BIOASSESSMENT OF THE DOG RIVER

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Introduction:

The Dog River is a 4th order stream in central Vermont, USA, approximately 30 km long, from its source in Roxbury to its confluence with the Winooski River in Montpelier (Fig. 1), and a drainage area of 243 km^2. Primary land uses are residential development, agriculture, gravel extraction, transportation, and recreation (athletic fields, golf course). The river is an important trout stream, with brook, rainbow, and brown trout, and is considered by some anglers to be **the** premier trout stream in the state. Complaints of nuisance or excessive growth of algae and aquatic macrophytes in the Dog River have been reported at least since 1992. Follow-up surveys in 1992 and 1993 did not detect nuisance growth of algae or macrophytes at any points along the river. However, the observation was made that the algae peaked in the late spring, and we may have missed this "bloom". Consequently, a more thorough investigation was undertaken in 1994 to respond to ongoing concerns with water quality and the health of the aquatic community, with additional follow-up activities in 1995.

The overall task was to first document whether or not there was nuisance algae and macrophyte abundance and, if so, then to determine the cause of such growth. Commonly, elevated levels of nutrients (phosphorus) associated with waste water treatment plant discharges can lead to excessive growth of periphyton (attached algae). Non-point sources of nutrients, such as agricultural and urban run-off, may also be contributing factors. Increases in algae and macrophytes could also be related to removal of riparian vegetation (allowing more sunlight to reach the stream and leading to increased in-stream temperatures), the removal of grazers due to toxic susbstances, changes in stream flow, and siltation (Welch *et al.*,1992).

The study objectives were: to examine visually, non-quantitatively, the longitudinal distribution and abundance of periphyton and macrophytes in the river and to relate observed patterns to point and non-point inputs to the

Fig. 1 Dog River and Tributaries

Montpelier

Northfield

Baker Pond

river; to document changes in the biotic community (macroinvertebrates and fish) above and below the treatment plant; to assess the toxicity potential and enrichment effects of the treatment plant; and to locate potential disturbances in, or discharges from, the riparian zone of the river and its tributaries; and to make recommendations to correct existing problems. The results of this study, in conjuction with other available data, will be used to initiate integrated watershed management planning for the protection, restoration or enhancement of the Dog River and its tributaries.

Methods:

Weekly observations were made at several sites (Table 1) along the Dog River, from the mouth at the Winooski River in Montpelier to above the village of Northfield, approximately 13 miles upstream, from May until the end of June 1994. Temperature and conductivity were recorded. Periphyton and macrophyte abundance were noted and algae samples were returned to the laboratory for identification. Stream and substrate conditions were noted at each site, as well as surrounding land use and the general condition of the riparian zone. Selected tributaries (Cox Brook, Union Brook, and Sunny Brook and three unnamed brooks) were also checked for obvious disturbances and discharges which could effect conditions in the Dog River.

Three Whole Effluent Toxicity (WET) Tests were conducted with effluent from the village of Northfield; a *Ceriodaphnia dubia* acute test (Weber, 1993) in June 1994, and a chronic *C. dubia* test (Lewis *et al.*, 1994) in July 1994, with a follow-up test in Sept. 1995. All tests used 24-hour composite samples of final effluent, with upstream Dog River water used for dilution and as the control. Chemical analyses for priority pollutants were run on the effluent and the Dog River samples at the DEC Laboratory in Waterbury, Vermont. (Table 2.)

Benthic macroinvertebrates were sampled at five sites, at mile 1.4, 8.6, 8.8, 9.0, and 12.7. Sampling followed standard VTDEC protocols (VTDEC, 1989 and 1994), using a timed (2 min.) standard D-frame kick net with a mesh size

Table 1. Dog River observation and sampling sites.

