Chenoweth Run Drainage

Biological and Water Quality Investigation

Division of Water
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CHENOWETH RUN
BIOLOGICAL AND WATER QUALITY INVESTIGATION

Kentucky Department for Environmental Protection
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Nutrients and Algal Growth in Chenoweth Run, Jeffersontown, Kentucky

Introduction

Nuisance growth of the filamentous green alga, *Cladophora glomerata*, often occurs in Kentucky streams during the summer. Moore (1977), Weitzel (1979), Biggs and Price (1987), Dodds (1991), Hansson (1992), Welch *et al.* (1992), and Dodds *et al.* (1997) have recently explored factors that possibly stimulate nuisance growths of algae. These factors include nutrient supply, substrate composition and stability, temperature, light, current velocity, pH, and scouring.

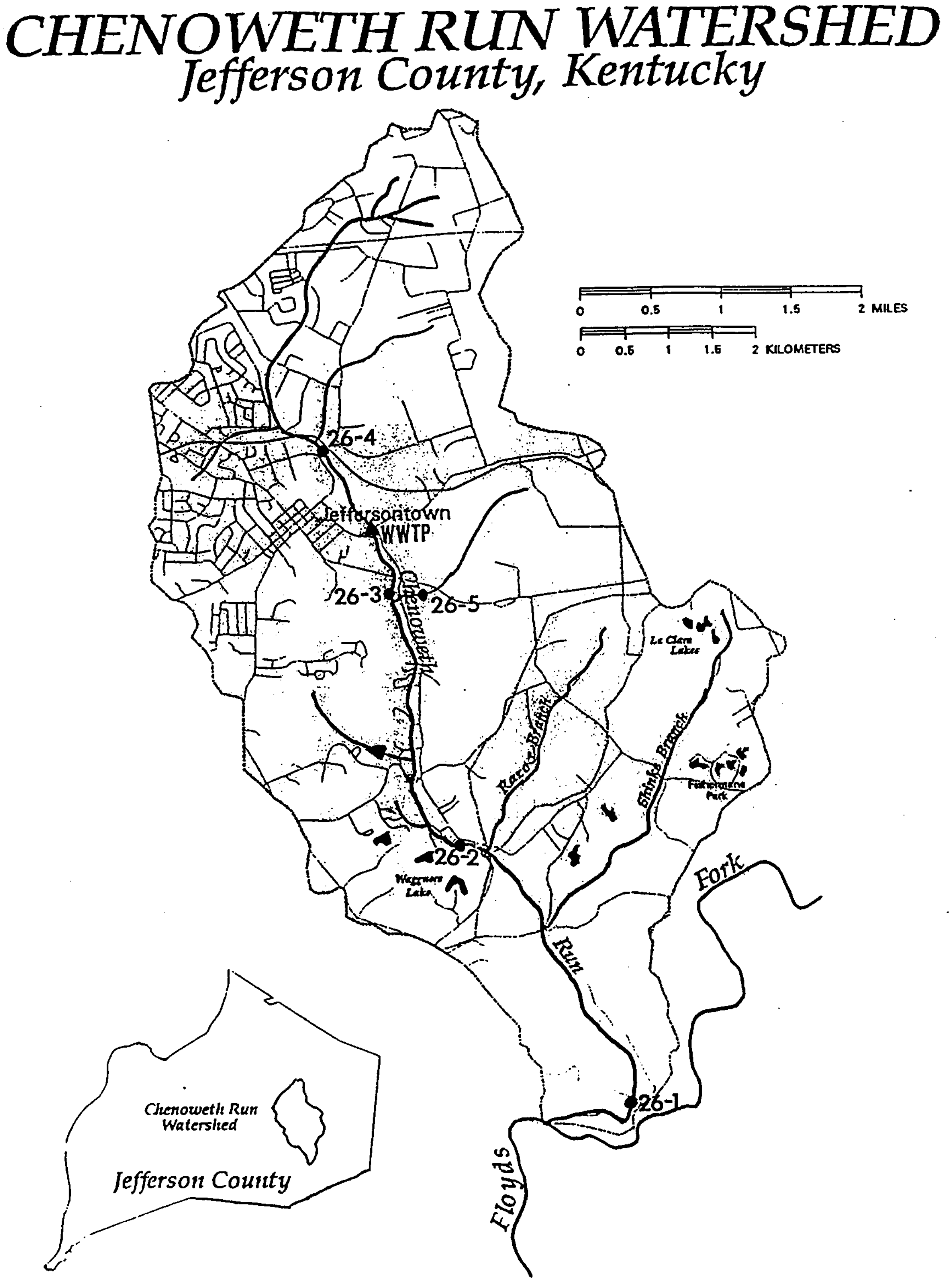
Although a definition of "nuisance" algal growth is subjective, Welch and others (1988) suggested that chlorophyll *a* concentrations greater than 100 to 150 mg/m^2 represent a "critical level" for an aesthetic nuisance. Dodds *et al.* (1997) presented approaches to assess target nutrient concentrations in streams. Biggs (1985) described other water quality problems related to excessive filamentous algal growth: diel fluctuations in pH and dissolved oxygen, clogging of water intakes, and interference with recreational uses (swimming and fishing).

