Effects of Nutrient Enrichment on Stream Ecosystems in the Upper Snake River Basin: Challenges for Nutrient Criteria Development

Christopher A. Mebane, Terry R. Maret, Ross G. Dickenson, Dorene E. MacCoy, Jerad D. Bales, Mark D. Munn

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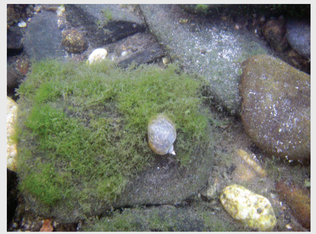
Introduction

In 2007, the U.S. Geological Survey's National Water Quality Assessment (NAWQA) program began investigating nutrient enrichment effects on stream ecosystems in the upper Snake River basin of Idaho and Nevada. The study provides nationally consistent and comparable data and analyses of nutrient conditions, including how they vary due to natural and human-related factors, and how they affect algae and other biological communities. This two-year study involved a one-time, large-scale synoptic study across the study area (n=30) in the first year, followed by temporal sampling at a subset of the sites (n=8) in the second year. The upper Snake River basin is one of eight agricultural regions being studied nationwide as part of the NAWQA program.



National protocols emphasize collecting periphyton algae that are attached to rocks or sediment (periphyton being grazed by a Lymnaea snail)

The objectives of the study include:

- determining the total algal biomass and the abundance, type, and diversity of algal and invertebrate communities in streams with different nutrient conditions, watershed characteristics, habitat, climate, and other natural factors
- determining the interrelations among nutrient conditions and stream metabolism

An excess of nutrients is the factor cited most often for U.S. waters listed as impaired, and 60% of those impaired waters can be attributed to excess nutrients. The detrimental effects of excess nutrients include nuisance plant growth, noxious algal blooms, anoxia, and fish kills. The U.S. Environmental Protection Agency (EPA) recommended numeric nutrient criteria for total phosphorous (TP), total nitrogen (TN), turbidity, and algae chlorophyll *a* (chl *a*) in phytoplankton or periphyton. However, the ecoregional nutrient criteria values were not directly linked with excess algae growth or other detrimental effects, but rather were the 25th percentile of ambient concentrations, grouped by nutrient ecoregions. Nutrient criteria based on 25th percentiles were intended to represent starting points for States and Tribes to develop more refined nutrient criteria.

Approach

The use of consistent national protocols allows comparisons across large geographic areas, but may not be well-suited for all regions. The NAWQA protocols emphasize algae, whereas in the upper Snake River basin streams, rooted aquatic plants may be abundant. Thus, we added biomass measures of rooted, submerged aquatic plants (macrophytes, AQM) and sediment nutrient chemistry to the national protocols. Aquatic macrophytes usually are thought to get nutrients from sediment rather than from water. For the upper Snake River basin we:

- conducted a large-scale synoptic field study across a gradient of nutrient conditions in agricultural watersheds
- followed similar protocols in order to compare results across study areas—measured nutrients in water, continuous stream stage, continuous temperature, physical habitat features, phytoplankton, periphyton, and benthic invertebrates at 30 sites
- estimated, at a subset of sites (n=7), stream metabolism using diurnal upstream-downstream dissolved oxygen changes to estimate whether streams were processing nutrients or just passing nutrients downstream
- studied seasonal changes in nutrient and biological conditions at a subset of sites (n=8)

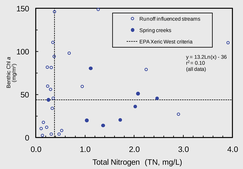
Where rooted aquatic macrophytes are abundant, measuring periphyton algae may be difficult and may not provide a meaningful measure of plant standing crop.

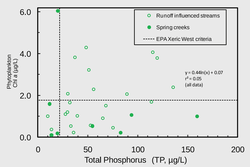
Findings

Preliminary review of data collected in summer 2007 indicates that algal and macrophyte standing crops are only weakly correlated with phosphorous or nitrogen concentrations in water. This finding suggests that other variables such as stream velocity or shading may be important co-factors. Algal nutrient limitation assays roughly agreed with predictions from molar nutrient ratios. Background concentrations of phosphorous in the study area appear to be about 2 times greater than recommended EPA criteria for the upper Snake River basin ecoregion, whereas background nitrogen concentrations in streams other than spring creeks are more or less equal to suggested EPA criteria. Background nitrogen concentrations in spring creeks appear to be about 2-3 times greater than background nitrogen concentrations in surface water streams; whereas background phosphorous concentrations in spring creeks appear to be about 30-50 percent of background concentrations found in runoff-influenced streams.

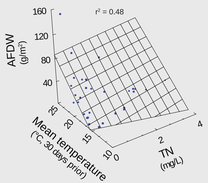
Relations among Nutrients, Algae, and Macrophytes

Simple relations between stream water nutrients and expected response metrics were weak and had no predictive value.

