BENTHIC ALGAL BIOMASS IN THE ETOWAH BASIN AND IMPLICATIONS TO ESTABLISHING NUTRIENT CRITERIA IN STREAMS

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Abstract. We determined algal biomass in 30 tributaries to the Etowah River in northern Georgia. Mean chlorophyll a ranged from extremely low to 150 mg/m^2. Several physical and chemical variables were measured as part of this study including dissolved nutrients, total suspended solids, substrate particle size and stream slope. In a multivariate model of algal biomass, three variables, average particle size (+), dissolved oxygen (+), and soluble reactive phosphorus (SRP) (-), entered into the model, which explained 78% of the variation in algal biomass. We subsequently determined that annual concentrations of SRP were strongly related to measures of sedimentation and fine particles at a site. Thus, higher concentrations of SRP were associated with increases in small particles and any positive effect of increased SRP on algal biomass was out-weighed by the negative effect of sedimentation among sites. In a model that included only dissolved nutrients and TSS as potential independent variables, dissolved inorganic nitrogen was positively related and TSS was negatively related to algal biomass. Our data illustrate that sedimentation strongly impacts availability of algae in these watersheds. In addition, these effects can obscure predictive relationships between nutrients and algal biomass, such that alternative nutrient criteria (e.g., biotic indicators) may be more robust where watersheds receive excess sediment.

INTRODUCTION

In the past, much of our focus on nutrients in streams has been in terms of their delivery to and effects in lakes. However, nutrients can strongly impact functioning of stream ecosystems and these within-stream effects are beginning to be addressed. The current effort in this regard in the U.S. is establishing nutrient criteria, which are separated by type of water body and include streams and rivers. The goal of establishing nutrient criteria is to determine the allowable concentration or range in concentration of nutrients in streams, by establishing relationships with meaningful endpoints. Some of the endpoints suggested by the U.S. EPA in establishing those criteria for rivers include algal biomass, pH, dissolved oxygen, transparency, biointegrity and nutrient concentrations relative to reference sites (U.S. EPA 2000). In this contribution, we focus on the use of algal biomass as a potential endpoint to determine maximum allowable nutrient concentrations in streams.

A central concern in establishing predictable relationships between nutrient concentrations and algal biomass, is that algal biomass in aquatic systems is controlled by several factors (Rosemond et al. 2000). Relationships between nutrient concentrations and algal biomass can sometimes be highly variable (Dodds et al. 1997). Incorporation of other factors in nutrient/algal biomass models can improve predictive capabilities. For example, a multiple regression model incorporating days of accrual since flood-related disturbance events, in addition to dissolved nutrient concentrations, was highly predictive of algal biomass (Biggs 2000). Thus, incorporating some other variables, such as grazing, turbidity or flooding can help us develop better predictive relationships between nutrients and algae.

METHODS

In this study, we were interested in those factors altered by changing land use and their effects on algal biomass. Conversion of forested land to urban uses can result in increased nutrient concentrations, increased sedimentation, and altered hydrology. Algal biomass was estimated as part of a larger study examining relationships between land use, and effects of altered sedimentation and hydrology on water quality in the Etowah River watershed (see Leigh et al., Paul et al., Roy et al., Walters et al., and Cifaldi and Kramer, this volume). Algal biomass was sampled quantitatively in the 30 study streams in a two week period in early April 1999 from the dominant substrata at each transect every 10 m in an 100 m reach of stream. We sampled a total of 15.9 cm^2 of surface area at each transect. For hard substrata, surfaces were scraped and collected under water and placed in Whirlpack bags. The same amount of surface area was collected from soft substrates, by collecting the top 2 cm of substrate and overlying stream water. Samples were processed within 24 hours of collection in the laboratory. Samples from soft substrata were sonicated for 1 minute prior to subsampling. Subsamples for chlorophyll a were filtered on Gelman GF/F (0.7μm) glass fiber filters. Samples for chlorophyll a were extracted in 90% acetone in the dark and read spectrophotometrically according to methods in Wetzel and Likens (1991). Chlorophyll a values by site are the mean values from 10 transects/site. Methods for water quality analyses and measures of sediment characteristics can be found in Paul et al. and Leigh et al. (this volume).

