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Effects of Lamprey Larvicides on Invertebrates in Streams

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By

RICHARD L. TORBLAA

Contribution No. 366, Bureau of Commercial Fisheries
Biological Laboratory, Ann Arbor, Michigan 48107

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RICHARD L. TORBLAA, Fishery Biologist

Bureau of Commercial Fisheries Biological Station
Marquette, Michigan 49855

ABSTRACT

The study was conducted on five streams tributary to Lake Superior and four tributary to Lake Michigan. Samples of the bottom fauna before and after chemical treatment revealed that most groups of aquatic organisms were not adversely affected by exposure to larvicides. The total number of invertebrates was smaller 1 week after treatment than before treatment, increased somewhat by 6 weeks after treatment, and had returned to pretreatment levels 1 year after treatment. Aquatic insects were affected less than other organisms, and invertebrates were more severely affected and recovered more slowly in areas of sand and detritus than in riffle areas.

INTRODUCTION

A program to control the sea lamprey, Petromyzon marinus, in the Great Lakes with the lamprey larvicide TFM (3-trifluoromethyl-4-nitrophenol) began in 1958 (Applegate, Howell, Moffett, Johnson, and Smith, 1961). In some treatments, 5,2'-dichloro-4'-nitrosalicylanilide (Bayluscide[1]) was used as a synergist with TFM to reduce cost (Howell, King, Smith, and Hanson, 1964). The toxicity of these compounds to several representative groups of aquatic invertebrates has been tested in the laboratory (Smith, 1967). The object of the present study was to determine the effects of these chemicals on aquatic invertebrates in natural waters.

MATERIALS AND METHODS

Streams were treated with TFM as described by Applegate et al. (1961). One stream (Three Mile Creek) was treated with a mixture of 98 percent by weight TFM and 2 percent Bayluscide (Howell et al., 1964).

Nine streams were selected for the study--five in the Lake Superior watershed and four in the Lake Michigan basin. Of these, one stream in each lake basin was an untreated control. I made collections in control streams on the same dates and in the same manner as on treated streams. The great variations in the physical and chemical characteristics of the water of the streams (Zimmerman, 1968) did not clearly influence the conclusions of this study. The nature of the substrate, however, influenced findings in different parts of a single stream.

Lake Superior streams sampled were Buck Bay Creek, Gongeau Creek, Iron River, Little Garlic River (control), and Wilson Creek; Lake Michigan streams were Little Scarboro Creek (control), Sturgeon River, Sunny Brook, and Three Mile Creek. Three Mile Creek was the only stream in this study treated with the synergistic mixture of TFM and Bayluscide. Study streams, chemical application sites, and sampling sites are shown in figures 1 and 2. Streams, locations, dates of collection, and number of samples are given in table 1.

All bottom samples were collected with a modified Hess sampler (Waters and Knapp, 1961).

Average concentrations of TFM for each treatment were above minimum lethal concentration for larval lampreys (table 2). The periods of exposure were the consecutive hours above minimum lethal concentration.

ORGANISMS COLLECTED AND IDENTIFIED

I separated organisms from the debris by a sugar flotation method (Anderson, 1959). Too

[1]Registered trade mark of Farbenfabriken Bayer AG, Leverkusen, West Germany. Mention of commercial products does not imply endorsement by the Bureau of Commercial Fisheries.

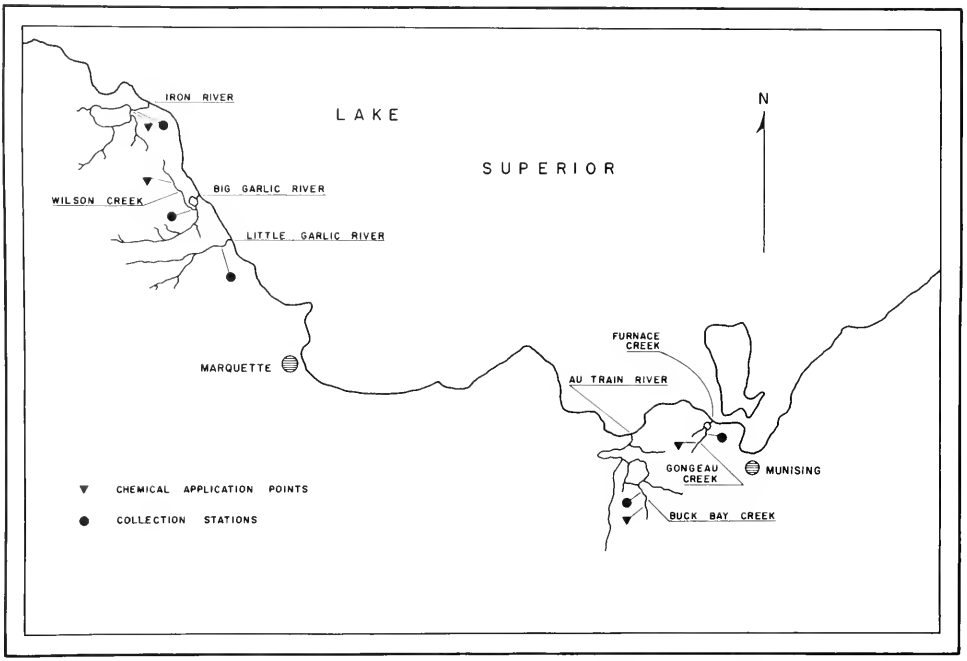

Figure 1.--Location of Lake Superior study streams, chemical application points, and collection sites in Michigan.

