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EFFECTS OF TFM LAMPRICIDE TREATMENT OF STREAMS ON RESIDENT TROUT POPULATIONS AND BENTHIC COMMUNITIES[1]

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[1]Contribution from Dingell-Johnson Project F-35-R, Michigan

Abstract

Benthic fauna in the Betsie, Baldwin, and Green rivers, and both benthos and trout in the Sturgeon River, were studied for effects of lampricide treatments with 3-trifluormethyl-4-nitrophenol (TFM).

Sensitive species of benthos were reduced in the treated area of the Baldwin River and there was some evidence of reduction (although not significant) in the Green and Sturgeon rivers. However, Betsie River showed no effect of TFM 4 years after treatment. The Betsie River was resampled on August 9-10, 1983, just 3 days following TFM treatment. Dead lamprey ammocoetes were evident throughout the treated area, however, numbers of mayfly nymphs were not diminished. No differences in the trout population of the Sturgeon River were evident.

Introduction

Rivers tributary to the Great Lakes are repeatedly treated with 3-trifluoromethyl-4-nitrophenol (TFM) to control sea lamprey ammocoetes. Stream treatments were started in 1961 and most lamprey spawning streams have been treated every 3 to 5 years since. Some streams have thus been treated as many as seven times.

A considerable amount of research has been done on the effects of lamprey treatments on non-target organisms. The principle emphasis of the research has been in the area of acute toxicity evaluations on important species of benthic macroinvertebrates, and short-term evaluations of stream benthic communities. Gilderhus and Johnson (1980) have presented an excellent review of the available literature concerning the effects of TFM on aquatic plants, invertebrates, and amphibians.

The minimum effective and maximum allowable concentrations of TFM are usually 1-3 and 3-9 mg per liter, respectively, in Lake Superior tributaries, and 2-8 and 6-16 mg per liter, respectively, in tributaries of lakes Michigan and Huron (Smith and Braem 1976).

Aquatic insects vary greatly in sensitivity even within orders. Megaloptera (24-hour LC50 of 36 mg per liter), Odonata (24-hour LC50 of 38 mg per liter), and Hemiptera (24-hour LC50 of 20 mg per liter) are particularly resistant (Maki et al. 1975). Diptera appear to be resistant with the exception of Simuliidae (24-hour LC50 of 5-6 mg per liter) (Smith 1967). Ephemeroptera and Trichoptera have a wide range of sensitivity to TFM. Resistance of mayflies may range from 40 mg per liter to as low as 2.5 mg per liter depending on species involved, pH, and total hardness of the treated water (Fremling 1975; Maki 1974; Chandler and Marking 1975; Smith 1967). Smith (1967) documented 50% mortality of _Hexagenia_ at 5 mg per liter.

Sensitivity of Trichoptera seems to vary greatly between case builders and net builders (Smith 1967). Torblaa (1968) recorded declines as high as 94% of numbers of caddisfly larvae in study streams within 1 week after treatment with TFM.

In general, the above studies indicate that stream treatment levels of TFM are toxic to Simuliidae and several species of Ephemeroptera and Trichoptera.

Crustaceans appear to be resistant to TFM. Maki et al. (1975) reported 24-hour LC50 values of 26 mg per liter for Daphnia magna, 38 mg per liter for Gammarus sp., and 36 to 46 mg per liter for crayfish.

Field studies have demonstrated a decline in benthic fauna immediately following TFM application (Torblaa 1968, Haas 1970). Torblaa reported recovery of the population within 1 year.

Severe mortality of suckers and stonecats is known to occur, and in two rivers of lower Michigan (Little Manistee and Rifle rivers) as many as 2,000 brown trout were killed.

Although numerous short-term studies have been completed on fish and invertebrates, there has not been a stream study of the long-term effects of repeated applications of TFM. The objective of this study was to assess the long-range impact of repeated lampricide treatments on stream fish and benthic communities by comparing populations in treated streams with comparable untreated upstream reaches of the same rivers.

Methods

Trout population estimates were conducted on the Sturgeon River, and benthic fauna were studied on the Green River, Baldwin River, Betsie River, and Sturgeon River (Table 1).