We ran multiple regression analyses with several variables to determine what factors were most useful in predicting chlorophyll a among sites. To reduce the number of variables that we put into this model, we used those that were significantly related to chlorophyll in our single variable correlations, but excluded any variables that were autocorrelated within a particular group of variables (e.g., water chemistry, sediment characteristics). The variables we used were: total suspended solids (TSS), soluble reactive phosphorus (SRP), dissolved oxygen (D.O.), substrate particle size (phi), thalweg slope, basin area, % bedrock and riffle depth. The second model we ran was to determine whether chlorophyll a could be predicted using dissolved nutrient concentrations and a simple measure of sediment at baseflow (TSS). Values used in stepwise multiple regression analysis were transformed prior to analysis if normality assumptions were violated. Multiple regression was run using JMP® statistical software.

RESULTS

Mean chlorophyll a values were extremely low at some sites (e.g, < 1 mg/m^2) to ca. 150 mg/m^2. Values less than 10 mg/m^2 may reflect potential food limitation for consumers, whereas concentrations in other streams (e.g., site 9) may reflect potential nusiance algal conditions (Table 1).

Three independent variables entered into the multivariate model of chlorophyll a (Fig. 1), explaining 78% of variance in chlorophyll a among sites. The most important variable was average particle size of the substrate (phi), with a partial R^2 of .69. The other variables that entered the model were D.O., which was positively related to chlorophyll a, and SRP, which was negatively related to chlorophyll a.

Table 1. Mean and (range) of chlorophyll a values in (mg/m^2) from each site. Site numbers reported here are as in Leigh et al. (this volume). Values of 0 indicate below level of detection.

Site	Chlorophyll a	(min - max)
1	20.32	(4.79 - 56.93)
2	16.18	(5.40 - 23.55)
3	15.35	(5.10 - 33.54)
4	22.75	(10.18 - 51.07)
5	44.43	(25.98 - 57.34)
6	29.52	(10.69 - 65.84)
7	4.02	(0.99 - 7.64)
8	32.13	(5.83 - 81.49)
9	152.02	(77.91 - 249.62)
10	47.14	(13.89 - 93.17)
11	16.08	(7.14 - 48.22)
12	27.08	(6.73 - 59.14)
13	6.00	(0 - 18.12)
14	14.28	(2.64 - 61.62)
15	19.07	(7.06 - 56.06)
16	18.71	(5.63 - 42.42)
17	20.60	(9.86 - 37.25)
18	6.52	(0 - 27.44)
19	50.17	(13.72 - 108.87)
20	33.02	(17.15 - 44.21)
21	0.67	(0 - 1.17)
22	19.85	(0 - 32.77)
23	4.06	(2.22 - 7.37)
24	15.38	(0 - 61.72)
25	5.51	(0.40 - 29.56)
26	3.89	(1.20 - 7.47)
27	21.66	(0 - 46.18)
28	78.57	(18.73 - 162.74)
29	21.15	(0 - 49.63)
30	19.79	(6.13 - 46.35)

The results of the model that used only TSS and dissolved nutrient concentrations indicated that dissolved inorganic nitrogen was positively related and TSS was negatively related to algal biomass (Fig. 2). SRP did not enter into the model.

We found it curious that in the multivariate model, we found a negative, rather than a positive, relationship between dissolved phosphorus concentrations and chlorophyll a. By examining correlations between SRP and other variables we collected, we found that SRP was strongly related to measures of sedimentation and fine particles at a site. Significant correlations with SRP were found with 1) average particle size, 2) % fine particles in riffle and pools (as measured by sieving), and 3) TSS. No such relationships between fine particles and DIN were observed.

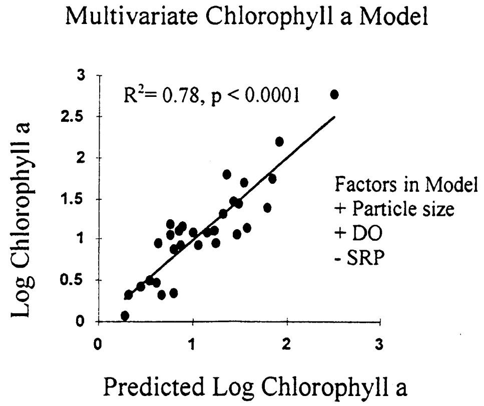

Figure 1. Multivariate model of chlorophyll a. Sediment particle size was the most important variable in the model (partial $R^2 = 0.69$). Dissolved oxygen (D.O.) and soluble reactive phosphorus (SRP) also entered into the model.