Site	River Mile	Site Description
1	0.0 - 0.4	Confluence with the Winooski R. to just above the Montpelier recreation field.
2	1.0	First road-side pull-off (Rt. 12), run with cobble/gravle substrate.
3	1.4	Side road, first Rt. 12 crossing; run/riffle/pool; gravel/cobble substrate.
4	2.7	RR crossing; run/pool with some bedrock
5	3.0	Small trib. mear apts. Turbid; silt/sand.
6	3.9	Side road with bridge crossing; farm site.
7	4.8	Straight reach near roadside pull-off; railroad and Rt 12 parallel river. Cobble.
8	5.7	At Rt. 12 Bridge in Riverton, bedrock chute into large pool; old dam site.
9	6.9	Side road; bridge construction. Bedrock; large pool.
10	7.7	Large bend in river; braided channel; riffle/pool;bank erosion; sand/gravel.
11	8.2	Northfield Falls at mouth of Cox Brook.
12	8.6	Northfield Falls above covered bridge.
13	8.9-9.0	Northfield at Treatment Plant.
14	10.4	Northfield at Water St. and Union Brook.
15	11.4	Northfield; Rec fields of Norwich University.
16	12.6	Rt 12A; mouth of Sunny Brook.
17	12.7+	Rt 12A; above Sunny Brook to Roxbury.

of 500 µm. Two replicates were collected at each site and preserved in 75% ethyl alcohol. In the laboratory, the samples were subsampled from a gridded white enamel tray by picking all of the macroinvertebrates from one quarter of the sample (6 sqares out of 24). Macroinvertebrates were identified to the lowest practicable taxonomic level, usually genus or species, and are preserved by taxonomic order in the Biomonitoring and Aquatic Studies Archive.

Table 2. Chemical & Physical Parameters

Parameter	**Procedure***	**Preservation**	**Detection Limit**
Temp	1.6.1		
pH	2.1	Cool, 4°C	N/A
Alk	2.1.1	Cool, 4°C	
Cond.	1.2.1	Cool, 4°C	
DO	2.9.2	---	
Hardness	2.7.1	HNO_3 - Cool, 4°C	
Ca	4.5.1 flame	HNO_3 - Cool, 4°C	50µg/l
Mg	4.13.1 flame	HNO_3 - Cool, 4°C	2µg/l
Ag	4.19.2 furnace	HNO_3 - Cool, 4°C	1µg/l
Zn	4.23.1 flame	HNO_3 - Cool, 4°C	50µg/l
Cd	4.4.1 flame		10µg/l

		HNO_3 - Cool, 4°C	
Fe	4.11.1 flame	HNO_3 - Cool, 4°C	50µg/l
Ni	4.16.1 flame	HNO_3 - Cool, 4°C	50µg/l
Cu	4.9.1 flame	HNO_3 - Cool, 4°C	50µg/l
Pb	4.12.1 flame	HNO_3 - Cool, 4°C	50µg/l
Hg	4.15.1 cold-vapor	HNO_3 - Cool, 4°C	0.2µg/l
As	4.2.2 furnace	HNO_3 - Cool, 4°C	5 µg/l
Cr	4.6.1 flame	HNO_3 - Cool, 4°C	50µg/l
Al	4.1.2	HNO_3 - Cool, 4°C	5µg/l
TP	3.6.1	none - room temp.	3µg/l
NH_3	3.2.1	H_2SO_4 - Cool, 4°C	.02
NO_x	3.3.1	H_2SO_4 - Cool, 4°C	.02
TKN	3.5.1	H_2SO_4 - Cool, 4°C	.2mg/l
TRC	2.12.2	none	0.5mg/l
TSS	1.4.1	Cool, 4°C	1 mg/l
VOC's	6.2.1	Cool, 4°C	SEE METHODS FOR DETECTION LIMITS
Semi-Volatiles	6.3.1	Cool, 4°C	
Pest/PCB's	EPA-8080	Cool, 4°C	

* Methods from Vermont DEC Laboratory Methods Manual, 1992.

The macroinvertebrate community at each site was assessed using several metrics (EPA, 1989) including: total species richness, density, richness of mayflies, stoneflies, and caddisflies (Ephemeroptera/Plecoptera/Trichoptera or EPT richness), ratio of EPT to Chironomid density, per cent dominance of the most abundant taxon, and a Biotic Index was calculated. Based on the metrics scores (Appendix), the community was given a rating of excellent, good, fair or poor.

Fish populations were sampled at mile 8.6 and 12.8, with the use of an electroshocker, at 600 volts DC, with two probes to adequately cover the width of the stream channel. Sampling protocols followed the VTDEC Field Methods Manual (VTDEC, 1989). Fish were identified and counted in the field.