Most of the studies cited have focused on the effects of nutrient levels on the algal biomass in streams. The KDOW undertook this study to assess the relationship between nutrient concentrations and algal biomass and to determine whether nutrient controls, in the form of phosphorus reduction, may decrease the ongoing problem of nuisance *Cladophora* growth in Chenoweth Run.

Study Area

Chenoweth Run is a third order stream in northeastern Jefferson County, Kentucky (Figure 1). It flows through the outer Blue Grass physiographic region into Floyds Fork, a tributary of the Salt River. One major nutrient point source, the Jeffersontown Wastewater Treatment Plant (JWWTP), and several minor point sources discharge to Chenoweth Run (KDOW, 1996).

Figure 1: Map of Chenoweth Run Watershed



Base from U.S. Geological Survey digital data, 1:100,000, 1983

Nonpoint sources of nutrients include urban runoff in the upper portion and pastures in the lower portion of the watershed. Chenoweth Run has historically had some of the highest concentrations of total and ortho - phosphorus in Jefferson County streams (USGS, 1992; Kentucky Division of Water, 1986). This study on benthic algal biomass is part of a comprehensive joint study by the Kentucky Division of Water (KDOW) and the United States Geological Survey (USGS) that was conducted to determine the most significant sources of nutrient pollution affecting Chenoweth Run (KDOW, 1996).

Methods

We sampled five sites in the Chenoweth Run drainage during the period from March 3 through July 19, 1995 (Figure 1). Station 26-4, the control site, was 0.8 miles upstream of the JWWTP. Stations 26-3, 26-2, and 26-1 were 0.3, 2.6, and 5.0 miles, respectively, downstream of the JWWTP. Station 26-5, a relatively unimpacted reference site, was near the mouth of an unnamed tributary (UT) to Chenoweth Run.

We collected samples at approximately three-week intervals to allow for natural changes in the benthic algal community to become apparent over the summer months. However, one sampling interval was longer (59 days) because of heavy rainfall and high flows during May 1995 (Table 1.) Sampling was terminated after the July collections because of low flow and a lack of change in the periphyton community. Subsequent visits to Chenoweth Run in August showed no observable changes in benthic algal biomass after the July sample.

During each sampling session, we collected field data, water samples, and algal biomass samples. We measured dissolved oxygen, pH, conductivity, and water temperature using a Grant/YSI Model 3800 water quality logger. Current velocity and depth were measured with a Marsh/McBirney Model 201D portable water current meter and measuring rod. We selected sites with similar current velocity and depth in areas with full sunlight in order to minimize effects of shading on algal growth.

