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Monitoring Algae Levels in the Clark Fork River

Abstract

In response to public concern over attached algae levels in the Clark Fork River that sometimes interfere with beneficial uses, a public-private consortium has developed a voluntary plan to reduce nutrient loads. A long term data base is needed to evaluate to what extent algae levels respond to changing nutrient loads in this river. To initiate such a data base, algal biomass was measured at 15 sites in the Clark Fork and compared to historic data. Recommendations are made for a long term monitoring plan and for criteria for algal levels. Algal levels exceeded the proposed criterion throughout the river in 1987 and in the upper river in 1995. Middle river algal levels were well below the criterion in 1995.

Key Words: attached algae, nutrients, Clark Fork River, long term monitoring, algal criteria

Introduction

Based on a three year study of the Clark Fork River of western Montana, the U.S. Environmental Protection Agency found that attached algae levels at times interfered with beneficial uses, such as recreation, aesthetics, and irrigation, from the river's headwaters to its confluence with the Flathead River (U.S. Environmental Protection Agency 1993). In addition, oxygen and metal levels in the river have violated state water quality standards in the past, and summer algal levels appear to contribute to wide diurnal swings in oxygen levels (Watson 1989a,b) and in water chemistry that may facilitate the release of heavy metals from the sediments of this mining-contaminated river (Brick and Moore 1996). Section 303(d) of the Clean Water Act, requires that pollution loads to a water body that is not supporting beneficial uses or meeting water quality standards be reduced to the level the water body can assimilate and meet state water quality standards. This is known as the total maximum daily load or TMDL. The two EPA regions and three states that comprise the river basin agreed to try a voluntary plan to reduce nutrients as long as measurable progress was made toward reducing and eliminating water quality problems associated with algae (U.S. Environmental Protection Agency 1993). A public-private consortium that includes dischargers and citizen groups developed such a plan (Tristate Implementation Council 1996).

To assist in evaluating progress toward the above goals, this study had the following objectives:

(1) determining algal biomass in the Clark Fork to initiate a database for evaluating trends in algal levels associated with changes in nutrient loads;

(2) determining the sampling effort required to detect trends;

(3) recommending an algal monitoring program and criteria.

Methods

To minimize the costs of sampling, we wished to identify one or two sample times that would likely include the peak algal levels of the year for all sites sampled. However, observations over the past decade made in connection with a series of algal studies

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on this river (Watson 1989c, 1990, unpubl.) suggested that algal levels vary dramatically from season to season, from year to year, and from one site to another on the river. In addition, different sites may experience peaks at different times. The upper river, above the confluence with the Blackfoot River, was dominated in some years by an attached filamentous green alga, *Cladophora glomerata* (L.) Kutz, that could produce massive growths in a short growing season by growing back from perennial holdfasts on rocks. However, when ice flows or high spring flows moved rocks or scoured away holdfasts, *Cladophora* levels were low the following year and slow to recover. The middle river, from the Blackfoot to the Flathead River, was dominated by a mixed community of diatoms that grows to maximum biomass and sloughs in a few weeks in most years (Watson and Bothwell 1988). Past experience suggested that peak levels typically occurred from early August to early September, which was also the time when algae had the greatest impact on beneficial uses. This pattern appeared to hold in 1995 based on visual observations of algal levels made during biweekly sampling runs for water samples. Hence, algal biomass was collected from natural substrates at 8 sites in the upper river and 7 sites in the middle river between July 31 and August 5, 1995.

Algal levels vary spatially to such a degree that random sampling over the entire river bed required a prohibitively large sample to detect even large trends; moreover, some parts of the channel were too deep for sampling. To reduce variability and contain costs, we sampled a fairly narrow depth range as a relative indicator of algal levels that could be compared from site to site and year to year. Past experience (Watson 1989) indicated that late summer algal biomass levels in the 30 to 40 cm depth range were moderate relative to shallower and deeper sites. This depth was shallow enough to be important in affecting beneficial uses like recreation and aesthetics, yet deep enough that it was unlikely to have been exposed by low water in the weeks prior to sampling. Past experience also showed that some of the variability in algal levels was explained by substrate size, hence only rocks from 10-20 cm in size were sampled. These rocks were large enough to support major *Cladophora* growth yet small enough for easy handling. To select replicate sample points at a site, a random number table generated coordinates on an imaginary grid laid over a site. If a sample point selected by a set of coordinates did not meet the requirements of 30-40 cm depth and 10-20 cm rocks, we proceeded to the next set of coordinates.