The fish community at both sites was assessed using the Vermont Index of Biotic Integrity (VTIBI), a modification of the IBI developed by Karr (1981). The Index (Appendix) is comprised of nine individual metrics, each measuring a different community attribute. Each metric is scored 5, 3, or 1 corresponding to the degree the attribute deviates from the expected in a reference condition stream. The VTIBI value is the sum of the metric scores, and ranges from 9 (very poor) to 45 (excellent).

Results and Discussion:

Algae and Macrophytes:

The only algae that reached abundance levels which could be perceived as "nuisance levels" were *Ulothrix zonata* and *Gomphonema* sp. *Ulothrix zonata* is a filamentous green alga that is a cold water species, usually appearing in the spring, disappearing in the summer, and present again in autumn.) *Ulothrix* was macroscopically visible on 5/11/94 in very small patches at sites 1, 2, and 3 when the water temperature was 7.5°C and the flows were moderate. It reached maximum abundance at sites 1 to 3 between 5/23/94 and 6/8/94. After this period of time, the *Ulothrix* filaments quickly deteriorated, turned brown, and sloughed off. By 6/23/94, sites one and two were completely free of any nuisance algae growth. Further upstream (above Site 3), the sites never became covered with significant levels of *Ulothrix*, although small patches or tufts occurred at all sites below Northfield village. At site 3, *Gomphonema* sp. (a diatom) appeared as brown, gelatinous masses on the gravel/cobble substrate after the *Ulothrix* had died back. This particular species of *Gomphonema* grew on short stalks and is an indicator of siltation and moderate enrichment in the stream (Welch et al., 1992). Below the treatment plant, blue-green algae, primarily *Phormidium* sp. and *Oscillatoria* sp. coated the rocks (100% cover) to Northfield Falls. In between Northfield Falls and site 3, there were no places where the substrate was 100% covered with either filamentous green algae or blue-green algae. Above the confluence with Sunny Brook, the cobble/gravel river bed was covered with a thin layer of diatoms, characteristic of low productivity, pristine streams in Vermont (Scott, 1982). In 1995, a year in which there were below normal amounts of spring runoff and of precipitation, *Ulothrix* followed the same temporal growth pattern, but it was less abundant, especially at site 3. Although present again at this site, *Gomphonema* did not grow to nuisance levels as it had in 1994. However, *Cladophora*, a common green filamentous algae, reached 100% cover with luxuriant growth at Northfield Falls and below the treatment plamt in Northfield later in the summer (late August through September 1995).

Elodea canadensis was the only abundant aquatic macrophyte found in the Dog River. In 1992 and 1993, it was observed only at site 9, where it occupied a small part of the soft sediment in a stream bend. Site 9 was also the site of the most abundant growth of *Elodea* in 1994. Additionally in 1994, patches of *Elodea* were scattered below site 9, especially at site 4. Generally, where there was a depositional area out of the main flow of the river with fine sediment, *Elodea* could become rooted. No *Elodea* patches were seen above Northfield Falls in the Dog River until 1995, when small patches or individual plants were observed up to the mouth of Sunny Brook. *Elodea* beds below site 9 continued to expand in 1995, such that the complete stream channel was closed just below this site and at site 4.

The source of *Elodea* appears to be Baker Pond, which has been drawn down in recent years to control the excessive abundance of this plant in the pond. Baker Pond is the source of Sunny Brook, which joins the Dog River just above Northfield (Fig. 1). Dispersal takes place by either by stem fragments or specialized vegetative propagules (condensed shoots with swollen nodes and apices), which easily root in a silty substrate (Bowmer *et al.*, 1995).

Fish Community Assessment: Index of Biological Integrity (IBI)

The results of fish sampling above and below the WWTF (sites 12.8 and 8.6) on the Dog River are presented in Table 3. The upstream site was dominated by slimy sculpin, which accounted for 76.8% of the total fish collected and a high percentage of the insectivores. Thirteen (13) Brook trout and 4 Rainbow trout comprised the carnivores, 3.5% of the total. All three species are known to be intolerant to most forms of environmental stresses and the sculpin is an indicator of excellent water and physical habitat quality. The VT IBI at this site was 41, for an "excellent" rating.

