An Overview of Champion International'sBenthological Water Quality Studies of the Clark Fork River

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Abstract

Benthological studies to define effluent impact have been conducted since 1956 at the pulp mill of Champion International Corporation near Missoula, Montana. The macroinvertebrates inhabiting riffle environments of the Clark Fork River are used to indicate water quality. The present study design uses the collection of replicate Surber samples from nine sites (three control plus six experimental) in a 20-mile river reach to characterize the fauna. Impact is determined by community analysis.

Present and historical data show no significant mill impact upon taxa occurrence within the study area. Plecoptera, Ephemoroptera, Trichoptera and Diptera constitute the dominant groups at all study sites. Study data as recent as 1984 document a limited and localized increase in organism abundance relative to the mill. Stream enrichment is indicated. Overall water quality is altered only slightly by treatment wastewater from the mill.

Introduction

Champion International Corporation presently owns and operates a kraft linerboard mill near Missoula, Montana (Frenchtown Mill), which began operation in the fall of 1957 (15). Estimated present mill production is 1,830 tons per day of kraft linerboard (6).

Process water usage at the Frenchtown Mill is approximately 21 million gallons per day (6). Mill wastewater treatment practices have evolved from simple ponding and regulated release to the present-day system, which includes clarification, aerated stabilization lagooning, rapid infiltration and controlled continuous release.

The Aquatic Biology Group of The Institute of Paper Chemistry has conducted biological assessments of the Clark Fork River since 1956. Most of these studies took the form of annual benthological water quality studies utilizing the resident invertebrate communities of the river. The benthic invertebrate complex was chosen for this monitoring effort because of its proven ability as an indicator of habitat quality (9), limited mobility and relatively long development period for many of these animals (18), and relatively low cost of this approach compared with chemical analysis (16). The remainder of this paper details the sampling approach and results from select studies through this 28-year history of Clark Fork River surveys.

Methods

Field Sampling

The study area for these Clark Fork River investigations extends from Missoula to Alberton, Montana (fig. 1). Sampling positions within the study area varied, particularly during the earlier studies. However, a core of nine stations (three controls and six experimentals) eventually emerged as the key monitoring locations (table 1). The river throughout the study area is characterized by riffles and deep run pools.

The benthos samples, upon which these studies are based, are collected from natural riffle habitats. Quantitative estimates of the invertebrates at these sites are obtained with a Surber sampler. All material within the open frame of the sampler is removed and examined for attached and/or associated organisms. All sites selected for sampling are similar in depth (6 to 12 inches), substrate composition (cobbles and gravel), and current velocity (2 to 4 ft/s). Four samples are collected at each station (exception: early studies).

Field collections are generally made during mid to late summer (July- September). Most recent studies have consistently occurred during the third week in August. This time period usually coincides with lowest river discharge and highest water temperatures.

The benthos collections are sieved (U.S. No.30 screen) in the field to reduce sample volume. Material retained on the sieve is transferred to containers and preserved with buffered formalin (approximately 10% by volume). All identifications and enumerations take place at The Institute of Paper Chemistry, Appleton, Wisconsin.

Laboratory Analysis

The laboratory analysis of the samples collected from 1956 through 1970 reflected the then current state of the art for benthos investigations. The Trichoptera, Plecoptera, and Ephemeroptera in general were given good systematic treatment. The Diptera, a major Clark Fork River group, received only a cursory taxonomic treatment.

Beginning with the 1971 samples, the following procedures were implemented and continue in the current studies. Individual samples are sorted under a low-power lens (approximately lOX) to separate the organisms from the other debris. Representatives of the Family Chironomidae (midges) and Class Oligochaeta (worms) are prepared for identification using the suggestions of Beck and Brinkhurst, respectively (3,5). Additionally, beginning in 1978, rose bengal stain was added to the -sample prior to sorting to aid in the recognition of small and inconspicuous organisms (8).

Identifications are carried to genus and/or species levels as permitted by available biological keys. Unusual or taxonomically difficult specimens are submitted to outside consultants (Ephemeroptera: Dr. W. McCafferty; Trichoptera: Dr. J. Unzicker; Plecoptera: Dr. R. Baumann; Oligochaeta: Mr. J. Hiltunen; Diptera: Dr. W. Coffman).

Data Analysis

All replicate benthos data for a sampling station are pooled. and mean abundance for each taxon is calculated. The impact assessment is based on changes in the diversity, density and taxonomic composition of the benthos community. Comparisons are conducted using a control vs. experimental design. Objective community analysis through multivariate clustering is also employed. The clustering technique utilizes the coefficient of similarity as developed by Tesmer and others (12).