Different collection methods were used depending on whether the indicator zone was dominated by diatom films or massive growths of *Cladophora*. Diatom-dominated communities were sampled by scraping all algae from a 2x 2 inch area (6.45 sq. cm), outlined by a flexible template, on each of 10 rocks. Unlike diatoms that grew in a relatively uniform film on rocks, *Cladophera* grew in long filaments attached to rocks by holdfasts. Most biomass was suspended in the current rather than attached to rocks and would be missed by template sampling. Hence, *Cladophora*-dominated sites were sampled by placing a 30 cm metal ring on the substrate and collecting all the algae in the ring. Six replicate ring samples were taken at each site.

Algae samples were kept on ice, out of direct sun, and frozen until analyzed for chlorophyll a and ash free dry weight (AFDW) according to Standard Methods (American Public Health Association 1985). AFDW analysis was performed on the extracted chlorophyll samples after drying, with one exception. The *Cladophora* samples were too massive to extract; hence, 4 small subsamples of each sample was analyzed for *chlorophyll a* and AFDW to obtain a ratio of these parameters. The bulk of each *Cladophora* sample was analyzed for AFDW and its chlorophyll content estimated from the AFDW to chlorophyll ratio of the subsamples.

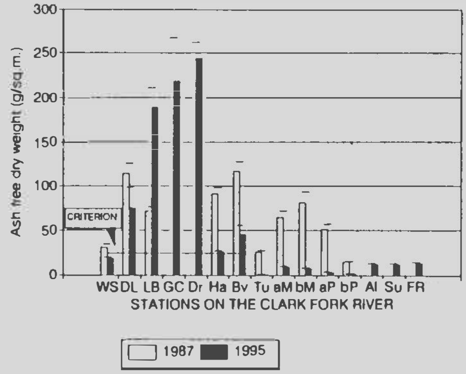
Water was sampled at all upper river algae sites biweekly from June 20 to September 7, to provide a baseline for the loading reduction expected when Deer Lodge begins to land apply its wastewater. Because of limited funds, data for the middle river were obtained from the state of Montana's regular quarterly sampling in mid August. All water samples were collected and analyzed for total and soluble forms of nitrogen (nitrates, nitrites, ammonia) and phosphorus (soluble reactive phosphorus) according to Standard Methods (American Public Health Association 1985).

Results and Discussion

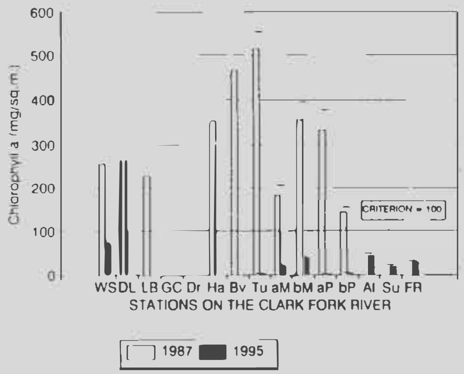
Algal Levels in the River

Figure 1 compares 1995 algal levels in the 30-40 cm depth zone to similar data collected in 1987 (Watson 1989c). Sampling was similar in both years, except in 1987 when sampling occurred in early September. Template sampling was used at all sites and fewer sites were assessed.

Only AFDW values (Fig. 1a) are presented for the *Cladophora* dominated sites, Deer Lodge to Beavertail, in 1995; because the 1995 estimates of chlorophyll were too variable to be useful. Samples collected in the 1980's were much less variable. Sample sizes for 1995 were set, assuming a similar amount of variability, but proved too low for the unexpected higher variability. In the future, more than 10 replicates of bulk samples and of subsamples should be analyzed to produce a better estimate of chlorophyll. Both AFDW (Fig. 1a) and chlorophyll a (Fig. 1b) levels are reported for diatom dominated sites because template sampling allows each replicate to be analyzed for both.



a. ash free dry weight (g/sq. m.)



b. chlorophyll a (mg/sq.m.)