Table 1: Sample Dates and Intervals for Chenoweth Run Algal Study

Date	**Interval (days between samples)**
March 21	
April 10	20
June 8	59
June 30	22
July 19	19

We collected three algal biomass samples on a transect across the stream at each site. Limestone bedrock was the primary substrate at each site, so we sampled it exclusively to eliminate problems associated with comparing samples from different substrate types. To collect the algal samples, we pressed a 3" high PVC cylinder, 9.2cm in diameter, against the substrate, scraped and removed the algae enclosed by the cylinder into a sample jar, and aspirated the remaining water and algal material into a filter flask using a battery operated pump. The periphyton and water collected in this manner were poured into the sample jar with the scraped algae. Samples were placed on ice and transported back to the KDOW laboratory for analysis.

We processed each replicate sample individually in the following way: sample area and volume were measured, then the sample was poured into a stainless steel blender. The sample was processed by blending for at least one minute and until all filaments were homogenized. We subsampled 1 ml for chlorophyll *a* analysis and 5 ml for dry weight (DW) and ash-free dry-weight (AFDW) analyses using 1 and 5 ml Oxford Micropipetters with disposable tips. Chlorophyll *a* analysis was performed following U.S. EPA method 445 (U.S.EPA 1992) using a Turner Designs Model 10-R fluorometer equipped with narrow-band wavelength filters. Dry weight and AFDW analyses were performed using methods outlined in Standard Methods for the Examination of Water and Wastewater, 18th edition (APHA 1992).

Results

Table 2 summarizes the physicochemical and biological data collected during this study. A detailed discussion of water quality data can be found in the water quality study of Chenoweth Run (KDOW 1996). Parameters used in the analysis were: dissolved oxygen (mg/l), temperature (°C), conductivity (uS/cm), and pH (field measurements); nitrate-nitrogen, ortho- and total phosphorus (nutrients, mg/l); and chlorophyll *a*, ash-free dry weight, and dry weight (biomass, mg/m^2).

Table 2: Chenoweth Run Study Physicochemical and Biomass Parameters, 1995

March 21

Station	DO	pH	Cond	Temp	Nitrate	Ortho P	Total P	Chl *a*	AFDW	DW
26-1	18.6	9.2	470	14.6	2.7	nd	0.32	648	362	2094
26-2	16.5	9.2	462	17.5	2.8	nd	0.64	199	162	1160
26-3	13.2	8.1	536	13.7	4	nd	1.1	430	328	2816
26-4	11.4	7.9	456	11.2	1.2	nd	0.004	654	199	2798
26-5	13.1	8.6	428	14.5	nd	nd	nd	42	59	378

April 10

Station	DO	pH	Cond	Temp	Nitrate	Ortho P	Total P	Chl *a*	AFDW	DW
26-1	24.0	10.7	536	19.0	7.32	0.059	0.145	1105	228	1133
26-2	20.6	10.2	536	19.0	9.91	0.231	0.387	859	209	937
26-3	14.1	8.5	562	16.8	11.6	2.16	2.63	569	346	2674
26-4	11.4	8.0	536	13.9	.678	0.006	0.012	374	348	3647
26-5	13.1	8.5	428	14.5	.025	0.008	0.009	76	403	377

June 8

Station	DO	pH	Cond	Temp	Nitrate	Ortho P	Total P	Chl *a*	AFDW	DW
26-1	11.0	8.9	626	23.7	2.23	1.29	1.49	265	322	2037
26-2	10.5	8.8	604	23.3	6.76	1.29	1.55	161	94	525
26-3	7.9	8.0	636	22.4	8.49	2.0	2.2	211	104	371
26-4	8.8	8.0	566	20.6	1.16	<0.005	0.018	165	100	764
26-5	8.8	8.5	500	22.1	0.13	<0.005	0.014	74	41	182