The downstream site had the same dominant species, slimy sculpin, but here they accounted for only 40% of the catch. Tolerant species, including blacknose dace, creek chub, and white sucker, increased in abundance to 37% of the total. There was also a high prevalence of "blackspot", a parasite, in the fish examined at this site. Brook trout decreased in numbers, while Rainbow trout increased, causing only a slight decrease in percentage of top carnivores, 3.5 to 2.0%. These factors contributed to an overall rating of "good", with an IBI of 37.

There are some significant differences in water chemistry between the two sites, primarily from the influence of Sunny Brook. The Dog River has a alkalinity of 23 mg/l as $CaCO_3$ and a conductivity of 60 µmhos/cm above Sunny Brook. These parameters increase to an alkalinty of 53 mg/l and a conductivity of 165 µmhos/cm below Sunny Brook. The 12.8 site also has different aquatic habitat than the 8.6 site, in that the lower site has more deep pool habitat and less riffle. These factors make a strict "above-below" comparison less straightforward in that they could effect the community structure in a way unrelated to the discharge. However, the overall evaluation indicates a slight degradation of the fish community, from excellent to good, due mainly to the prevalence of blackspot at the below site and an increase in tolerant species.

Table 3. Dog River Fish Community Analysis: Biometric scores for Vt IBI at two sites, above (12.8) and below (8.6) the Northfield Wastewater Treatment Plant.

Community Metric	Above (12.8)	Below (8.6)
Richness	7	9
Intolerant Species	3	3
Benthic Insectivores	3	3
% Blacknose Dace	12.9	28.1
% Generalist Feeders	2.1	15.3
% Insectivores	94.5	82.6
% Top Carnivores	3.5	2.0
% Anomalies	0.0	42.6
Density	59.3	58.0
Species Diversity	1.2	2.3
VT IBI score	41	37
Overall Assessment	Excellent	Good

Macroinvertebrate Community Assessment:

In 1994, macroinvertebrate samples were taken at 5 sites along the river, with the majority focused on the village of Northfield and its sewage treatment plant. Summary results are listed in Table 4. Site 12.7, located above the village and the treatment plant, was rated "excellent", with a Biotic Index of 1.08. The dominant taxa at this site was *Brachycentrus lateralis*, a cold-water Trichopteran (caddisfly), of the collector-filterer functional group. The Trichoptera accounted for almost 50% of the composition of the benthic community at this site, followed by 32% Ephemeroptera, 9.9% Diptera, and 6.6% Plecoptera. At Site 9.0, which is located below the main village, but above the treatment plant, the community retained an "excellent" rating, although there was an increase in the Biotic Index to 1.76, and the Plecoptera decreased to only 1.8% of the community composition, due primarily to a drastic reduction in the number of Chloroperlidae. The overall composition by functional feeding group remained relatively the same.

Below the treatment plant, Site 8.8, the BI increased to 2.43 and the number of EPT taxa declined. While the overall abundance increased and the Diversity Index remained the same, sensitive taxa were replaced by more tolerant species. The number of Diptera increased markedly, from 13% to 51% of the total abundance. The % composition by functional feeding group shifted from collector-filterer to collector-gatherer, while the scrapers declined from 11% to 2%, and the percentage of predators almost doubled (from 8% to 15%) along with a large increase in algal shredders. These changes in the benthic community are typical responses to enrichment and to toxic stress. The overall rating at this site was "fair"; a significant alteration from the "excellent" assessment at sites 12.7 and 9.0.

The two sites further down stream, 8.6 and 1.4, show some recovery to an overall "good" benthic community rating. This is largely due to an increase

Table 4. Macroinvertebrate Community Metrics for five sites in the Dog River. September, 1994.

Biometric	Site 12.7	9.0	8.8	8.6	1.4
Density	1836	2770	3282	4244	2966
Richness	43	51	43	47	51.5
EPT	24	25.5	16	18.5	22.5
EPT/Richness	.51	.50	.37	.38	.46
Bio Index (BI)	1.08	1.76	2.43	2.42	2.43
% Scraper	10	11	2	3	16
Dominant Taxa	*Brachycentrus*	*Brachycentrus*	*Orthocladius*	*Ephemerella*	*Ephemerella*
Rating	Excellent	Excellent	Fair	Good	Good

in Total Richness and Total EPT Richness. The scraper feeding group also rebounds at the lower site due to a change in the periphyton from blue-green algae to diatoms. The BI remains the same, however, indicating that the river is effected by nutrient enrichment throughout the downstream section even though toxic effects may be attenuated.