Figure 1. *Biomass of attached algae in the Clark Fork River in Sept., 1987 and August, 1995. Bars represent means; horizontal lines above bars represent means plus one standard error. Sites identified in Table 1.*

Both chlorophyll and biomass levels were higher in 1987 at most sites. One exception was the LB site below Deer Lodge where AFDW was higher in 1995, probably because the 1987 template sampling underestimated the heavy *Cladophora* growths there. Two of the highest biomass sites in 1995, GC and Dr, were not sampled in 1987. Heavy *Cladophora* growth was bank to bank in 1987, while in 1995, it was confined to bands along the banks. In 1995, we estimated the percent of river channel covered by continuous bands of *Cladophora* (Table 1). The highest degree of channel coverage occurred below Deer Lodge and decreased downstream. In the middle river, heavy *Cladophora* growths were observed only at Missoula and Alberton with AFDW at 1703 and 93 mg/sq. m. respectively. These measurements were made with the ring method and were much higher than levels measured outside these patches, but still at the indicator depth, using the template method.

Visual observations in 1995 suggested that biomass at most sites decreased or remained the same after the early August sampling, except for two upper river sites. Beavertail and below Deer Lodge appeared to increase and were resampled in late August. The AFDW at these sites rose 3 fold from early to late August, suggesting that long term monitoring should sample in the first weeks of August and September to catch peak biomass at all sites. The higher biomass levels in 1987 may, in part, be due to the later sampling that year; however, had mean biomass levels tripled from August to September in 1995, they would still be lower than average levels in 1987 at most sites.

Detecting Trends in Algal Levels Given Observed Variability

One objective of this study was to determine the sampling effort required to detect changes and trends in algal levels. The authors collaborated with Land and Water Consulting of Missoula

Table 1. *Percent of channel covered by visible* Cladophora *in the Clark Fork River, August 1995.*

Site	River km (mi) from Warm Sp.	Channel width in meters (ft)	Channel coverage *Cladophora*	Sampling method
WS = below Warm Springs Creek	0 (0)	11(35)	None visible	template
DL = Grant Kohrs ranch, Deer Lodge	53(33)	15(50)	Patchy in 1/3 of channel	ring
LB = above Little Blackfoot River, below Deer Lodge	77(48)	18(60)	Heavy in 90-100% of channel	ring
GC = below Gold Creek (at bridge)	98(61)	27(90)	Heavy in 1/2 of channel	ring
DR = Drummond below Flint Creek	130(81)	24(80)	Heavy in 1/3 of channel	ring
Ha = BLM fishing access	152(95)	30(100)	Heavy in 1/8 of channel	ring
Bv = Beavertail camp ground	179(112)	30(100)	Heavy in 1/6 of channel	ring
Tu = Turah fishing access	208(130)	37(120)	<5% of rocks w/visible algae	template
aM = above Missoula discharge (Van Buren Br.)	224(140)	37(120)	Heavy in 1/10 of channel	both (template graphed)
bM = below same	235(147)	46(150)	1/10 of rocks with 1" *Cladophora*	template
aP = above pulp mill, Frenchtown	253(158)	53(175)	None visible	template
bP = below same	272(170)	53(175)	None visible	template
Al = Alberton above Petty Cr.	288(180)	67(220)	Heavy in 1/20 of channel	both (template graphed)
Su = Superior	349(218)	91(300)	None visible	template
FR = above Flathead River	411(257)	91(300)	None visible	template

in the development of a water quality monitoring system for the Clark Fork basin (Land and Water 1996). Using a Kendall test with Sen slope estimate, Bruce Anderson of Land and Water analyzed our data and concluded that detecting a 50% change in annual means of *Cladophora* AFDW with 80% power and 90% confidence would require about 10 replicates per site per sample time. These same 10 replicates repeated over 10 years would permit the detecting of a 35% monotonic linear trend at one site.