June 30

Station	DO	pH	Cond	Temp	Nitrate	Ortho P	Total P	Chl *a*	AFDW	DW
26-1	9.7	8.6	472	23.7	nd	0.834	0.911	61	14	39
26-2	10.1	8.6	510	24.2	9.1	0.934	1.07	54	20	13
26-3	7.5	7.8	560	22.8	12.0	1.49	1.6	119	79	75
26-4	7.2	7.9	408	21.3	0.71	<0.005	0.015	51	51	45
26-5	7.8	8.1	566	21.9	nd	0.148	0.234	68	43	57

July 19

Station	DO	pH	Cond	Temp	Nitrate	Ortho P	Total P	Chl *a*	AFDW	DW
26-1	10.0	8.6	736	24.6	9.84	nd	2.92	44	14	20
26-2	9.8	8.5	740	22.9	10.7	nd	3.06	117	18	30
26-3	6.8	7.8	770	24.5	11.2	nd	3.55	110	43	63
26-4	6.0	8.1	592	21.2	.458	nd	0.016	86	15	14

nd=not determined

We used the statistical package StatMost for Windows (DataMost 1994) to calculate Pearson correlation coefficients for these data. Table 3 shows which parameters were significantly correlated with one another.

Table 3: Pearson Correlation Coefficients for Parameters in Chenoweth Run, 1995

	DO	**pH**	**Cond**	**Temp**	**Nitrate**	**TP**	**Ortho-P**	**Chl *a***	**AFDW**
pH	0.8774								
Cond	X	X							
Temp	-0.4763	X	0.5827						
Nitrate	X	X	0.6297	0.5010					
TP	X	X	0.8079	0.4747	0.7780				
Ortho-P	X	X	0.5821	X	0.6947	0.9968			
Chl *a*	0.8230	0.6571	X	-0.4740	X	X	X		
AFDW	0.5659	X	X	-0.6853	X	X	X	0.5719	
DW	0.4053	X	X	-0.7125	X	X	X	0.5878	0.7940

X= not significant at $p<.05$ n=24

Biomass parameters (chl *a*, AFDW, and DW) were significantly correlated with one another. None of the biomass parameters were correlated with any of the nutrient parameters; however, all three were positively correlated with dissolved oxygen and negatively correlated with temperature. Nutrient parameters were correlated only with other nutrients, temperature, and conductivity.

Maximum algal biomass occurred in Chenoweth Run in April at Stations 26-1 and 26-2, with mean chlorophyll *a* values of 1105 and 859 mg/m^2, respectively (Table 2, Figure 2). These were the highest mean values observed throughout the study. Biomass levels in Chenoweth Run decreased sharply after a heavy rainfall event in May that scoured the substrate and removed most of the heavy *Cladophora* growth (Figure 2.) The nuisance levels of algae observed in the spring of 1995 and measured during March and April did not return to pre-spate levels for the remainder of the study. At station 26-1, near the mouth of Chenoweth Run, the chlorophyll *a* concentrations that had peaked at over 1000 mg/m^2 in April dropped to 265 mg/m^2 in June and in June and continued to decrease to a low of 44 mg/m^2 in July. The other Chenoweth Run sites followed a similar pattern, even though nutrient concentrations remained high (Figures 3 and 4).