An assessment done from sampling at sites 9.0 and 8.8 in 1995 reinforces the findings of 1994. The Dog River continues to be adversely impacted below the Northfield Waste Water Treatment Facility from moderate enrichment (reflected in an increase in the Biotic Index) and toxic stress (decrease in EPT Index). The changes in the community metrics from the upstream site to the site below the treatment plant are summarized in Tables 4 and 5.

Table 5. Macroinvertebrate Community Biometrics and the per cent change from two sites on the Dog River in Northfield, VT. Site 9.0 is located just above the WWTF and site 8.8 is immediately below. Sept. 1995

Biometric	Site 9.0	Site 8.8	% Change
Density	785	1037	+32%
Richness	47.5	41	-14%
EPT	22.5	16	-29%

EPT/Richness	.47	.39	-17%
E/P/T	10/6/12	6/4/14	-40/-30/+17%
Biotic Index	2.0	2.42	+21%
EPT/EPT&Chiro	.83	.52	-37%

Whole Effluent Toxicity Testing:

The first test, June 1992, ended with 100% mortality in all treatments, presumably from a large amount of dechlorination agent in the sample. The treatment plant was sampled and tested again in June 1994, which resulted in 50% mortality in the 100% effluent (LC50=100%). A chronic test to validate this low level acute toxicity was then done in July 1994. The No Effect Concentration (NOEC-C) for the chronic test was 12%, with significant effects (low reproduction) at 25% effluent and above. There was again 50% mortality in the 100% effluent, but not until day 6. No significant acute (48 hr) mortality was observed. The organisms exposed to 50% or more effluent concentration showed no growth, and reproduction was absent in the 75% and 100% effluent. Both samples from 1994 had a reddish hue, especially the first renewal sample.

Another chronic test was run in Sept. 1995 to augment findings of a private laboratory contracted to investigate the toxicity of the effluent. The results were similar to the July 1994 test (Table 5), with a NOEC-C of 12%, a LOEC-C of 25%, and no acute (48 hr) mortality. The effluent was very dark, with a blue/violet color, and contained a large amount of suspended material.

Table 6. Summary Results of Whole Effluent Toxicity Tests of Northfield WWTF. Test Organism: *Ceriodaphnia dubia*.

Date of Sample*	Duration	Endpoint	Comments
6/25/92	Chronic 7 day	100% mortality all dilutions	Dechlorination agent?

6/08/94	Acute 48 hr.	LC50 = %100	faint red color in sample
07/08/94	Chronic 7 day	NOEC-C = 12%	renewal sample dark red
9/28/95	Chronic 7 day	NOEC-C = 12%	all samples blue; suspended matter

*Date of first sample for Chronic Tests.

The chemical analyses (Table 7) revealed copper to be the only analyte consistently at elevated levels in the effluent, in a range in concentrations from 80 to 184 µg/l. The last sample analyzed, September 1995, had a marked increase in conductivity, alkalinity, total suspended solids, aluminum, iron, zinc, ammonia, and TKN. This sample was noted at the time of sample collection to be strongly colored and with a large amount of suspended material. Levels of total phosphorus (3.7 - 6.6 mg/l) are significantly above background levels in the Dog River above the treatment plant (0.006 - 0.024 mg/l).

Table 7. Chemical and Physical Attributes of Northfield WWTF effluent. All samples were 24 hr composites.

Parameter	6/92	6/94	7/94	9/95
pH std unit	-	6.70	6.86	7.02
Alkalinity mg/l	-	67.5	65	117
Conductivity umhos/cm	-	640	605	1590
Hardness mg/l	50.2	70.0	63.0	61.7
Dissolved Oxygen mg/l	-	8.5	7.8	7.2
Total Suspended Solids mg/l	-	18.0	17.4	60.5
Aluminum µg/l	59	135	138	295
Arsenic µg/l	<5	<5	<5	<5
Cadmium µg/l	<2	<2	<2	<2
Calcium µg/l	15.4	21.4	19.3	18.8
Chromium µg/l	<10	<10	<10	<10
Copper µg/l	175	80	184	144