few individuals of most species and of some families were present for meaningful interpretation. Thus data for insects are presented for families, and sparsely represented families of an order are sometimes combined in tables and shown under the order. Data for other invertebrates are usually presented by phylum and order. Individual insects were identified to genus and species when possible. The following list (after the order of Pennak, 1953) gives the most precise identification made for various organisms.

INSECTS
- Plecoptera
  - Pteronarcidae
    - Pteronarcys
  - Nemouridae
    - Nemoura
  - Perlidae
    - Paragnetina media
    - Neoperla clymene
    - Phasganophora capitata
  - Perlodidae
    - Isoperla
  - Chloroperlidae
    - Hastaperla brevis
    - Alloperla
- Ephemeroptera
  - Ephemeridae
    - Ephemera simulans
    - Hexagenia
  - Caenidae
    - Tricorythodes
    - Brachycercus
    - Caenis
  - Ephemerellidae
    - Ephemerella
  - Baetiscidae
    - Baetisca
  - Heptageniidae
    - Stenonema
    - Epeorus
  - Leptophlebiidae
    - Paraleptophlebia
  - Baetidae
    - Baetis
- Odonata
  - Gomphidae
    - Ophiogomphus
  - Cordulegasteridae
    - Cordulegaster
  - Libellulidae
  - Agrionidae
    - Agrion

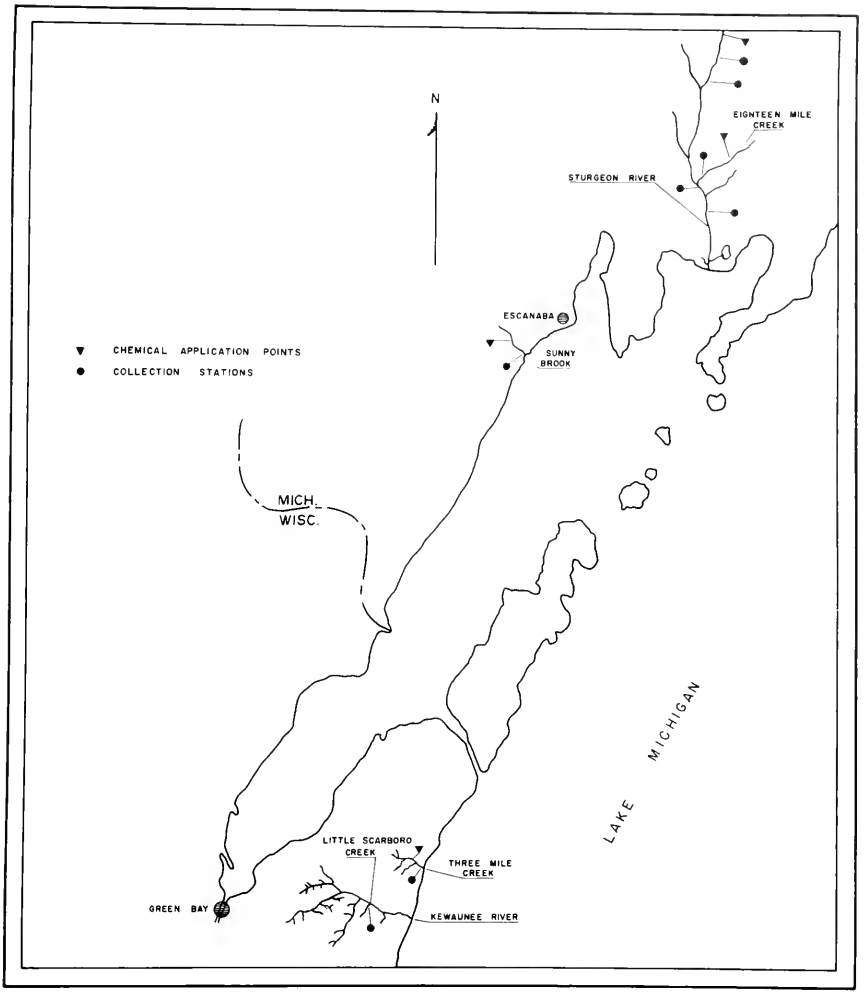

Figure 2.--Location of Lake Michigan study streams, chemical application points, and collection sites.