Figure 2: Chlorophyll a and Average Water Temperature in Chenoweth Run, 1995

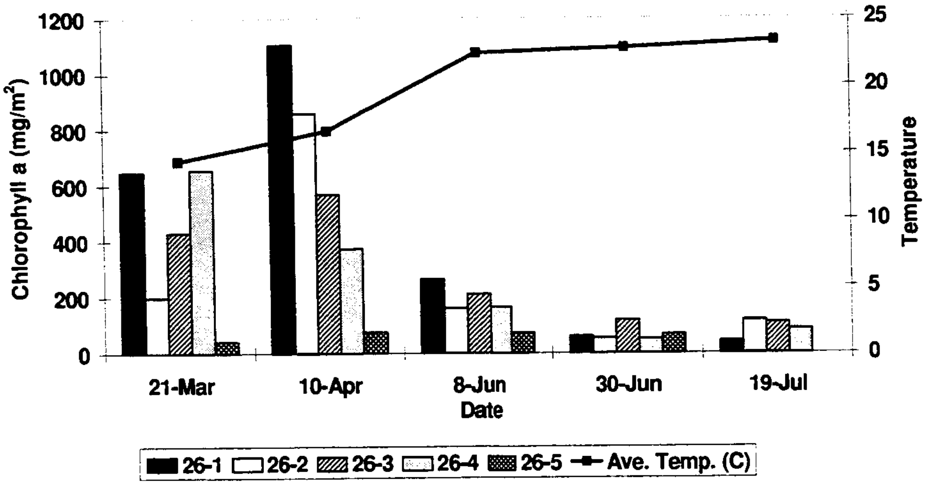
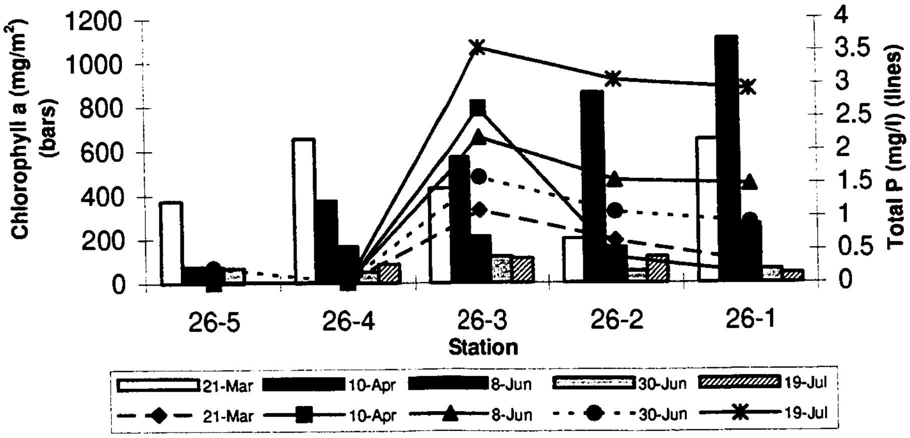
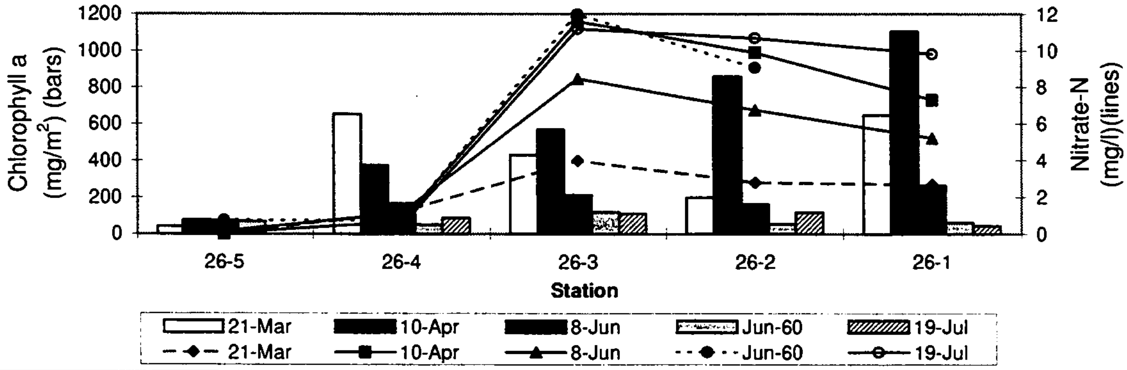