Anderson's analysis of the 1987 data for diatom dominated sites produced results similar to the above, but the 1995 data for diatom dominated sites were much more variable, requiring about twice as many replicate samples to detect similar trends. Variability appears to increase as algal levels decrease. Some samples were below detection and were recorded as zero biomass. To be consistent from year to year, at least 20 samples should be collected each year at each site, 10 in August and 10 in September.

Criteria for Algal Levels

The success of nutrient management efforts in the Clark Fork will be evaluated largely by analyzing trends in algal levels . However, it would be useful to have some goals or criteria for acceptable or desirable levels of algae. The U.S. Environmental Protection Agency (EPA) is currently drafting a guidance document for setting goals for nutrients and attached algae (U.S. Environmental Protection Agency 1995). Approaches include: a) identifying algal levels thought to be typical of the site before major change occurred based on historical data or nearby reference sites, and b) identifying levels of algae that would not interfere with beneficial uses or cause unacceptable changes in water chemistry or the biological community.

The British Columbia Ministry of the Environment recommends algal levels below 50 mg chlorophyll a/sq.m. to protect recreation and aesthetics and below 100 mg/sq. m. to protect against undesirable changes in the biotic community (Nordin 1985). These criteria were developed to apply across the width of small, shallow streams. When consulted in 1996, Richard Nordin, who developed the criteria, agreed that it is reasonable to apply the recreation and aesthetics criterion to the shallow riffles of large rivers. Welch et al. (1987) demonstrated that filamentous species tend to dominate communities with chlorophyll levels above 100 mg/sq. m. and proposed that nuisance levels existed above 100-150 mg/sq. m. Shallow riffles account for much of a river's macroinvertebrate production. If this habitat becomes dominated by an unpalatable filamentous species like *Cladophora*, the aquatic community would likely undergo substantial change. Based on Welch's and Nordin's work, we propose that chlorophyll levels above 100 mg/sq. m. be considered undesirable aesthetically and ecologically, unless such levels can be shown to be natural and desirable for a particular stream.

This criterion appears as the lowest line on Figure 1b, which shows chlorophyll levels in the river. Since we could not reliably convert the 1995 upper Clark Fork AFDW values to chlorophyll values, we converted the chlorophyll criterion into an AFDW criterion. This conversion involved one less source of variability than estimating chlorophyll levels from AFDW samples and AFDW/chlorophyll ratio samples. Pooling all the 1995 AFDW/chlorophyll ratio data for the *Cladophora* dominated sites reveals that 100 mg chlorophyll a corresponded to about 25 g of AFDW at these sites. Hence, the criterion is represented as a straight line at 25 g AFDW/sq. m. on Figure 1a. If future chlorophyll estimates prove too variable at *Cladophora* dominated sites, this AFDW criterion can be recalculated based on that year's AFDW/chlorophyll ratio.

In the upper river, early August AFDW levels at 30-40 cm exceeded this criterion at all sites (200 river kilometers) in 1987 and from Deer Lodge to Beavertail (100 km) in 1995 (Fig. 1a). In the middle river, summer 1987 chlorophyll levels exceeded the criterion at all sites (Fig. 1b) from Missoula to Huson—the site below the pulp mill (50 km). In 1995, algal levels were well below the criterion for 200 km from Missoula to the confluence with the Flathead, except in rare patches of *Cladophora* growth.

Factors Affecting Algal Growth

Lower biomass levels and smaller areas of heavy *Cladophora* growth in 1995 may be a product of the higher flows of 1995. The USGS records (Shields et al., 1988, 1994, unpubl. data) indicate that 1995 summer flows were above long term averages while 1987 summer flows were below average (Table 2). Therefore, less dilution and scour in 1987 may have contributed to higher algal levels. In addition, P levels have dropped in the river since phosphate detergents were banned in Missoula in 1990 (Ingman, 1995). We noted high numbers of grazers at the sites above and below the pulp mill in 1995, which may help explain the extremely low algal levels at these sites.