Hemiptera
Hebridae
Gerridae
Corixidae
Megaloptera
Sialidae
Sialis
Corydalidae

Chauliodes
Neuroptera
Sisyridae
Trichoptera
Rhyacophilidae
Philopotamidae
Chirmarra
Psychomyiidae

Psychomyia
Hydropsychidae
Hydropsyche
Cheumatopsyche
Diplectrona
Hydroptilidae
Orthotrichia
Phryganeidae

Table 1.--Location, date of collection, and number of square-foot (0.092 m.^{2}) bottom samples collected to determine effects of lamprey larvicides, Lakes Superior and Michigan, 1962-64

Lake and stream	Length	Treatment point (kilometers above mouth)	Sample location[1] (kilometers above mouth)	Date of collection	Samples
Lake Superior:	Km.	Km.	Km.		Number
Buck Bay Creek	8.0	6.4	1.6	May 4, 1964	3
				May 12, 1964	3
				June 23, 1964	3
Gongeau Creek	6.4	3.2	1.6	Apr. 28, 1964	1
				May 6, 1964	1
				June 10, 1964	1
Iron River	4.8	4.8	4.3	July 26, 1962	6
				Aug. 3, 1962	6
				July 26, 1963	1
Little Garlic River[2]	14.5	-	1.6	Aug. 27, 1964	3
				Sept. 4, 1964	3
Wilson Creek	11.3	4.8	1.6	Aug. 27, 1964	3
				Sept. 4, 1964	3
Lake Michigan:					
Little Scarboro Creek[2]	3.2	-	0.5	Apr. 16, 1964	3
				Apr. 24, 1964	3
				June 6, 1964	3
Sturgeon River	64.4	61.2	57.9 (1)	May 1, 1963	1
				May 9, 1963	1
				June 20, 1963	1
				May 1, 1964	1
Do	64.4	61.2	45.1 (2)	May 3, 1963	1
				May 11, 1963	1
				June 22, 1963	1
				May 3, 1964	1
Do	64.4	61.2	29.0 (3)	May 5, 1963	1
				May 13, 1963	1
				June 24, 1963	1
				May 5, 1964	1
Sturgeon River[3]	11.3	8.0	1.6	May 7, 1963	1
				May 15, 1963	1
				June 26, 1963	1
				May 7, 1964	1
Do	64.4	61.2	17.7	May 7, 1963	1
				May 15, 1963	1
				June 26, 1963	1
				May 7, 1964	1
Sunny Brook	6.4	3.2	0.5	Apr. 19, 1963	1
				Apr. 27, 1963	1
				June 28, 1963	1
Three Mile Creek	4.8	2.4	0.5	April 16, 1964	3
				Apr. 24, 1964	3
				June 6, 1964	3

[1] Station numbers in parentheses.
[2] Control, stream not treated.
[3] This station is on Eighteen Mile Creek, a tributary of the Sturgeon River.

Table 2.--Stream, date of treatment, average concentration of TFM, and period of exposure, Lakes Superior and Michigan, 1962-64

Stream	Date of treatment	Average concentration of TFM	Period of exposure
		P.p.m.	Hours
Buck Bay Creek...	May 5, 1964	3.4	2.8
Gongeau Creek....	Apr. 29, 1964	5.6	9.0
Iron River.....	July 27, 1962	3.8	16.5
Sturgeon River[1]..	(1) May 2, 1963	4.0	15.7
Do.....	(2) May 4, 1963	3.4	7.0
Do.....	(3) May 6, 1963	2.3	10.1
Do.....	(4) May 8, 1963	2.3	9.3
Do.....	(5) May 8, 1963	1.9	13.4
Sunny Brook.....	Apr. 20, 1963	4.6	6.7
Three Mile Creek.....	Apr. 17, 1964	[2] 5.2	7.5
Wilson Creek.....	Aug. 28, 1964	2.9	5.0

[1] Numbers in parentheses refer to corresponding numbers of locations on table 1; dates, concentrations, and exposure periods reflect passage of chemical at each location as it moved downstream.

[2] Concentration included 2 percent by weight of Bayluscide.