Figure 3: Chlorophyll a and Total Phosphorus in Chenoweth Run, 1995



The primary abiotic factors that appear to have affected biomass levels in Chenoweth Run were stream flow and temperature. Stream flow ranged from 1.81 to 331 cubic feet per second at station 26-1 (USGS data reported in KDOW 1996.) The storm that produced the maximum flow occurred in early May and scoured the substrate of the heavy *Cladophora* growth that we had observed during March and April. Chlorophyll *a* concentrations decreased drastically at all sites and did not exceed a mean of 150 mg/m^2 (the "nuisance" benchmark) in any later samples. Water temperatures increased throughout the summer from an average of 15° C in March to 23° C in July, and biomass and temperature were negatively correlated for all biomass parameters (Table 3 and Figure 2).

Figure 4: Chlorophyll a and Nitrate-N in Chenoweth Run, 1995



Station 26-4, located above the JWWTP, generally had lower mean chlorophyll *a*, AFDW, and DW levels than the sites downstream of the discharge point, but even that was not consistent and wasn't correlated with nutrient concentrations. Nutrient concentrations were lower at 26-4 than the downstream sites, but chlorophyll *a* was still above 150 mg/m^2 until after the spates. Station 26-5, the control site, which is unimpacted by point sources of nutrients, had the lowest nutrient concentrations and biomass levels. That site was not sampled in July because it was dry.

Figure 5 illustrates the differences in biomass and TP at stations 26-4 (upstream from the JWWTP) and 26-1 (furthest downstream from the JWWTP). Before the spate, TP was low compared to the high biomass at both stations. After the spate, which removed a high percentage of the biomass from both sites, TP continued to be low at station 26-4, but increased dramatically at station 26-1. It remains unclear why biomass was high at 26-4 before the spate, since TP concentration was low both before and after. In contrast, it is clear that the algal biomass at 26-1 had been assimilating the TP, since its removal caused TP concentrations instream to increase from <0.5 mg/l in March and April to almost 3 mg/l in July.

Figure 5: Chlorophyll a and Total Phosphorus levels above (26-4) and below (26-1) the JWWTP