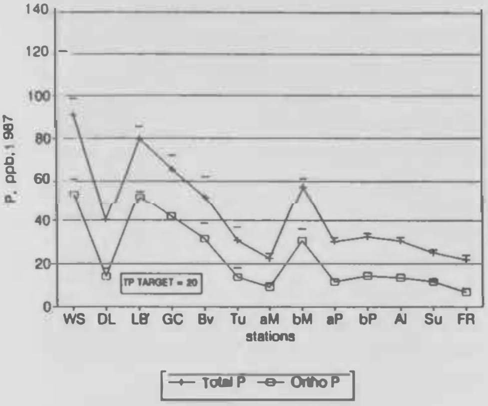
The Tristate Implementation Council (1996) has adopted target nutrient concentrations for the river to reduce algal biomass to acceptable levels based on multi-river databases and artificial stream studies. Using a 200 river database, Dodds and Smith (1995) correlated attached algal levels to total nitrogen and phosphorus levels. Based on their results, the Council predicted that average and peak summer algal levels would be unlikely to exceed 100 and 150 mg chlorophyll a/sq. m. respectively, if summer nutrient levels stayed below 300 ppb total nitrogen (TN) and 20 ppb total phosphorus (TP). Based on nutrient levels in river reaches where algal levels were not a problem and on artificial stream studies of Bothwell (1989) and Watson (1990), the Council predicted that algal levels were most likely to be noticeably reduced below maximum levels if soluble nutrients were kept below 6 ppb soluble reactive P and 30 ppb soluble inorganic N (Ingman 1992).

Nutrient levels, temperature and pH measured by this project in 1995 are summarized in Watson and Gestring (in prep.) for addition to the growing Clark Fork database available from the Montana Dept. of Environmental Quality (Ingman and Kerr 1990). Nutrient levels were generally lower in 1995 than in 1987 (Fig. 2). Phosphorus targets were exceeded at most sites in

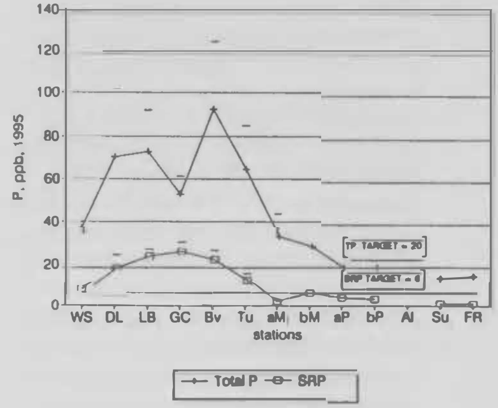
Table 2. *Instream flows in the Clark Fork River* [a]

Site	1987 (cfs)	1995 (cfs)	Average cfs (years averaged)
Clark Fork at Deer Lodge			
Annual mean flow	174	274	260 (15 yrs)
Mean July/Aug. flow	31	260	155 (15 yrs)
Clark Fork below Missoula			
Annual mean flow	2775	4682	5325 (64 yrs)
Mean July/Aug. flow	1550	4872	4042 (64 yrs)

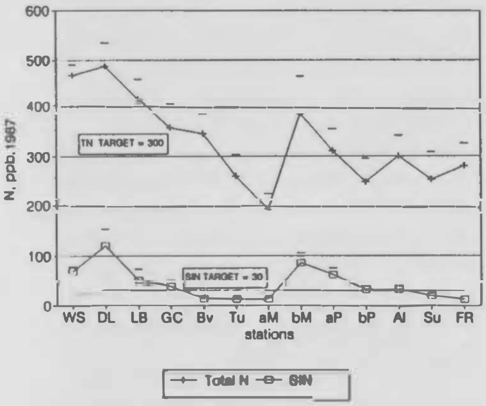
[a] Shields et al. 1988, 1994, unpubl. data



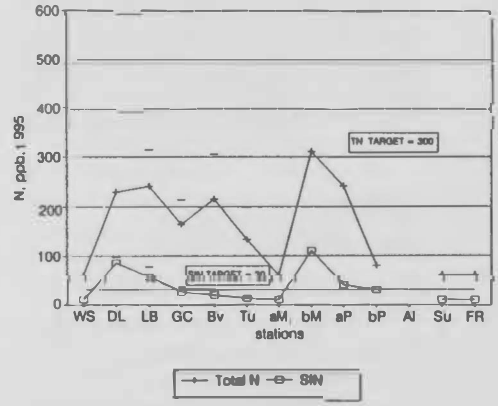
a. Total phosphorus and orthophosphate phosphorus, 1987.