- Limnephilidae
- Molannidae
  - Molanna
- Leptoceridae
- Lepidostomidae
  - Lepidostoma
- Brachycentridae
- Helicopsychidae
  - Helicopsyche
- Lepidoptera
  - Pyralididae
- Coleoptera
  - Haliplidae
  - Dytiscidae
  - Gyrinidae
  - Elmidae
    - Optioservus
    - Stenelmis
    - Dubiraphia
  - Helodidae
  - Chrysomelidae
    - Donacia
  - Curculionidae
- Diptera
  - Tipulidae
    - Antocha
  - Simuliidae
  - Chironomidae
  - Heleidae
    - Palpomia
  - Stratiomyiidae
  - Tabanidae
    - Tabanus
  - Rhagionidae
    - Atherix variegata
  - Empididae
  - Dolichopodidae
  - Muscidae
- Hymenoptera
- Thysanoptera
  - Thripidae

OTHER INVERTEBRATES

- Nematoda
- Bryozoa
- Annelida
- Crustacea
  - Cladocera
  - Copepoda
  - Isopoda
    - Asellidae
  - Amphipoda
    - Gammaridae
      - Gammarus
  - Decapoda
- Hydracarina
- Mollusca
  - Gastropoda
  - Pelecypoda

EFFECTS OF TREATMENT IN DIFFERENT STREAMS

The effects of lamprey larvicides on aquatic invertebrates were studied from a comparison of bottom samples taken before and at various periods after treatment. Two pairs of treated and control streams were studied, as were two pairs of riffle and sand-detritus areas. The treated-control series included Wilson Creek and Little Garlic River (control) from Lake Superior, and Three Mile Creek and Little Scarboro Creek (control) from Lake Michigan. Riffle and sand-detritus areas compared were Iron River and Sturgeon River, and Gongeau Creek and Buck Bay Creek. In addition a riffle area of Sunny Brook was studied.

Changes in Treated and Control Streams

Samples were collected in riffle areas 1 day before and 1 week after chemical treatment of Wilson Creek, and on the same dates on Little Garlic River, the untreated control stream (table 1). The total number of organisms in Wilson Creek 1 week after treatment was 40 percent of the pretreatment number (table 3). Of the organisms represented by 10 or more individuals before treatment, 10 had declined (Leptophlebiidae, Baetidae, Rhyacophilidae, Brachycentridae, Elmidae, Tipulidae, Chironomidae, Heleidae, Annelida, and Hydracarina) and 1 had increased (Chloroperlidae).

The total number of organisms in the control stream, Little Garlic River, changed little after 1 week, and the composition of organisms showed no clear major change. The total number of organisms after 1 week was 104 percent of the first sample; of the organisms represented by 10 or more individuals, 6 declined and 6 increased. The changes in total number of organisms in Little Garlic River (control stream) and in Wilson Creek (treated stream) showed no relation that would indicate that the major reduction of invertebrates in Wilson Creek was not caused by the treatment; decreases of some aquatic insects may have been somewhat exaggerated, however, because of seasonal emergence. Leptophlebiidae and Chironomidae declined in both streams.

Table 3.--Number of insects and other organisms per square foot (0.092m.^{2}) collected in riffle areas in Wilson Creek before chemical treatment and 1 week after treatment, and on the same dates in the little Garlic River (untreated control), Lake Superior, 1964

Organism	Wilson Creek		Little Garlic River	
	Pretreatment	1 week	Pretreatment	1 week
	Number per square foot			
Insects:				
Plecoptera				
Perlidae	0	0	5	23
Chloroperlidae	18	25	24	16
Ephemeroptera				
Ephemeridae	0	0	2	0
Caenidae	1	0	0	1
Ephemerellidae	7	2	3	2
Heptageniidae	9	1	22	20
Leptophlebiidae	10	5	102	66
Baetidae	40	23	19	26
Odonata				
Gomphidae	0	0	2	4
Megaloptera				
Sialidae	0	0	1	0
Trichoptera				
Rhyacophilidae	21	4	1	1
Philopotamidae	0	0	0	4
Psychomyiidae	0	0	1	0
Hydropsychidae	7	0	117	158
Leptoceridae	0	0	1	1
Brachycentridae	21	6	20	17
Coleoptera				
Elmidae	123	29	16	22
Diptera				
Tipulidae	13	5	9	9
Simuliidae	2	1	0	1
Chironomidae	23	17	47	27
Heleidae	13	6	6	10
Tabanidae	0	1	0	0
Rhagionidae	8	2	2	5
Empididae	0	0	0	1
Muscidae	0	0	1	2
Other invertebrates:				
Annelida	14	4	29	21
Crustacea				
Isopoda	6	2	0	0
Hydracarina	31	14	28	34
Mollusca				
Gastropoda	4	1	3	4
Total	371	148	461	481
Percentage of pretreatment number	100	40	100	104

Three Mile Creek was treated with a mixture of TFM and Bayluscide. Samples were taken in riffle areas 1 day before treatment, and 1 week and 6 weeks after treatment; on the same dates riffle areas of Little Scarboro Creek were sampled as a control. The total number of organisms had not changed greatly in Three Mile Creek 1 week after treatment, but the number of Psychomyiidae, Chironomidae, and Amphipoda had declined (table 4). If Elmidae had not increased greatly 1 week after treatment, the total number of organisms would have been 69 percent of the pretreatment count. Without the large influx of Baetidae 6 weeks after treatment, the total count would have been 117 percent of the pretreatment number. No major adverse effect of the use of TFM or of Bayluscide as a synergist with TFM can be seen; indeed, increases in numbers of organisms were relatively greater in the treated than in the control stream.