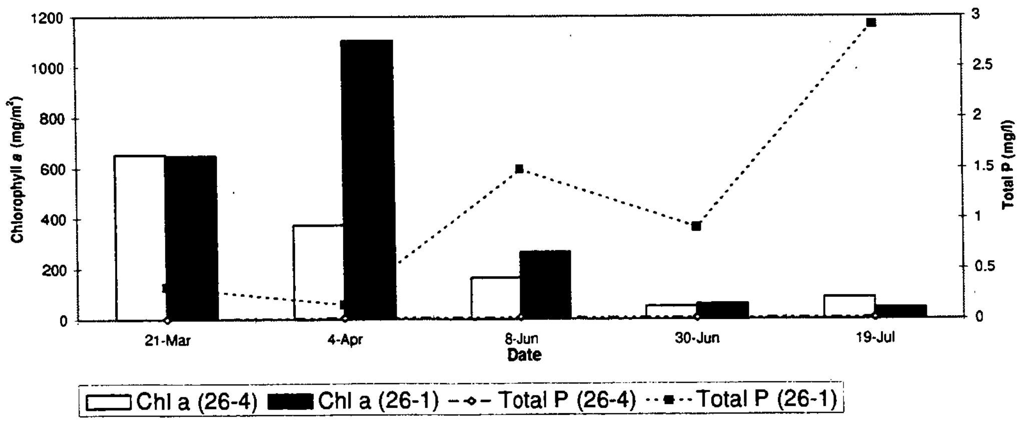
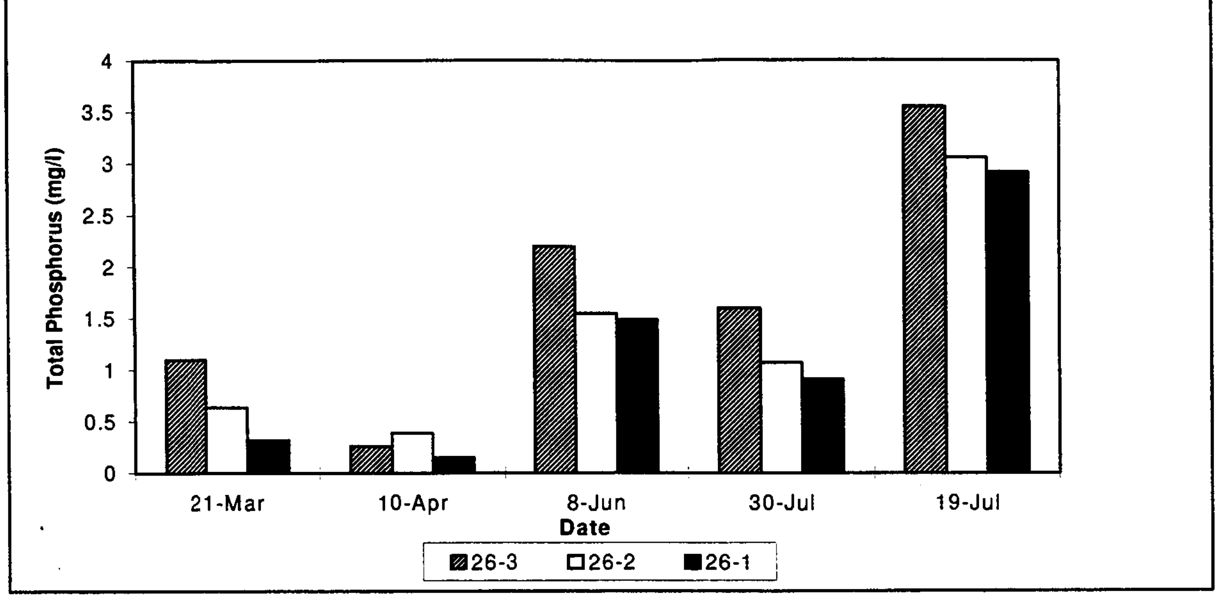


Figure 6 further illustrates the assimilation and export dynamics of total phosphorus in Chenoweth Run below the WWTP. Pre-spate levels of total P were low in March and April, when biomass was at its highest levels. After the *Cladophora* was scoured from the streambed in May, nutrient uptake by the algae decreased as biomass dropped below 200 mg/m^2 (refer to Fig. 3). As a result, total P concentration instream was higher and only decreased slightly downstream from the WWTP (station 26-3) to the mouth (station 26-1.)

Figure 6: Total Phosphorus Export in Chenoweth Run



Conclusions

Some studies have indicated that high nutrient concentrations have led to nuisance algal growths in streams (Dodds *et al.* 1997). Delong and Brusven (1992) measured chlorophyll *a* levels of greater than 150 mg/m^2 in a stream enriched by nutrients from agricultural runoff. It would seem intuitive that controlling nutrient inputs into streams would help to manage the amount of biomass present. However, other studies have found it difficult to define the complex relationship between nutrients and algal growth in streams because of the many other abiotic factors (temperature, current velocity, turbidity, light availability, grazing, scouring) that affect algal growth (Borchardt 1996). Horner *et al.* (1990) found that an increase in soluble reactive phosphorus (SRP) in experimental streams increased benthic algal biomass, but only up to SRP concentrations of 7.5 ug/l. Increased current velocity increased biomass until velocity exceeded 60 cm/s, after which any higher velocity tended to decrease algal biomass. Current velocity ranged from 20 to 40 cm/s in Chenoweth Run during sampling, but greatly exceeded this value during the spates in the spring of 1995, during which the substrate was scoured of benthic algae. Kjeldsen (1994) found that phosphorus played a major role in determining algal biomass in streams with sandy substrates, but there was no similar correlation in stony streams. However, he did observe higher maximum biomass when the dissolved inorganic phosphorus (DIP) concentration was greater than 90 ug/l.