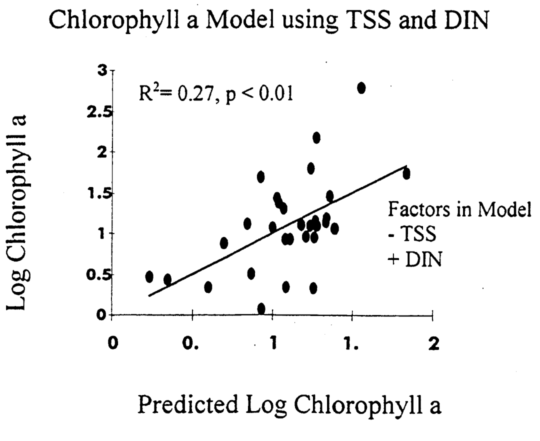

Figure 2. Model of chlorophyll a that included total suspended solids (TSS) and dissolved inorganic nitrogen concentrations (DIN).

DISCUSSION

Predictive models are needed of how nutrient concentrations, which are elevated in fresh waters world-wide, affect stream ecosystems. Current efforts to determine nutrient criteria in streams include determining nutrient effects on algal biomass. However, in many systems, particularly agricultural and urban systems, some variables (e.g., pesticides, sediment) explicitly co-vary with nutrients and negatively affect algal biomass, such that nutrient/biomass relationships may not be informative in moderately to heavily impacted systems.

We've shown that predictions of nutrient/algal biomass relationships can be improved by including information on sedimentation and substrate particle size. However, the variable that explained most of the variation in algal biomass among sites was sediment particle size.

The negative relationship between phosphorus concentrations and algal biomass may be due to associations between sediment input into streams and phosphorus concentrations in the water. Phosphorus enters these systems primarily attached to sediments. Measurements of dissolved phosphorus may reflect dissolution from fine sediments. Dominance of fine sediments may result in decreased light availability, instability of the benthic substrate, or increased scour, all factors which reduce algal biomass in streams. These negative effects may override positive effects of inorganic nutrients.

In determining nutrient criteria in streams in disturbed landscapes, algal biomass may not be a good endpoint to use due to overriding negative effects of sediment. In assessing nutrient effects in streams, alternative endpoints, such as algal or invertebrate indicators, may be better under such conditions.

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LITERATURE CITED

Biggs, B.J.F. 2000. Eutrophication of streams and rivers: dissolved nutrient-chlorophyll relationships for benthic algae. Journal of the North American

Benthological Society of America 19: 17-31.

Cifaldi, R.L. and E.A. Kramer. Land cover and geomorphic indicators of variation in riparian forest patches of the Etowah River watershed, Georgia. Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia, Kathyrn J. Hatcher, Ed., Institute of Ecology, Athens, Georgia.

Dodds, W.K., V.H. Smith, and B. Zander. 1997. Developing nutrient targets to control benthic chlorophyll levels in streams: a case study of the Clark Fork River. Wat. Res. 31: 1738-1750.

Leigh, D.S., M.C. Freeman, B.J. Freeman, E.A. Kramer, C.M. Pringle, A.D. Rosemond, M.J. Paul, D.M. Walters, A.H. Roy, and C.P. Lo, 2001. Overview of land cover and geomorphic indicators of biotic integrity in the Etowah River basin, Georgia. Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia, Kathyrn J. Hatcher, Ed., Institute of Ecology, Athens, Georgia.

Paul, M.J., D.S. Leigh, and C.P. Lo, 2001. Urbanization in the Etowah River basin: effects on stream temperature and chemistry. Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia, Kathyrn J. Hatcher, Ed., Institute of Ecology, Athens, Georgia.

Roy, A.H., A.D. Rosemond, D.S. Leigh, M.J. Paul, and J.B. Wallace, 2001. Effects of changing land use on macroinvertebrate integrity: identifying indicators of water quality impairment. Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia, Kathyrn J. Hatcher, Ed., Institute of Ecology, Athens, Georgia.

Rosemond, A.D., P.J. Mulholland, and S.H. Brawley. 2000. Seasonally shifting limitation of stream periphyton: response of algal populations and assemblage biomass and productivity to variation in light, nutrients, and herbivores. Canadian Journal of Aquatic Sciences 57:66-75.

U.S. Environmental Protection Agency 2000. Nutrient Criteria Technical Guidance Manual. U.S. E.P.A. Office of Water, Office of Science and Technology, Washington, D.C. EPA-822-b-00-002

Walters, D.M., M.C. Freeman, D.S. Leigh, B.J. Freeman, M.J. Paul and C.M. Pringle, 2001. Bed texture and turbidity as indicators of fish biotic integrity in the etowah river system. Proceedings of the 2001 Georgia Water Resources Conference, held March 26-27, 2001, at the University of Georgia, Kathyrn J. Hatcher, Ed., Institute of Ecology, Athens, Georgia.

Wetzel, R.G. and G.E. Likens. 1991. Limnological Analyses. Second edition. Springer-Verlag, New York.