The increase in total number of organisms in Little Scarboro Creek, the control stream, after 1 and 6 weeks (table 4) was brought about largely by Elmidae, as in Three Mile Creek. Trichoptera declined 65 percent in the treated stream and increased 49 percent in the control 1 week after treatment, although the Hydropsychidae, the only family that was well represented in this series, showed little change in either stream. Chironomidae declined in both the treated and control streams.

Changes in Riffle and Sand-Detritus Areas

Two habitats were sampled in the Iron River; one was an area of sand, detritus, and waterweed (Anacharis sp.) and the other a riffle. Posttreatment samples were taken 1 week after exposure at each location and 1 year later in the riffle area (table 5).

One week after treatment of the Iron River, the total number of organisms was 64 percent of the pretreatment number in the riffle area and 51 percent in the sand-detritus area. The 76 percent decline of Trichoptera in the riffle area was similar to the declines in Wilson Creek and Three Mile Creek. Other aquatic insects that declined were Caenidae, Elmidae, and Chironomidae in the riffle and Caenidae, Elmidae, Dytiscidae, and Heleidae in the sand-detritus area. Among the other organisms that were represented, Cladocera, Amphipoda, and Hydracarina were reduced in the sand-detritus area, and Pelecypoda in the riffle area. The sample taken 1 year after treatment in the riffle area showed good recovery of most groups; the total of all organisms was 108 percent of the pretreatment number.

Collections were made at five locations on the Sturgeon River 1 day before, and 1 week, 6 weeks, and 1 year after treatment. The three upstream stations were in areas of sand and detritus, and the two lower stations were in riffles (table 1). The greatest reduction in number of organisms (to 25 percent of the pretreatment number) came 1 week after treatment in the upstream sand and detritus areas (table 6) where concentrations of TFM were higher than in riffles (table 2). The total number of organisms was 65 percent of the pretreatment number in the riffle areas. Some of the same groups that declined in the Iron River also declined in this stream; namely, Caenidae, Heleidae, and Hydracarina in the sand and detritus areas, and Elmidae in riffles. After 6 weeks invertebrate populations had recovered to 101 percent of the pretreatment number in the riffle areas but were only 56 percent of the pretreatment abundance in the more heavily depleted sand and detritus areas. The number of organisms had recovered fully in both areas after 1 year.

Gongeau Creek was sampled in a sand and detritus area 1 day before, and 1 week and 6 weeks after treatment. For all groups of aquatic invertebrates taken in sand and detritus areas of Gongeau Creek numbers were fewer 1 week after treatment than before treatment

Table 4.--Number of insects and other organisms per square foot (0.092 $m.^2$) collected in riffle areas in Three Mile Creek before chemical treatment and 1 week and 6 weeks after treatment, and on the same dates in Little Scarboro Creek (untreated control), Lake Michigan, 1964

Organism	Three Mile Creek			Little Scarboro Creek		
	Pretreatment	1 week	6 weeks	Pretreatment	1 week	6 weeks
	Number per square foot					
Insects:						
Plecoptera						
Nemouridae	0	0	0	8	1	4
Chloroperlidae	0	0	0	1	0	1
Ephemeroptera						
Heptageniidae	3	1	0	0	1	0
Baetidae	0	0	497	18	14	55
Trichoptera						
Rhyacophilidae	6	2	4	55	78	40
Psychomyiidae	32	2	3	0	0	0
Hydropsychidae	17	15	13	14	25	11
Hydroptilidae	0	0	9	0	0	0
Brachycentridae	0	0	0	0	0	1
Coleoptera						
Elmidae	106	207	105	293	379	544
Haliplidae	1	1	0	0	0	6
Diptera						
Tipulidae	1	1	7	5	7	9
Simuliidae	1	1	0	1	1	14
Chironomidae	42	19	30	15	9	23
Tabanidae	1	0	0	0	0	0
Rhagionidae	0	0	0	1	1	0
Empididae	0	0	0	2	1	5
Other	0	0	0	0	1	0
Other insects	0	0	1	0	0	1
Other invertebrates:						
Annelida	3	0	0	2	0	10
Crustacea						
Isopoda	7	8	10	0	0	0
Amphipoda	29	15	111	87	55	65
Hydracarina	6	5	5	18	15	11
Total	255	277	795	520	588	800
Percentage of pretreatment number	100	109	312	100	113	154

(table 7); the total number was 40 percent of the pretreatment sample. The decline of Heleidae was similar to those in sand and detritus areas of Iron River and Sturgeon River (tables 5 and 6). The sample taken 6 weeks after treatment showed complete recovery; the total number was 120 percent of the pretreatment number.