Considerable effort was devoted to choosing study streams for this job. Criteria established for selecting study streams were: (1) similar stream habitat above and below the application point, (2) application point consistent for past several treatments, (3) diverse habitat to include both riffle fauna and burrowing mayflies, (4) not intensively used as a salmon spawning stream, and (5) a resident population of brown trout.

The Green and Baldwin rivers are treated downstream from low-head dams. The dams on both rivers furnish an impounded water supply for small private trout hatcheries. These small impoundments necessitated going upstream a short distance to locate a suitable control area. It is possible the hatcheries result in enrichment of the control (untreated) areas and a consequent increased productivity. However, it is unlikely they degrade the water quality.

The Betsie River is treated downstream from a low-head lamprey barrier dam which necessitated locating the control station a minimum of 5 km upstream. However, both the control and treated sites contained good habitat for burrowing mayflies, and appeared to be ecologically similar. Riffle fauna was not sampled in the Betsie River.

Lamprey do not spawn in the headwaters of the Sturgeon River, and the stream above the upstream application point is a good control for the treated section. Only burrowing mayflies were sampled in the Sturgeon River.

The sampling scheme was not the same for all rivers due to variable bottom types. The Baldwin River has diverse bottom types, and was thus sampled for riffle fauna and burrowing mayflies. An Ekman dredge was used to sample silt beds along the stream banks. A modified Surber sampler was used to collect riffle fauna. Ten silt beds were selected visually and three Ekman samples were taken from each silt bed.

The control area of the Baldwin River was located at the first access upstream from US-10 (T18N, R13W, Sec. 35) approximately halfway between the highway and Bray Creek campground. The treatment area was approximately 100 m downstream from the Baldwin rearing station (T17N, R13W, Sec. 2). The two areas were quite similar. The river was sampled on May 20, 1982.

Five riffle samples were collected from each of four transects in both the treatment and control areas. Samples were taken at 2-m intervals along a line stretched across the stream. If samples near the stream banks were in silt beds, an Ekman sample was taken. Only four Ekman samples were collected in the control area and one in the treatment area. It was later decided that these samples could not be compared with the Surber samples and they were discarded. Thus, there were 16 usable samples from the control area and 19 from the treatment area. A description of the river was recorded at each sample site in order to compare the treatment and control areas. The description consisted of a visual evaluation of the bottom material, the water depth, and an estimate of velocity made by recording the time required for an orange to float 20 feet downstream from the sample site (Table 2). Both areas of the Baldwin River were sampled on May 20, 1982.

Burrowing mayflies were sampled in the same control area of the Baldwin River as the riffle fauna. However, due to the fact there were no satisfactory silt beds immediately below the application point, Ekman samples were collected in the treatment area at a public access site approximately 1 km downstream from the riffle samples.

The Green River was sampled on July 21, 1982. The treatment area was sampled between Penny Bridge Road and Weber's trout ponds (T30N, R6W, Sec. 18). The control area was sampled immediately downstream from the second M-66 Bridge above the trout ponds (T30N, R6W, Sec. 18). No suitable habitat for burrowing mayflies was found so only riffle fauna was sampled. The stream flows through a thick cedar swamp, consequently transects could not be established. Thus, samples were taken at individual riffle areas, one sample per riffle. Twenty samples were taken in both the treated and the control areas. It also proved to be impossible to measure velocity at each sample site because of the number of logs and other obstructions in the stream. In general the stream was approximately 20 feet wide, less than 1 foot deep, flowing at 2 feet per second, with a bottom of clean gravel of 2-inch maximum size. The control area was not as disrupted by the cedar swamp as the treatment area and tended to be more laminar in flow with less shade.