Results and Discussion

Early Studies

For purposes of this presentation I have summarized the early Frenchtown Mill river studies by contrasting the 1956-57 data (premill) with the 1958 and 1974 data (mill operational) for three reference sites (fig. 2). The year 1974 was selected as an endpoint because the wastewater treatment system at the Frenchtown Mill emerged in largely its present form in the fall of that year and conveniently separates histor1cal from current conditions.

The early community composition based on taxa richness (fig. 2A), while variable, shows that the Clark Fork River supports an invertebrate fauna comprised, mainly of Plecoptera, Ephemeroptera, Trichoptera and Diptera. Only minor taxonomic compositional changes are evident either temporally at a site or spatially. even following mill startup. The 1974 information stands out largely on the basis of a more extensive taxonomic treatment of the chironomid dipterans.

Community composition based on abundance (fig. 2B) shows temporal and spatial variability within the Clark Fork River invertebrate community and suggests several water quality relationships. The fish kill of 1958 (11) is evidenced in the outfall area and Huson samples by significant reductions in the Trichoptera and increases in Diptera. The 1974 data also depict a reduction in Trichoptera density from Harper Bridge to outfall area sites; however, these forms recover at the Huson site. Ephemeroptera abundance displays an inverse relationship at the control and experimental sites compared to the caddis flies. In general. the magnitude of the 1974 water quality impacts is small and typifies the period 1959-73.

Present Studies

Taxa Inventory

The present Clark Fork River study area fauna is quite diverse (78 taxa from the 1983-84 samples) (table 2). Diptera represent the most diverse group (31 taxa). The Ephemeroptera are also well represented (14 taxa). Other groups contributing significantly to the total invertebrate complex include the Trichoptera (10 taxa), Plecoptera (9 taxa), and the Oligochaeta (8 taxa).

Forty-eight taxa are common to both the control and experimental portions of the study area. Twenty-one taxa are found only at the experimental sites, while six taxa are restricted to the control area. Unequal sampling effort within these two zones may have biased these numbers. Treated Frenchtown Hill effluent does not appear to limit occurrence among the sampling locations.

Approximately one-half of the taxa found within the Clark Fork River study area have previous Montana occurrence records (2,11,12,13,14). Most taxa are reophilic organisms showing a preference for lotic erosional habitats (10). Only minor speciation changes are currently taking place (1978-84).

Community Composition

Species richness at each site has remained relatively constant through the recent studies. Generally, diversity ranges from 30 to 45 taxa per site. No significant disruptions of the basic compositional status of the Plecoptera, Ephemeroptera, Trichoptera, or Diptera are apparent in recent data fig. 3). Control and experimental site comparisons of species richness do not indicate any water quality degradation relative to the Frenchtown Mill.

The current Plecoptera standing crop is quite sparse, but universally present among the sampling locations (table 3). Pteronarcella badia is relatively abundant at the control sites, while Isogenoides elongatus is relatively dominant at the experimental sites. Compositional changes in the Plecoptera among the sites appear to reflect microhabitat inconsistencies, particularly rock size and percentage of finer material in the riffle, rather than Frenchtown Mill effluent impact.

Ephemeroptera nymphs of the Family Baetidae (Baetis sp., B. insignifiaans. B. triaaudatus) are the dominant mayflies within the study area. Current abundance for these forms is approximately 10 times that noted in the early studies in this series and work of Averett and Brinck (1). The response to Frenchtown Mill effluent by these forms ranges from none to slight and is usually confined spatially to that portion of the river adjacent to the wastewater treatment ponds.

While approximately eight taxa of Trichoptera are normally found at all sites studied, an unidentified species of Hydropsyahe (8. sp. 1) is the numerically dominant form. Typically this organism will constitute between 30% and 45% of the total fauna at any location. The 1984 data, and to a lesser extent the 1983 data (table 3), show that Trichoptera abundance increases in the vicinity of the Frenchtown Mill and then decreases to baseline levels as distance from the mill increases. While the exact mechanism resulting in this change is beyond the scope of these studies, the effluent functioning as an additional food source (7,19) or fostering food growth (4) is suspected.

The current Diptera community in the Clark Fork River study area is quite diverse and several taxa are relatively abundant. Principal community components found upstream as well as downstream from the Frenchtown Mill include Cardioaladius sp., Eukiefferiella pseudomontana group, several species of Orthoaladius, and the Family Simulidae (Prosimulium and Simulium). The spatial and temporal occurrence of the Family Simulidae appear independent of water quality changes relative to the Frenchtown Mill. The dynamics of these forms, generally acknowledged to be poor indicators, are ignored to the extent possible in assessing the Diptera throughout these studies. Most of the other Diptera follow closely the pattern described for the Trichoptera. Peak numbers are usually reached in the immediate vicinity of the Frenchtown Mill. Added food reserves and/or additional protective cover (e.g., thicker periphytic growths) provided by mill effluent are suspected as contributing to these increases in abundance.