Iron µg/l	-	368	329	1380
Lead µg/l	<10	<5	<5	7.0
Magnesium mg/l	2.9	4.1	3.5	3.6
Mercury µg/l	<0.2	<0.2	<0.2	<0.2
Nickel µg/l	<10	<50	<50	<50
Silver µg/l	<5	<5	<5	<5
Zinc µg/l	<40	<50	<50	154
Total Phosphorus mg/l				
Nitrate + Nitrite mg-N/l	-	7.3	5.9	0.3
Nitrogen Ammonia mg-N/l	-	3.1	2.1	14.4
TKN mg-N/l	-	7.2	4.2	22.8
Volatile Organics µg/l	N.D.	N.D.	8-toluene	N.D.
Semi-volatile Organics	N.D.	N.D.	N.D.	N.D.
PCB's	N.D.	N.D.	N.D.	N.D.
Pesticides	N.D.	N.D.	N.D.	N.D.
Notes	No color noted	Faint red color	Dark red	Dark blue violet

Summary:

Overall, throughout most of its length, the Dog River is in good physical and biological condition. It is in excellent, pristine condition from Roxbury until it enters the village of Northfield. (There had been a bridge construction in the upper section, just below the village of Roxbury, and some siltation was noted.) From the mouth of Sunny Brook to Northfield village a few plants of *Elodea* occur and there are fewer trees in the riparian zone, creating an open canopy and some unstable banks. Beginning in the village of Northfield, there is a noticeable increase in fine silt and sand in the river, coming both from Union Brook and street runoff. Periphyton abundance begins to increase, and there is an increase in the biotic index, indicating slight enrichment. The Northfield waste water treatment plant has a documented impact on the periphyton, the macroinvertebrates and the fish community due to nutrient enrichment and toxicity. The river remains enriched, as reflected in the Biotic Index, but the toxic effects are attenuated downstream.

Elodea canadensis has been increasing in abundance each year. In 1992, there was only one small group of plants just below Northfield Falls. By 1995, it had dramatically increased at this site, and occurred several places downstream where the substrate was suitable, completely crossing the river channel in two places (at sites 4 and 9).

The pattern of algae growth, both spatially and seasonally, remained relatively constant from year to year, but abundance was variable. The variability was related to amounts of precipitation, run-off, stream flow, and temperature. It is hypothesized that more precipitation and consequent run-off, especially during the spring, increases non-point enrichment and leads to localized reaches of excessive algae growth (Delong and Brusven, 1992).

Recommendations:

1. The waste water treatment plant in Northfield, the single largest impact biologically and aesthetically to the Dog River, is required to be upgraded for phosphorus removal by December 31, 1997, contingent on the availability of state funds. Until the project is completed and phosphorus imputs are decreased, enrichment effects will continue to be noted. It is recommended that the plant receive high priority for state funding to complete this upgrade.

2. A Toxic Reduction Evaluation is in progress. Successful completion of this evaluation and subsequent measures to eliminate the toxicity of the effluent are essential. Preliminary results indicate that copper and or surfactants from a textile dye house may be the source of the toxicity.

3. Operation of the treatment plant needs to be improved to eliminate coloration of the Dog River with textile dyes, periodic discharges of suspended solids above the permit limit, and to control the production of ammonia in the treatment process. All of these problems may be addressed through 1. and 2. above.

4. A more thorough evaluation of the Dog River and its tributaries for additional sources of non-point enrichment. Preliminary indications are that farms along the Dog River and Sunny Brook are contributing to nutrient enrichment, and should be evaluated in terms of manure storage and application, spreading of sludge, and riparian zone management. Run-off from developed areas in Northfield and Norwich University may also be contributing nutrients.

5. Stream bank stabilization and riparian improvement projects at several locations in the watershed will help limit the amount of silt and sand in the river, decrease algae and macrophyte growth through shading, decrease the amount of silty substrate to inhibit the spread of *Elodea canadensis*, while protecting important fish habitat. Coordination with Natural Resource Conservation Service.

6. In-stream structures could enhance fish habitat in several reaches of the river that have been channelized along Rt. 12 and the railroad tracks. Coordination with Fish and Wildlife.

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