The Betsie River was sampled for burrowing mayflies only on June 3-4, 1982, and again on August 9-10, 1983. The river was treated with TFM in 1978 and on August 6, 1983. The 1982 benthic sampling was thus 4 years following treatment, while the 1983 samples were collected 3 days after application. Dead lamprey ammocoetes were evident throughout the treated area on August 9-10, 1983, however, all mayfly nymphs seen were alive and active. In 1982, the Betsie was sampled immediately above Homestead Dam (T25N, R15W, Sec. 2) for control samples and upstream from M-31 Bridge (T25N, R15W, Sec. 2) in the treated area. Different sampling sites were chosen in 1983, because more extensive silt beds were located. The control samples were collected approximately 0.25-mile upstream from M-115 Bridge (T25N, R14W, Sec. 19), and the treated section was sampled immediately above Love Road Bridge (T26N, R15W, Sec. 34).

The 1982 samples were collected just prior to emergence. The nymphs were thus mature and species identification was possible. The 1983 samples, collected in August, contained many early instars and consequently species identification proved to be impossible.

The upstream application point on the Sturgeon River was a private bridge in the Green Timbers Club property (T32N, R2W, Sec. 21). Samples were collected approximately 200 m above and below the bridge. Silt beds tended to be small and sparse in the Sturgeon River. However, where present, they seemed to provide good habitat for burrowing mayflies. Only one or two Ekman samples were taken from each silt bed, and a total of 20 samples were collected from both the treatment and control areas. The two areas of the Sturgeon appeared to be quite similar.

Mark-and-recapture trout population estimates were conducted by electrofishing on the Sturgeon River during the period of September 30 to October 6, 1982. Estimates were made for 1 mile downstream from the application point (treatment area) and 1.5 miles of river upstream (control area).

Streams which were considered for this study and rejected are listed here (Table 3) because the reasons for rejection may prove useful to others considering similar studies. Most trout streams in the lower peninsula of Michigan were considered. Several upper peninsula rivers were considered (not listed), but none were found to contain abundant populations of burrowing mayflies.

Results and Discussion

The Sturgeon is one of the few rivers in Michigan where treatment does not extend upstream to an obvious physical or ecological barrier. It also does not have a salmon spawning run. Thus, it is a stream very well suited to study the effects of TFM.

Mark-and-recapture trout population estimates were conducted by electrofishing on 1 mile of stream below the application point and 1.5 miles above. While working in the river it was obvious many of the larger brown trout (*Salmo trutta*) were migrant fish on a spawning run from Burt Lake; also that the small rainbow trout (*Salmo gairdneri*) were migratory fish that would move downstream to Burt Lake. This was evident from the scarcity of rainbows larger than 9 inches. It thus seems a large part of the productivity of the Sturgeon River is devoted to serving as a nursery stream for Burt Lake trout. The numbers of trout per acre estimated to be in the study sections are presented in Table 4. No adverse effects of TFM in the treatment area were evident. Numbers of brook trout (Salvelinus fontinalis) were insignificant at all sizes. There were more brown trout and rainbow trout, of most all sizes, in the treatment area than in the control area.

Numbers of burrowing mayflies in the Betsie, Baldwin, and Sturgeon rivers are presented in Table 5. Lithobrancha recurvata was the only species of burrowing mayfly abundant in the Sturgeon River. The data suggest a reduction, however, due to excessive variability the differences are not significant. Larger sample sizes would be necessary to determine significance of these data.

Hexagenia limbata and Hexagenia bilineata were prevalent in the Baldwin River and both indicated a reduction in numbers in the treated area. The reduced abundance of Hexagenia limbata was significant, but the numbers of Hexagenia bilineata were not. Lithobrancha recurvata (= Hexagenia recurvata) and Ephemera simulans were also present in moderate numbers in the control area, but absent in the treated area.

Hexagenia munda, Hexagenia limbata, and Hexagenia bilineata were identified from the Betsie River in 1982. Earlier instars were sampled in 1983 making species distinction impossible. No significant differences in numbers were evident in the samples for either year. Hexagenia sp. appeared to be more abundant in the treated area in 1983. The greater abundance of nymphs in 1983 was probably due to sampling better silt beds, and to sampling shortly after emergence and egg deposition, prior to significant predation and natural mortality.

Estimated numbers of riffle fauna per square meter in the treatment and control areas of the Baldwin River are given in Table 6. Confidence limits are presented for those organisms exceeding 10 per square meter. Taxa of lesser abundance are recorded as present or absent.