Buck Bay Creek was sampled in a riffle area 1 day before, and 1 week and 6 weeks after treatment. The sample taken 1 week after treatment showed only a small change in total number of organisms. Chloroperlidae, Baetidae, and Lepidostomatidae were reduced somewhat; Chironomidae, Empididae, and Annelida had increased; and other organisms changed little (table 7). Treatment concentrations and period of exposure to TFM (table 2) were less than on most study streams; this difference may account for the lesser reduction in total number of organisms. Organisms were abundant 6 weeks after treatment, when the total was 137 percent of the pretreatment number.

A riffle area of Sunny Brook was sampled 1 day before, and 1 week and 6 weeks after treatment. The reduction in total number of invertebrates after 1 week to 60 percent of the

Table 5.--Number of insects and other organisms per square foot (0.092 $m.^2$) collected in Iron River before chemical treatment and 1 week and 1 year after treatment, Lake Superior, 1962-63

Organism	Riffle area			Sand and detritus area	
	Pretreatment	1 week	1 year	Pretreatment	1 week
	Number per square foot				
Insects:					
Plecoptera					
Perlidae	7	7	2	0	1
Other	2	1	1	0	1
Ephemeroptera					
Ephemeridae	0	0	1	6	13
Caenidae	30	6	3	195	24
Baetiscidae	0	0	0	2	20
Heptageniidae	57	138	19	2	8
Leptophlebiidae	1	1	3	1	2
Baetidae	68	77	201	4	16
Other	0	0	63	3	1
Odonata					
Gomphidae	0	4	1	6	11
Other	0	0	0	2	4
Hemiptera					
Corixidae	0	0	0	0	1
Trichoptera					
Philopotamidae	4	1	11	0	0
Psychomyiidae	70	3	8	3	0
Hydropsychidae	124	33	25	4	3
Phryganeidae	14	12	1	0	0
Other	2	2	1	3	5
Coleoptera					
Elmidae	111	51	116	23	9
Dytiscidae	0	0	0	10	0
Diptera					
Chironomidae	234	118	298	69	57
Heleidae	1	2	3	13	1
Other	6	11	7	9	2
Other invertebrates:					
Bryozoa	1	0	1	2	2
Annelida	3	0	5	3	2
Crustacea					
Cladocera	0	0	0	33	26
Amphipoda	0	0	0	156	74
Decapoda	0	0	4	0	0
Hydracarina	0	0	0	10	4
Mollusca					
Gastropoda	0	0	0	1	1
Pelecypoda	13	8	34	3	1
Total	748	475	808	563	289
Percentage of pretreatment number	100	64	108	100	51

pretreatment number (table 8) was similar to the 65 percent reduction in the riffle area of the Sturgeon River. The percentage of pretreatment numbers 5 weeks later, however, was only 39 percent. Elmidae and Chironomidae, which were abundant before and 1 week after treatment, were sharply reduced 6 weeks after treatment. The reduction of Chironomidae may have resulted from emergence, but the cause of the decline in Elmidae is uncertain. Some larval forms of Elmidae leave the streams to pupate (Sanderson, 1938); this egress may explain the reduction, as the time of year was appropriate for this movement.

Table 6.--Number of insects and other organisms per square foot (0.092 $m.^2$) collected in the Sturgeon River before chemical treatment and 1 week, 6 weeks, and 1 year after treatment, Lake Michigan, 1963-64

Organism	Riffle areas				Sand and detritus areas			
	Pre-treatment	1 week	6 weeks	1 year	Pre-treatment	1 week	6 weeks	1 year
	Number per square foot							
Insects:								
Plecoptera								
Nemouridae	4	4	2	0	0	0	0	0
Perlidae	1	4	0	2	0	0	0	0
Chloroperlidae	5	9	0	3	0	0	0	2
Other	0	1	0	0	0	0	0	0
Ephemeroptera								
Ephemeridae	0	0	1	4	14	4	5	25
Caenidae	0	0	0	0	59	20	22	62
Heptageniidae	17	10	6	9	0	0	0	27
Leptophlebiidae	23	31	5	17	0	0	0	28
Baetidae	15	14	97	35	3	0	15	18
Other	0	1	1	0	1	0	1	0
Odonata								
Gomphidae	9	6	10	5	1	0	0	0
Other	0	1	1	0	0	0	0	0
Megaloptera								
Corydalidae	1	0	0	1	0	0	0	1
Hemiptera								
Hebridae	0	0	1	0	0	0	0	0
Trichoptera								
Rhyacophilidae	1	0	0	12	0	0	0	0
Psychomyiidae	2	1	2	1	0	0	0	0
Hydropsychidae	9	12	1	23	0	0	0	3
Hydroptilidae	4	1	0	1	0	0	0	0
Phryganeidae	10	10	3	0	2	0	0	0
Leptoceridae	0	0	0	2	0	0	0	14
Other	1	1	1	1	1	0	0	1
Lepidoptera								
Pyralididae	0	0	1	0	0	0	0	0
Coleoptera								
Elmidae	155	41	34	109	7	2	3	11
Other	0	1	0	0	0	0	0	4
Diptera								
Tipulidae	3	1	3	4	0	0	2	3
Simuliidae	3	3	1	1	1	2	1	24
Chironomidae	45	41	155	68	248	60	129	137
Heleidae	7	12	1	3	15	0	7	11
Tabanidae	0	1	0	1	2	1	0	0
Rhagionidae	13	10	2	2	0	0	0	0
Empididae	0	1	13	5	0	0	0	2
Other	6	2	3	6	1	0	0	0
Other invertebrates:								
Bryozoa	0	1	0	0	0	0	0	0
Annelida	7	1	2	9	0	0	9	9
Crustacea	0	0	1	0	2	0	1	1
Hydracarina	6	4	4	6	10	3	7	10
Mollusca	1	0	2	10	0	0	3	12
Total	348	225	353	340	367	92	205	405
Percentage of pretreatment number.	100	65	101	98	100	25	56	110