Under the ideal (for *Cladophora*) environmental conditions that occurred in April of 1995, high nutrient concentrations in Chenoweth Run led to nuisance algal growth (greater than 150 mg/m^2), especially at stations 26-1 and 26-2. Chlorophyll *a* levels at station 26-4, above the JWWTP, were also above 150 mg/m^2, even though the TP concentration was low (0.01 mg/l). Nutrient levels and chlorophyll *a* were below any levels of concern in the control tributary (station 26-5).

After the heavy storms in May scoured the substrate, the *Cladophora* never reached its previous levels. Since nutrient inputs, turbidity, current velocity, and other abiotic factors remained constant, it may be that increased temperature (greater than 20° C) inhibited *Cladophora* growth once the substrate had been scoured. Where there had been filaments up to ½ meter long, post - spate conditions kept the filaments to less than 6 cm in length.

Since nuisance levels of *Cladophora* were present only during the spring of 1995, this study did not produce enough information to answer whether the control of nutrients, specifically phosphorus, from the JWWTP would decrease the potential for nuisance algal growth downstream of the discharge point. To complicate the picture, chlorophyll *a* levels were above 150 mg/m^2 upstream of the JWWTP, even though nutrient concentrations were much lower than downstream.

It is possible that the low nutrient concentrations upstream of the JWWTP were a result of assimilation of the nutrients by the benthic algae. Downstream, benthic algal biomass was high, at least proir to the scouring event, and nutrient concentrations instream were also high, indicating that nutrients were not limiting algal growth and were being exported downstream to Floyds Fork. After the algal growth was scoured by the spate, even higher concentrations of nutrients were available to be exported downstream to Floyds Fork.

Information from other benthic algal growth studies on the optimum ratios and threshold concentrations of nutrients required for algal growth suggest that nutrients are in excess in Chenoweth Run (Borchardt, 1996). In their work on the Clark Fork River, Dodds *et al.* (1997) modeled chlorophyll *a* and nutrient concentrations to derive target instream nutrient concentrations that would limit mean benthic algal chlorophyll *a* to densities below nuisance levels. Those concentrations (total N less than 0.350 mg/l and total P less than 0.03 mg/l) were applicable to that stream to reduce benthic algal chlorophyll *a* biomass to less than 100 mg/m^2. Similar target nutrient concentrations may be useful to control algal biomass in Kentucky.

Ambient water quality stations in Kentucky (STORET 1993) had a median TP concentration of 0.042 and a median Nitrate-Nitrite-N concentration of 0.495 mg/l during the period from 1983 - 1993. No nuisance algal growths have been reported from those sites, but the only biomass data collected during that time period were chlorophyll *a* values from plankton samples and artificial substrates (glass slides), so the available data are not really comparable to this study of Chenoweth Run. Further studies need to be carried out to determine what instream nutrient limits would help maintain benthic algal biomass at sub-nuisance levels.

Management of nutrient concentrations for limiting algal biomass is complicated by the multitude of variables that control algal biomass and the resulting lack of a simple correlation between increased nutrients and increased biomass. In addition, the limited number of studies that have addressed this problem have used a variety of experimental methods and have measured phosphorus in several different ways (TP, DIP, ortho-P, SRP). Dodds *et al.* (1997)

found that TN and TP were more indicative of the nutrients available for benthic algal growth than measurements of DIP and SRP. According to them, management criteria should be based on total, rather than dissolved, nutrients.

It may be that under "ideal" algal growth conditions, target nutrient concentrations needed to limit nuisance algal biomass in certain streams, such as Chenoweth Run, may be difficult to achieve unless other nonpoint sources of nutrient input can also be controlled. However, controls that limit instream concentrations of nutrients in Chenoweth Run may help prevent export of nutrients and control nuisance algal biomass further downstream in Floyds Fork and the Salt River.

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