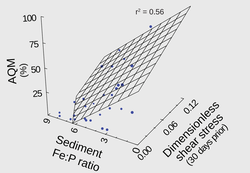




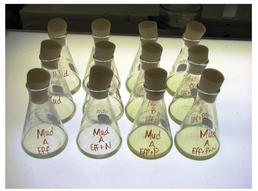
In stepwise linear regression, two factors, total nitrogen and mean temperature for the month prior to sampling explained half of the variability in periphyton biomass attached to rocks (ash free dry weight, AFDW). Some theoretically important metrics turned out to be unimportant in the AFDW regression, including phosphorus, flow disturbance as shear stress, invertebrate grazer biomass, and light availability.



The percentage of stream bottoms covered by submerged aquatic macrophytes (AQM) had no direct relation to nutrients in water, but two factors, sediment phosphorus normalized to iron and shear stress from flow explained over half of the variability in the data.

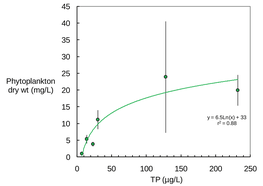


Supplemental Nutrient Limitation Experiments



In a variation on the green algae whole effluent toxicity (WET) test, N, P, or N+P were added to site water, inoculated with *Pseudokirchneriella subcapitata* (the algae formerly known as *Selenastrum capricornutum*) and incubated for 12-14 days until maximum standing crop was achieved.

The photo illustrates a P-limited series. P additions increased algal growth (green flasks), but N additions alone had little effect.



In contrast to the lack of strong patterns between phytoplankton and TP in stream water in the field surveys, in laboratory conditions where light, temperature, and flow are all the same, hyperbolic growth patterns with TP resulted, with TP explaining nearly 90% of the variability in algal standing crop.

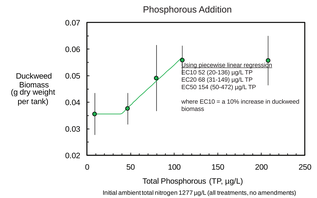
Nutrient diffusing substrates were incubated in situ for 21 days. Agar enriched with nutrients (N, P, N+P, plus agar-only controls) slowly diffused through fritted glass disks. Periphyton accrued on the glass disks. The photo illustrates an N+P co-limited response—neither N (blue) nor P (red) additions alone resulted in visibly increased periphyton accrual, but the combined N+P additions (green) did.

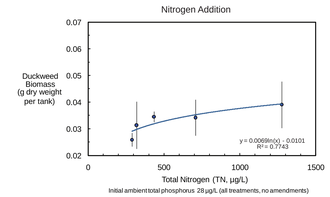
Duckweed Nutrient Addition Experiments

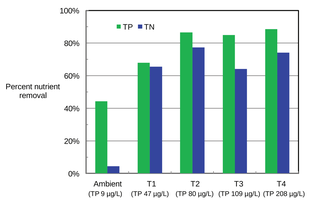
Duckweed (*Lemna minor*) is a true macrophyte that obtains nutrients through water. Growth was tested in separate phosphorous (P) and nitrogen (N) addition series:

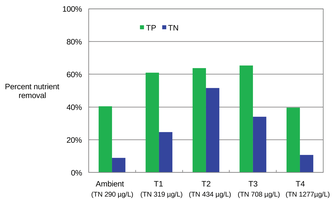
- added P to stream water that had very low ambient TP (8 µg/L) and typical TN (~1200 µg/L) for the region
- added N to stream water that had low ambient TN (290 µg/L) and typical TP (~28 µg/L) for the region

After 11 days, we measured duckweed biomass, number of plants, number of fronds, root elongation, and algae chlorophyll *a* and biomass. With P additions, clear thresholds of increased growth and P saturation were captured. With N additions, no thresholds were obvious. Nearly 90% of P and 80% of N were taken up in the treatments with high growth. These percent nutrient removals at fairly low plant densities likely relate to the weak correlation between nutrients and plant growth observed in field settings.

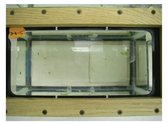






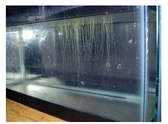


Duckweed is common around stream edges and quiescent zones



Tanks were seeded with 100 field-collected samples

Five treatments with three replicates



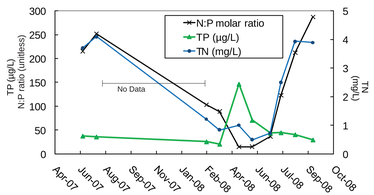
Root growth after 11 days

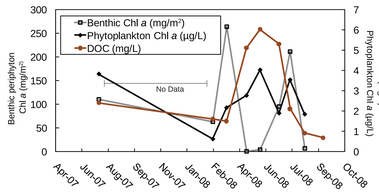
Future Plans: Examine Seasonal Patterns across Landscapes

Future plans include:

- attempting to synthesize the field surveys and lab responses
- to examine seasonal patterns in nutrients, other environmental factors, biological response variables

For example at the Camas Creek site, concentrations of nutrients, algae, and dissolved organic carbon (DOC) concentrations sampling during the late summer were greatly different from other times of the year.





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