In summary, the community composition parameters of diversity and density, as documented through the recent studies, indicate that the Frenchtown Mill impact is almost exclusively expressed by fauna density. Further, these take the form of density increases, changes in organism abundance usually thereby showing an enrichment of the system due to treated mill wastes. Spatially, only those areas nearby to the Frenchtown Mill appear to be affected. The overall water quality of the Clark Fork River does not appear degraded to any significant degree.

Cluster Analysis

Cluster analysis of the 1984 Clark Fork River data (fig. 4) shows several groupings of stations based on faunal similarities as well as the overall basic constancy within the study area. The particular associations as found through the recent studies are variable; however, most depict good similarity between control and experimental stations. Such relationships among the sites existed even before the Frenchtown Mill began effluent discharge. The changes of station alignments between the 1983 and 1984 studies may indicate another adjustment of the fauna relative to the present practice of continuous discharge of Frenchtown Mill effluent. Additional studies under the current effluent discharge regimen are needed to evaluate the situation at Stations 7,81, 8R, and 9. Cluster analysis of all current data sets, in general, depicts all stations as having highly similar faunas and supports the conclusions of minimal impact for the Frenchtown Mill drawn by the subjective analysis of invertebrate composition.

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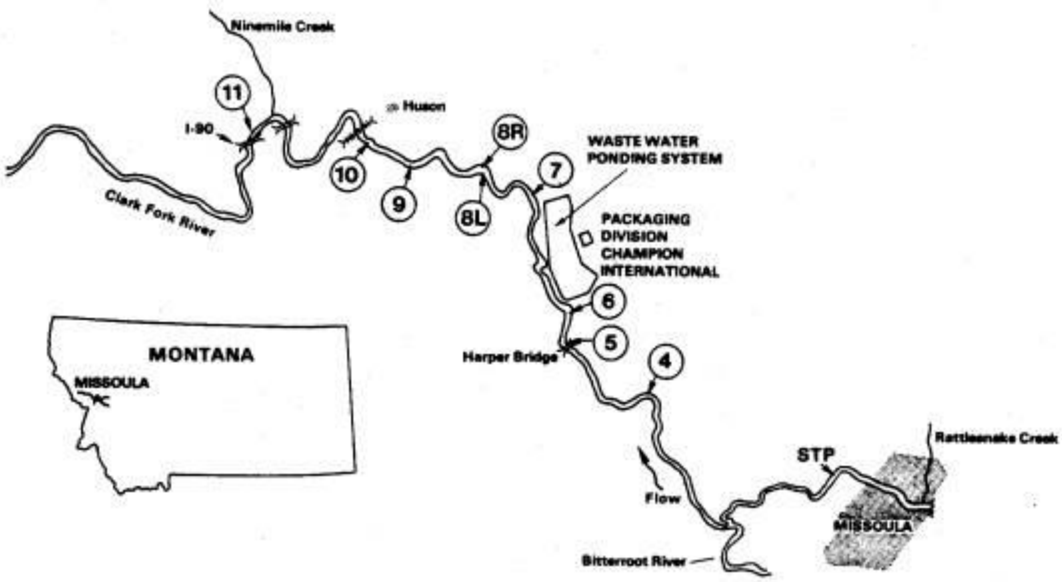

Figure 1. Map of Clark Fork River showing benthological sampling stations.

Table 1.--Benthic invertebrate sampling positions for Frenchtown Mill studies, Clark Fork River, Montana

Study reach	Station number	Mileage[1]	Location (Left Bank-Right Bank)[2]
Control	4	25.6	Sherman Gulch, upstream Warm Slough (LB)
	5	28.5	Harper Bridge (RB)
	6	30.6	O'Keefe Creek, near Indian Face Cliff (RB)
Outfall		32.0	Champion Diffuser
	7	32.2	Just downstream Champion Diffuser (RB)
	8R	33.6	Downstream "Marcure" Slough (RB)
	8L	33.6	Downstream "Marcure" Slough (LB)
	9	36.5	Approximately 5 miles downstream Champion Diffuser (LB)
	10	40.5	Upstream Huson Trestle (LB)
	11	47.0	Interstate bridge downstream Nine Mile Creek (RB)

[1]Mileage index follows that used by Montana Water Quality Bureau.

[2]Riverbanks are referenced with observer looking downstream.