Nineteen species were reduced in abundance in the treatment area while five species were more abundant there than in the control area. Sensitivity of insect larvae to TFM is known to vary considerably even within orders of insects (Gilderhus and Johnson 1980). Megaloptera (alderflies and dobsonflies), Odonata (dragonflies and damselflies), and Plecoptera (stoneflies) are among the more resistant, while Ephemeroptera (mayflies) and Trichoptera (caddisflies) are mostly quite sensitive. Diptera (flies) are resistant with the exception of black flies (Simuliidae) which are among the most sensitive forms. Precise comparisons with literature references are difficult because most workers did not report their taxa at the species level. All forms believed to be sensitive to TFM are reduced in abundance in the treated area with the exception of _Baetis flavistriga_. Sensitivity levels for this species are not available in the literature, however, _Baetis_ sp. is considered to be quite sensitive (Maki et al 1975).

Ephemerella dorothea, _Ephemerella excrucians_, _Ephemerella_ sp. A, _Ephemerella_ sp. B, _Drunella lata_, and _Drunella walkeri_ all are significantly reduced in the treatment area.

Twenty-five species present in the control area were not found in the treatment area, while the reverse occurrence was true for nine species.

Chironomidae were significantly more abundant in the treatment area. They are resistant to TFM (Smith 1967), and their abundance probably reflects increased productivity resulting from the trout rearing station.

Numbers of benthic riffle fauna collected in the Green River are given in Table 7. Twenty species were recorded in sufficient abundance to establish confidence limits. Of these species, 13 were more abundant in the treated area and 7 were more prevalent in the control area, however, few of the differences were significant. _Epeorus vitrea_ was the only mayfly significantly more numerous in the treatment area. Rithrogena impersonata and Paraleptophlebia sp. were considerably more abundant in the control area. Numbers of the caddisfly Glossoma sp. were significantly higher in the control area. As seen in the Baldwin River, the resistant Chironomidae in the treated area probably had responded to nutrient input from the trout ponds.

Two species of riffle beetles (Optioservus) were also more abundant in the treatment area. Sinclair (1964) reported these beetles to inhabit recovery zones of streams receiving treated sewage. They would thus be expected to respond to increased productivity below the trout hatchery.

Management Implications

Field studies of this kind seldom lead to positive conclusions. Regardless of the experimental design or sample size, it is always difficult to compare fauna of one reach or one river with that of another. This study indicates there may be a reduction in numbers of a few sensitive species in some streams after repeated applications of TFM. The evidence is sufficient to warrant additional studies of other treated streams and to consider an integrated approach to lamprey control.

Acknowledgments

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Table 1. Rivers selected for benthic sampling with years of TFM treatment and application points.

River	Year	Application point
Sturgeon	1966	Wolverine Rearing Station, Cheboygan Co., T33N,R2W,Sec.6
	1971	Green Timbers Bridge, Otsego Co., T32N,R2W,Sec.10
	1975	Trowbridge Road, Cheboygan Co., T33N,R2W,Sec.20
	1979	Green Timbers Bridge, Otsego Co., T32N,R2W,Sec.10
Baldwin	1968	Baldwin Rearing Station, Lake Co., T17N,R13W,Sec.3
	1972	Baldwin Rearing Station, Lake Co., T17N,R13W,Sec.3
	1976	Baldwin Rearing Station, Lake Co., T17N,R13W,Sec.3
	1979	Baldwin Rearing Station, Lake Co., T17N,R13W,Sec.3
Betsie	1963	Homestead Dam, Benzie Co., T25N,R15W,Sec.2
	1967	Homestead Dam, Benzie Co., T25N,R15W,Sec.2
	1971	Homestead Dam, Benzie Co., T25N,R15W,Sec.2
	1974	Homestead Dam, Benzie Co., T25N,R15W,Sec.2
	1978	Homestead Dam, Benzie Co., T25N,R15W,Sec.2
	1983	Homestead Dam, Benzie Co., T25N,R15W,Sec.2
Green	1961	Penny Bridge Road, Antrim Co., T30N,R6W,Sec.8
	1965	Webers Trout Pond, Antrim Co., T30N,R6W,Sec.8
	1969	Webers Trout Pond, Antrim Co., T30N,R6W,Sec.8
	1973	Webers Trout Pond, Antrim Co., T30N,R6W,Sec.8
	1977	Webers Trout Pond, Antrim Co., T30N,R6W,Sec.8
	1981	Webers Trout Pond, Antrim Co., T30N,R6W,Sec.8