b. TP and soluble reactive phosphorus, 1995.



c. Total nitrogen and inorganic nitrogen (nitrates, nitrites, ammonia), 1987.



d. TN and inorganic N, 1995

Figure 2. *Nutrient levels in the Clark Fork River, summer 1987 and 1995. Sites are the same as those identified in Table 1. Lines with symbols represent means of monthly or biweekly samples; horizontal bars represent means plus one standard error; sites without horizontal bars were sampled once in mid August 1995.*

both years; however, levels were generally lower in 1995. Total phosphorus at some sites was higher, possiblely due to higher flows. It should be noted that 1987 was the last year that the state of Montana analyzed Clark Fork water samples for orthophosphate rather than soluble reactive P (SRP). However, there was a significant decline in SRP levels from 1988 to 1994 (Ingman 1995); so it is likely that 1987 SRP levels were higher than 1995 levels. In 1987, TN usually exceeded the target level in the upper river and below the Missoula waste water plant. In 1995, this target was rarely exceeded, possibly because there was much less algae to slough in the river. In 1987 and 1995, the soluble N target was exceeded at all sites in early summer, but by late summer, it was depleted below the target at all sites except at Deer Lodge and below Missoula's wastewater discharge. These results clearly show that the value of instream nutrient targets is not in their ability to predict algal levels, which is marginal at best, but rather that trying to achieve them will drive a reduction in nutrient loading.

Conclusions and Recommendations for Algal Monitoring

We recommend considering algal levels over 100 mg chlorophyll a/sq. m. to be unacceptable unless it can be shown that higher levels are natural and not problematic for a particular site. Mid summer algal levels in the upper Clark Fork exceeded this criterion in 1987 and 1995, despite the latter's higher flows and cooler temperatures. Algal levels in the middle river were much lower in 1995 than in 1987, possibly as a result of higher flows and lower nutrient loads. Though sampling occurred a month later in 1987, had average algal levels in the middle river tripled from August to September in 1995, they would have been lower than in 1987 and below the proposed criterion.

The seasonal pattern of algal accumulation varies greatly from year to year in response to differences in weather. In a high flow year with low water temperatures continuing into late summer, algae, especially diatoms, may not reach peaks until late August or early September. However, in a hot dry year with low flows by early July, diatoms may reach their peak by late July or early August and slough. To ensure catching the peak, we recommend sampling the first weeks of August and September.

Template sampling is a quick, low cost method that provides chlorophyll and AFDW estimates of biomass for sites dominated by a fairly uniform diatom film. However, this method cannot accurately estimate biomass at sites with massive filamentous *Cladophora* growths. Here, we recommend sampling a larger area of the substrate, using a method similar to the ring method described herein. Because of the difficulty of estimating chlorophyll in such large samples, it may be necessary to focus on AFDW as the primary measure of biomass at these sites. Based on sample variability in 1995, the number of replicate samples needed to detect year to year changes and long term trends is 20 replicates per site—10 collected the first weeks of August and September.

Because of the great variability in algal levels across the river bed, we recommend intensively sampling a single depth (30-40 cm) and substrate type (10-20 cm) in fast flowing water as an indicator of algal levels that can be compared from site to site and year to year. To evaluate whether the river bed is becoming increasingly dominated by massive filamentous growths, a more extensive sampling scheme is necessary. We recommend taking 4 transects across the river at each site, measuring depth and collecting 5 samples every 5 meters until water is too deep to wade. Algae in this deeper water probably represents a small portion of total algal biomass. Because of the greater number of samples required for this extensive sampling, fewer sites could be characterized.

We recommend the following sites, at a minimum for long term monitoring of the Clark Fork: two sites that bracket Deer Lodge's discharge (DL and LB), Gold Creek (GC), Beavertail (BV), the four sites that bracket the discharges of Missoula (aM and bM) and the Stone Container mill (aP and bP), Superior (Su) and above the Flathead River (FR).

Acknowledgments

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