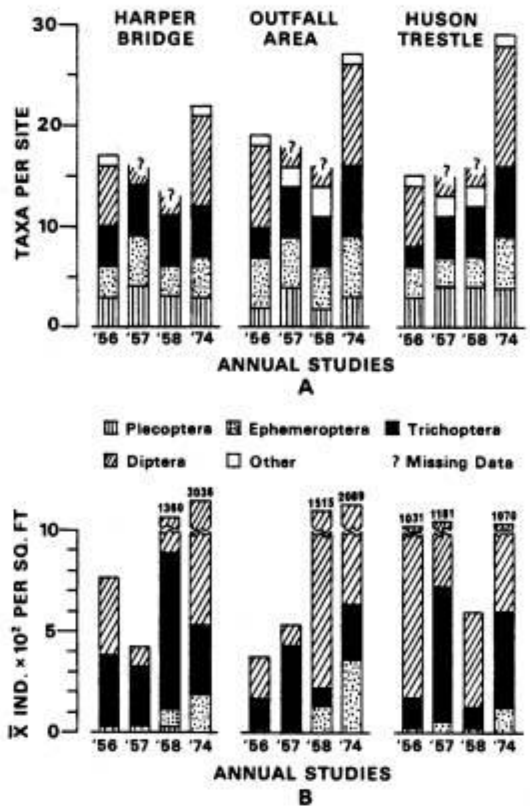

Figure 2. Histograms depicting Clark Fork River benthos composition at selected sites for the years 1956, 1957, 1958, and 1974.

Table 2.--Fauna currently present in the Clark Fork River study area

Order/Class	Taxon
Nematoda	
	Unidentified
Oligochaeta	
	Aulodrilus pluriseta
	Family Enchytraeidae
	Limnodrilus hoffmeisteri
	Nais behningi
	Nais communis
	Ophidonais serpentina
	Pristina foreli
	P. osborni
Plecoptera	
	Family Chloroperlidae
	Claassenia sabulosa
	Cultus sp.
	Hesperoperla pacifica
	Isogenoides elongatus
	Pteronarcella badia
	Pteronarcys californica
	Skwala sp.
Ephemeroptera	
	Attenella margarita
	Baetis hageni
	B. insignificans
	B. cf. tricaudatus
	Drunella grandis
	Epeorus albertae
	Heptagenia sp.
	Paraleptophlebia bicornuta
	Pseudocloeon sp.
	Rithrogena hageni
	R. morrisoni
	R. undulata
	Serratella tibialis
	Tricorythodes sp.
Aquatic Coleoptera	
	Cleptelmis sp.
	Family Hydrophilidae
	Optioservus percosensis
	O. seriatus
Trichoptera	
	Alisotrichia sp.
	Arctopsyche grandis
Trichoptera (Continued)	
	Brachycentrus occidentalis
	Cheumatopsyche sp.
	Glossosoma sp.
	Hydropsyche sp. 1
	H. sp. 3
	Psychomyia flavida
	Symphitopsyche sp. 2
	Zumatrichia notosa
Diptera	
	Antocha sp.
	Atherix pachypus
	Cardiocladius sp.
	Cladotanytarsus vanderwulpi group
	Corynoneura sp.
	Cricotopus (C.) cf. bicinctus group
	C. (C.) trifascia group
	Family Empididae
	Eukiefferiella pseudomontana group
	Hexatoma sp.
	Micropsectra sp.
	Microtendipes tarsalis
	Nanocladius parvulus group nr. rectinervus
	Nilotanypus sp.
	Orthocladius (Euorthocladius) sp.
	O. (Orthocladius) sp. 1
	O. (Orthocladius) sp. 2
	O. (Orthocladius) nr. obumbratus
	Pentaneura sp.
	Phaenopsectra sp.
	Polypedilum fallax
	Prosimulium sp.
	Protanyderus sp.
	Protanypus sp.
	Rheotanytarsus exiguus group
	Simulium sp.
	Synorthocladius sp.
	Tanytarsus coffmani
	Thienemanniella sp.
	Thienemannimyia group
	Tvetenia discoloripes group
Hemiptera	
	Family Corixidae
Aquatic Lepidoptera	
	Parargyractis sp.