Table 2. Depth, velocity, and bottom material at sample sites on the Baldwin River, May 20, 1982.

Sample	Depth (inches)	Velocity (ft./sec.)	Bottom material
Control Area			
1-A	3.2	0.0	Silt (Ekman sample)
1-B	21.7	0.8	Sand and gravel, 2-inch maximum
1-C	24.8	2.0	Sand and gravel, 2-inch maximum
1-D	24.8	2.0	Sand and gravel, 2-inch maximum
1-E	18.0	1.0	Sand and gravel, 2-inch maximum
2-A	18.0	1.3	Sand
2-B	16.0	2.1	Sand and gravel, 2-inch maximum
2-C	21.7	2.0	Sand and gravel, 2-inch maximum
2-D	21.3	0.0	Silt (Ekman sample)
2-E	15.5	0.0	Silt (Ekman sample)
3-A	20.1	0.0	Silt (Ekman sample)
3-B	18.5	1.0	Sand, leaves, and detritus
3-C	18.0	2.2	Gravel, 2-inch maximum
3-D	18.0	1.4	Gravel, 2-inch maximum
3-E	14.2	0.8	Sand
4-A	13.4	1.9	Gravel, 2-inch maximum
4-B	11.0	1.7	Gravel, 2-inch maximum
4-C	9.5	2.2	Gravel, 2-inch maximum
4-D	13.0	2.0	Gravel, 2-inch maximum
4-E	14.6	1.2	Gravel, 2-inch maximum
Treatment Area			
1-A	20.0	1.7	Sand
1-B	18.5	2.0	Sand and gravel, 1-inch maximum
1-C	17.0	1.7	Sand and fine gravel
1-D	28.5	1.4	Sand and fine gravel
1-E	11.5	1.0	Sand
2-A	10.0	1.1	Sand
2-B	16.0	2.2	Sand and gravel, 2-inch maximum
2-C	22.0	2.2	Gravel, 2-inch maximum
2-D	16.5	2.2	Gravel, 2-inch maximum
2-E	10.0	0.0	Silt (Ekman sample)
3-A	5.0	1.8	Sand and gravel, 2-inch maximum
3-B	7.0	2.4	Sand and gravel, 2-inch maximum
3-C	8.3	3.0	Sand and gravel, 2-inch maximum
3-D	18.0	2.1	Sand and gravel, 2-inch maximum
3-E	20.0	2.1	Sand and gravel, 2-inch maximum
4-A	15.5	1.4	Sand
4-B	11.0	1.4	Gravel, 2-inch maximum
4-C	11.8	1.5	Gravel, 2-inch maximum
4-D	9.5	1.1	Gravel, 2-inch maximum
4-E	17.3	1.1	Sand and gravel, 2-inch maximum

Table 3. Michigan rivers, treated with TFM, which were considered for this study and rejected for various reasons.

County	River	Reason for rejection
Alcona	So. Branch Pine	limited silt beds, probably few burrowing mayflies; could be used for study of riffle fauna
Arenac	E. Br. Au Gres	treated to headwaters; no control area
Benzie	Platte	treatment sites varied
Charlevoix	Boyne	treated to Kirchers Dam; river of different character above impoundment
Charlevoix	Horton	treatment sites varied
Charlevoix and Antrim	Jordan	treatment sites have varied, but essentially the entire river is treated; no control area
Charlevoix	Loeb Creek	tributary of Lake Charlevoix; entire creek treated from outlet of Adams Lake
Charlevoix	Porter Creek	only treated at mouth in order to cover bay in Lake Charlevoix
Emmett	Big Sucker	entire stream treated; no control area
Emmett	Maple	East Branch treated from outlet of Douglas Lake; West Branch has very limited, scattered silt beds; difficult to find comparable treatment and control areas
Grand Traverse	Acme Creek	only treated in 1963
Grand Traverse	Boardman	treated to Sabin Dam, river of much different character above impoundment
Grand Traverse	Mitchell Creek	small; stream bed silt with very little gravel
Grand Traverse	Yuba Creek	small; entire stream treated; no control area
Isoco	Silver Creek	treated to Dailey's Dam; stream small above dam

