic N:P supply ratios indicating slight P deficiency or co-limitation by N and P, both were oligotrophic, both supported a phytoplankton community dominated by chrysophytes, cryptophytes, and diatoms, and both had a zooplankton community dominated by copepods. The main difference was morphometry which contributed to very different nutrient levels in potential supply water for the Nechako River under KCP. Near the Murray Lake outlet, the basin is shallow and it did not thermally stratify during this project. Conversely the deep, steep-walled embayment of the Kenney Dam on Knewstubb Arm did thermally stratify and density layers separated autotrophic and heterotrophic activity. Nutrient depletion occurred in the euphotic zone and higher nitrate concentrations were found in the hypolimnion in July through September. The higher hypolimnetic nitrate concentrations were attributed to oxidation of precipitated organic matter produced in the epilimnion. These data indicate that when hypolimnetic water is withdrawn from Knewstubb Arm after KCP, the supply water to the Nechako River will be co-limited by N and P at times of complete mixing, but beginning in July of each year, the system will shift to being primarily P-limited.