Table 7.--Number of insects and other organisms per square foot (0.092 $m.^2$) collected in Gongeau Creek (sand and detritus area) and Buck Bay Creek (riffle area) before chemical treatment and 1 week and 6 weeks after treatment, Lake Superior, 1964

Organism	Gongeau Creek			Buck Bay Creek		
	Pretreatment	1 week	6 weeks	Pretreatment	1 week	6 weeks
			Number per square foot			
Insects:						
Plecoptera						
Pteronarcidae....	2	0	0	0	0	0
Nemouridae.....	20	1	8	0	1	11
Perlidae.....	1	0	10	0	0	0
Perlodidae.....	0	0	0	1	0	0
Chloroperlidae...	6	5	45	21	14	108
Ephemeroptera						
Ephemerellidae...	4	3	47	2	1	15
Heptageniidae....	2	1	8	0	0	0
Leptophlebiidae..	3	1	2	2	1	1
Baetidae.....	70	41	38	60	22	24
Odonata						
Cordulegasteridae	0	0	2	0	0	0
Hemiptera						
Hebridae.....	0	1	0	0	0	0
Megaloptera						
Sialidae.....	0	0	2	0	0	0
Trichoptera						
Rhyacophilidae...	11	4	16	13	14	6
Psychomyiidae....	0	0	0	0	0	8
Hydropsychidae...	2	0	0	0	2	0
Hydroptilidae....	2	0	0	0	0	0
Phryganeidae.....	6	0	0	1	0	1
Limnephilidae....	0	0	0	4	0	5
Molannidae.....	1	0	0	0	0	0
Lepidostomatidae.	0	0	4	11	5	6
Brachycentridae..	0	0	0	0	0	1
Coleoptera						
Elmidae.....	8	6	7	5	6	6
Diptera						
Tipulidae.....	6	1	14	4	8	3
Simuliidae.....	1	0	1	0	3	7
Chironomidae.....	45	18	47	63	76	45
Heleidae.....	16	1	7	1	4	3
Rhagionidae.....	0	0	1	0	0	0
Empididae.....	11	3	3	13	23	24
Other.....	0	1	0	0	0	0
Other invertebrates:						
Nematoda.....	0	2	0	0	0	0
Annelida.....	5	0	5	6	13	6
Crustacea.....	0	0	1	0	0	0
Hydracarina.....	0	0	0	7	5	14
Mollusca.....	2	0	0	0	1	0
Total.....	224	89	268	214	199	294
Percentage of pretreatment number.....	100	40	120	100	93	137

Table 8.--Number of insects and other organisms per square foot (0.092 m.^{2}) collected in a riffle area in Sunny Brook before chemical treatment and 1 week and 6 weeks after treatment, Lake Michigan, 1963

Organism	Pretreatment	1 week	6 weeks
	Number per square foot		
Insects:			
Plecoptera			
Nemouridae	0	0	13
Ephemeroptera			
Baetidae	3	0	94
Trichoptera			
Phryganeidae	4	1	0
Other	1	0	0
Coleoptera			
Elmidae	278	165	57
Diptera			
Tipulidae	1	0	0
Chironomidae	170	108	10
Heleidae	5	1	0
Empididae	5	9	1
Other	1	1	0
Other insects	1	0	0
Other invertebrates:			
Annelida	1	0	6
Crustacea			
Isopoda	5	3	4
Amphipoda	2	1	2
Hydracarina	1	1	1
Mollusca			
Gastropoda	9	1	0
Total	487	291	188
Percentage of pretreatment number	100	60	39

SUMMARY OF EFFECTS 1 WEEK AFTER TREATMENT

Sixteen families of insects and four other groups of aquatic invertebrates were represented by five or more individuals per square foot (0.092m.^{2}) in samples from sand and detritus areas. In these samples, 77 percent of the groups decreased in number 1 week after treatment of the stream, 17 percent increased, and 6 percent showed little or no change (table 9). Elmidae and Heleidae declined in all streams. The decline of various groups was more general in Sturgeon River and Gongeau Creek; however, these streams were subjected to greater concentrations of TFM than was Iron River (table 2).