Table 3. Continued:

County	River	Reason for rejection
Manistee	Big Manistee	treated to Tippy Dam; river too large below dam for satisfactory benthic sampling and of different character above impoundment
Manistee, Mason, and Lake	Little Manistee	treated to dam at Luther; stream of much different character above impoundment
Manistee	Pine Creek	entire stream treated; no control area
Mason	Gurney Creek	slow, brown water, sand bottom, canopy of tag alders, probably not a trout stream
Mason	Lincoln	entire stream treated; no control area
Mason and Lake	Pere Marquette	most tributaries treated to the headwaters including Big South Branch, Little South Branch, Middle Branch, Danaher Creek, and McDuffee Creek; no suitable control area; only exception was Baldwin River which was selected for study
Newaygo	White	treated to dam at White Cloud; river of different character above impoundment; no control area
Oceana	No. Br. White	treated to headwaters; no control area
Oceana	Pentwater	treated to headwaters; no control area
Oceana	Stony Creek	treated to headwaters; no control area
Ogema and Arenac	Rifle	the Rifle River and most tributaries were treated to the headwaters; no control areas. Tributaries considered included Houghton Creek, Vaughan Creek, Gamble Creek, Klacking Creek, and West Branch Rifle
Presque Isle	Ocqueoc	treatment sites varied; limited silt beds with probably few burrowing mayflies; could be used to study riffle fauna
Presque Isle	Trout	small; treatment sites varied

Table 4. Number per acre of brown trout, rainbow trout, and brook trout estimated to be present in 1 mile of the Sturgeon River downstream from the TFM application point (treatment area), and in 1.5 miles of river upstream (control area).

Size group (inches)	Treatment area				Control area			
	Brown	Rainbow	Brook	All trout	Brown	Rainbow	Brook	All trout
1	0.0	0.6	0.0	0.6	0.0	1.5	0.0	1.5
2	0.0	45.7	0.2	45.9	0.5	44.0	0.0	44.5
3	131.1	10.6	2.0	143.7	52.1	33.7	2.1	87.9
4	42.1	1.6	0.2	43.9	50.8	0.3	0.5	51.6
5	41.7	9.4	1.6	52.7	22.4	18.2	1.1	41.7
6	67.9	35.3	5.6	108.8	65.8	22.0	0.8	88.6
7	41.9	14.0	4.8	60.7	37.2	4.0	2.8	44.0
Total 1-7				456.3				359.8
8	34.5	1.6	0.4	36.5	29.8	0.6	0.8	31.2
9	17.0	0.6	0.2	17.8	16.3	0.2	0.2	16.7
10	13.6	0.0	0.0	13.6	9.3	0.0	0.0	9.3
11	3.8	0.0	0.0	3.8	6.0	0.2	0.2	6.4
Total 8-11				71.7				63.6
12	4.2	0.0	0.0	4.2	3.8	0.0	0.0	3.8
13	1.8	0.0	0.0	1.8	12.2	0.2	0.0	12.4
14	0.8	0.0	0.0	0.8	1.2	0.0	0.0	1.2
15	0.6	0.0	0.0	0.6	1.2	0.0	0.0	1.2
Total 12-15				7.4				18.6
16	1.2	0.0	0.0	1.2	0.5	0.2	0.0	0.7
17	0.4	0.0	0.0	0.4	0.6	0.0	0.0	0.6
18	1.6	0.0	0.0	1.6	0.5	0.0	0.0	0.5
19	2.4	0.0	0.0	2.4	0.3	0.0	0.0	0.3
20	0.6	0.0	0.0	0.6	0.3	0.0	0.0	0.3
21	0.4	0.0	0.0	0.4	0.3	0.0	0.0	0.3
22	0.2	0.0	0.0	0.2	0.3	0.0	0.0	0.3
23	0.4	0.0	0.0	0.4	0.2	0.0	0.0	0.2
24	0.2	0.0	0.0	0.2	0.2	0.0	0.0	0.2
25	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.3
Total 16+				7.4				3.7
Grand total				542.8				445.7