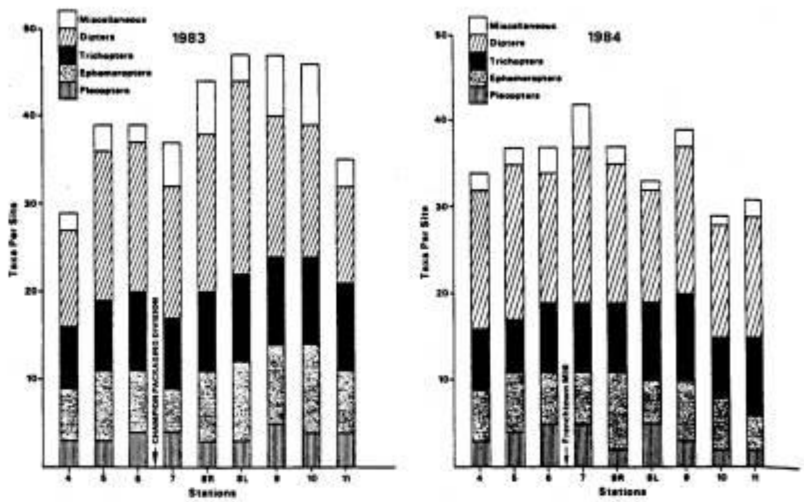

Figure 3. Histograms of 1983-84 Clark Fork River species richness.

Table 3.--A comparison of Clark Fork River major group invertebrate abundance, 1984, 1983, and the period 1978-82 (data given as individuals per ft^2)

Major Group	Year	Stations							
		4	5	6	7	8R	8L	9	10
Plecoptera	1984	8	14	7	6	8	15	6	1
	1983	2	3	7	4	15	7	14	26
	$\bar{x}$ 1978-82	5	5	7	5	9	8	7	5
Ephemeroptera	1984	302	762	421	535	335	489	243	390
	1983	264	346	365	145	281	280	274	486
	$\bar{x}$ 1978-82	369	372	367	344	226	288	369	276
Trichoptera	1984	793	1344	1239	2037	1060	1868	1131	1202
	1983	453	478	996	750	587	647	705	785
	$\bar{x}$ 1978-82	489	622	879	753	696	1105	1017	932
Diptera	1984	720	1276	622	1174	1201	1171	839	910
	1983	945	702	1081	2157	938	683	782	474
	$\bar{x}$ 1978-82	786	614	767	772	585	903	826	864
Total	1984	1827	3400	2292	3767	2609	3544	2225	2505
	1983	1665	1532	2456	3066	1856	1623	1787	1874
	$\bar{x}$ 1978-82	1654	1615	2022	1883	1524	2308	2223	2085

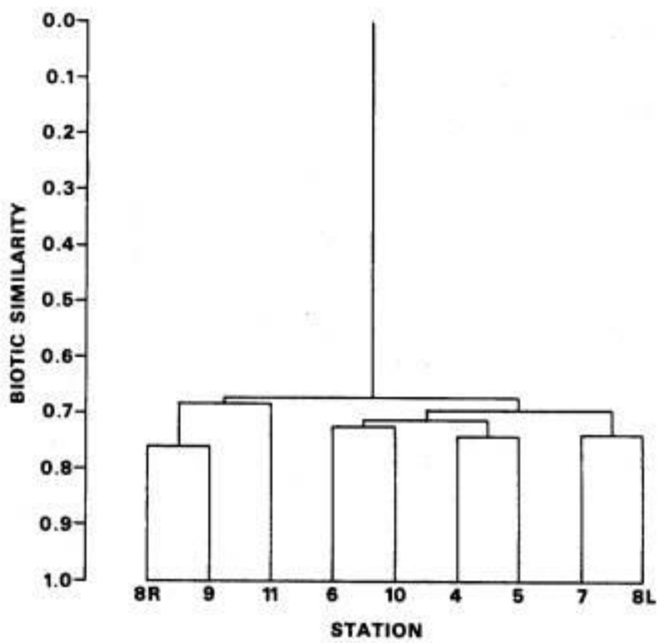

Figure 4. Cluster analysis dendogram of 1984 Clark Fork River invertebrate data.

Table 4.--A comparison of Clark Fork River cluster analysis results for selected study years. Station clusters were derived using a 0.7 biotic similarity level

Year	Cluster	Station Number
1956	1	(5) , (6)
	2	10
1957	1	(5) , 8R
	2	(6) , 10 , 11
1983	1	(4) , 7
	2	(5) , (6) , 8L , 8R , 9 , 11
	3	10
1984	1	(4) , (5) , (6) , 10
	2	7 , 8L
	3	8R , 9
	4	11

( ) = Denotes Clark Fork River control area.
4 = Sherman Gulch.
5 = Harper Bridge.
6 = O'Keefe Creek.
7 = Champion diffuser.
8L = Marcure - left.
8R = Marcure - right.
9 = 5 Miles DS diffuser.
10 = Huson.
11 = Interstate Bridge.