Table 5. Numbers of burrowing mayflies (Ephemeroptera: Ephemeridae) per square meter in TFM treatment and control sections of three Michigan rivers, 1982 and 1983.

Taxa	Date sampled	Treatment area Number per M^2 ±95% confidence limits	Control area Number per M^2 ±95% confidence limits
BETSIE RIVER			
Hexagenia munda	6/3-4/82	124.7± 31.5	106.6± 23.9
Hexagenia limbata	6/3-4/82	29.6± 10.5	44.4± 16.8
Hexagenia bilineata	6/3-4/82	34.0± 12.7	68.1± 22.0
Hexagenia sp.	8/09/83	705.9±112.9	542.2±113.9
BALDWIN RIVER			
Hexagenia limbata	6/19-20/82	40.0± 13.2	236.0± 45.3
Hexagenia bilineata	6/19-20/82	22.9± 14.2	40.0± 17.1
Lithobrancha recurvata	6/19-20/82	0	32.9± 17.7
Ephemera simulans	6/19-20/82	0	5.7± 5.3
STURGEON RIVER			
Lithobrancha recurvata	9/03/82	71.6± 60.9	204.0±104.0

Table 6. Numbers of riffle organisms per square meter in TFM treatment and control sections of the Baldwin River, May 19-20, 1982. Organisms with less than 10 individuals per square meter recorded only as present (X) or absent (0).

Taxa	Treatment area Number per M^2 ±95% confidence limits	Control area Number per M^2 ±95% confidence limits
EPHEMEROPTERA		
Ephemerella dorothea	9.3± 5.7	60.7± 34.6
Ephemerella excrucians	49.9±15.7	301.5±118.4
Ephemerella needhami	X	X
Ephemerella species A[1]	21.5±11.3	92.5± 37.4
Ephemerella species B[2]	23.2±12.5	238.7± 75.5
Drunella lata	38.9±20.7	676.9±165.6
Drunella walkeri	17.4±16.3	110.4± 55.8
Danella sp.	X	X
Epeorus vitrea	X	X
Caenis sp.	X	0
Rithrogenia impersonata	X	X
Stenonema sp.	X	0
Paraleptophlebia sp.	X	X
Pseudocloeon sp.	X	X
Baetis tricaudatus(=vagans)	13.9± 7.1	0
Baetis flavistriga	274.9±87.0	42.1± 18.2
Baetis macdunnoughi	X	0
Hexagenia limbata	0	X
Litobrancha recurvata	0	X
Ephemera simulans	0	X
Serratella deficiens	0	X
ODONATA		
Cordulegaster sp.	0	X
Hylogomphus sp.	0	X
Ophiogomphus sp.	0	X
Stylogompus sp.	0	X
PLECOPTERA		
Pteronarcys sp.	X	0
Isoperla sp.	X	X
Paragnetina sp.	0	X
MEGALOPTERA		
Nigronia sp.	0	X
Sialis sp.	0	X

Table 6. Continued:

Taxa	Treatment area Number per M^2 ±95% confidence limits	Control area Number per M^2 ±95% confidence limits
TRICHOPTERA		
Symphitopsyche sparna	X	X
Symphitopsyche slossonae	13.3± 7.3	17.3± 18.3
Symphitopsyche sp.	0	X
Hydropsychidae	0	X
Cheumatopsyche sp.	X	X
Hydroptila sp.	29.6± 13.0	32.4± 41.0
Brachycentrus sp.	X	11.0± 11.0
Micrasema sp.	X	X
Protoptila sp.	8.1± 5.6	36.6±104.8
Lepidostoma sp.	0	28.9± 12.1
Glossoma sp.	0	89.0± 47.1
Neophylax sp.	0	18.6± 18.3
Nyctiophylax sp.	0	X
Symphitopsyche sp.	0	X
Hydropsyche sp.	0	X
Lype sp.	0	X
Pycnopsyche sp.	0	X
COLEOPTERA		
Optioservus sp.	20.3± 7.6	221.5± 72.2
Optioservus ovalis	X	0
Optioservus trivittatus	182.1±134.9	111.1± 58.0
Optioservus fastiditus	23.8± 12.7	15.8± 7.8
DIPTERA		
Tipulidae	X	0
Chironomidae	101.3±542.2	420.9±276.3
Ceratopogonidae	X	0
Tabanidae	12.1± 10.3	22.8± 14.1
Simulium sp.	37.7± 26.0	104.9± 81.8
Atherix sp.	X	20.7± 12.4
Dicranota sp.	X	X
Hexatoma sp.	9.9± 4.8	29.0± 11.6
Empididae	0	X
Antocha sp.	0	X
Tipula	0	X

[1] *Ephemerella* species A is intermediate between *E. dorothea* and *E. excrucians*.

[2] *Ephemerella* species B is either *E. rotunda* or *E. invaria*: adults are needed for positive identification.

Table 7. Numbers of benthic organisms per square meter in TFM treatment and control sections of the Green River, July 1982. Organisms with less than 10 individuals per square meter recorded only as present (X) or absent (0).

Taxa	Treatment area Number per M^2 ±95% confidence limits	Control area Number per M^2 ±95% confidence limits
EPHEMEROPTERA		
Ephemerella dorothea	30.8± 22.5	16.8± 9.4
Ephemerella excrucians	10.5± 8.4	16.8±16.2
Ephemerella needhami	X	18.6±14.2
Ephemerella species A[1]	74.8± 21.0	69.1±20.1
Ephemerella species B[2]	76.5± 21.7	58.6±23.1
Ephemerella aurivilli	X	X
Drunella lata	102.9± 37.6	85.3±35.7
Drunella walkeri	X	X
Epeorus vitrea	38.5± 17.4	X
Rithrogenia impersonata	22.0± 11.1	174.0±56.2
Paraleptophlebia sp.	X	118.3±47.2
Heptagenia sp.	X	X
Baetis tricaudatus	317.4±106.9	371.2±89.6
Baetis flavistriga	X	0
Baetis pygmaeus	X	0
Baetis sp.	X	0
DIPTERA		
Chironomidae	972.9±672.9	77.1±32.2
Ceratopogonidae	X	X
Simulium sp.	29.7± 19.0	92.8±81.6
Antocha sp.	16.5± 8.1	X
Dicranota sp.	X	X
Pedicia sp.	X	0
Empididae	X	X
PLECOPTERA		
Isoperla sp.	34.7± 11.9	23.8±13.2
Amphinemura sp.	X	X
Isogenoides sp.	X	X
COLEOPTERA		
Optioservus fastiditus	150.2± 41.8	23.8±10.7
Optioservus sp.	184.8± 61.2	81.2±29.6

Table 7. Continued:

Taxa	Treatment area Number per M^2 ±95% confidence limits	Control area Number per M^2 ±95% confidence limits
TRICHOPTERA		
Hydroptila sp.	X	0
Neophylax sp.	39.6±27.2	X
Glossosoma sp.	68.7±28.2	328.9±154.2
Rhyacophila acropedes	73.7±28.1	56.8± 23.2
Symphitopsyche sp.	X	X
Hydropsychidae	X	X
Cheumatopsyche sp.	14.3± 7.3	0
Brachycentrus sp.	X	X
Dolophilodes sp.	0	X
Lepidostoma sp.	0	X

[1] *Ephemerella* species A is intermediate between *E. dorothea* and *E. excrucians*.

[2] *Ephemerella* species B is either *E. rotunda* or *E. invaria*: adults are needed for positive identification.

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