Twenty-one families of insects and six other groups of aquatic invertebrates were represented by five or more individuals per square foot (0.092m.^{2}) in samples from riffles in treated and untreated streams. In the six treated streams, 64 percent of the groups decreased in number 1 week after treatment, 19 percent increased, and 17 percent showed little or no change (table 10). In the two control streams, 33 percent of the groups decreased. 50 percent increased, and 17 percent showed no significant change. For the orders of aquatic insects that were well represented, Trichoptera, Coleoptera, Ephemeroptera, and Diptera declined in the treated streams. Most other groups of invertebrates also declined in treated streams but showed no change in abundance in the two control streams.

Table 9.--Change in the abundance of organisms[1] in sand and detritus areas of various streams 1 week after treatment, Lakes Superior and Michigan, 1962-63

[Increase or decrease is greater than 20 percent change; increase (+), decrease (-), little or no change (0)]

Organism	Iron River	Sturgeon River	Gongeau Creek
Insects:			
Plecoptera			
Nemouridae	...	...	-
Chloroperlidae	...	...	0
Ephemeroptera			
Ephemeridae	+	-	...
Caenidae	-	-	...
Baetiscidae	+	...	...
Heptageniidae	+	...	...
Baetidae	+	...	-
Odonata			
Gomphidae	+	...	...
Trichoptera			
Rhyacophilidae	...	...	-
Phryganeidae	...	...	-
Coleoptera			
Elmidae	-	-	-
Dytiscidae	-	...	...
Diptera			
Tipulidae	...	...	-
Chironomidae	0	-	-
Heleidae	-	-	-
Empididae	...	...	-
Other invertebrates:			
Annelida	...	...	-
Crustacea			
Cladocera	-	...	...
Amphipoda	-	...	...
Hydracarina	-	-	...
Increase	5	0	0
No change	1	0	1
Decrease	7	6	10

[1]Based on groups that contained five or more individuals per square foot (0.092 m.^{2}).

SUMMARY OF EFFECTS 6 WEEKS AND 1 YEAR AFTER TREATMENT

Recovery was rapid in four of the five streams in which the abundance of organisms was reduced 1 week after treatment: samples collected 6 weeks after treatment indicated that the pretreatment numbers of organisms had been exceeded in three streams, partially restored in one, and further reduced in one (table 11). The one further decline (in Sunny Brook) was probably not entirely due to the effects of TFM.

Rapid reestablishment of decimated populations of invertebrate fauna has been demonstrated also by Moffett (1936). Most of the factors that contribute to rapid reestablishment as reported by Frey (1961) existed in the present study: (1) most of the aquatic forms were not eliminated from the treated areas and they, themselves, could help in recolonization; (2) untreated streams near the treated

Table 10.--Change in the abundance of organisms[1] in riffle areas of various streams 1 week after treatment and in control streams, Lakes Superior and Michigan, 1962-64

[Increase or decrease is greater than 20 percent change; increase (+), decrease (-), little or no change (0)]

Organism	Treated streams						Control streams	
	Wilson Creek	Three Mile Creek	Iron River	Sturgeon River	Buck Bay Creek	Sunny Brook	Little Garlic River	Little Scarboro Creek
Insects:								
Plecoptera								
Nemouridae	...	...	...	...	...	...	...	-
Perlidae	...	...	0	...	...	...	+	...
Chloroperlidae	+	...	...	+	-	...	-	...
Ephemeroptera								
Caenidae	...	...	-	...	...	...	...	...
Ephemerellidae	-	...	...	...	...	...	+	...
Heptageniidae	-	...	+	-	...	...	0	...
Leptophlebiidae	-	...	...	+	...	...	-	...
Baetidae	-	...	0	0	-	...	+	-
Odonata								
Gomphidae	...	...	...	-	...	...	...	...
Trichoptera								
Rhyacophilidae	-	-	...	...	0	...	...	+
Psychomyiidae	...	-	-	...	...	...	...	...
Hydropsychidae	-	0	-	+	...	...	+	+
Phryganeidae	...	...	0	0	...	...	...	...
Lepidostomatidae	...	...	...	...	-	...	...	...
Brachycentridae	-	...	...	...	...	...	0	...
Coleoptera								
Elmidae	-	+	-	-	0	-	+	+
Diptera								
Tipulidae	-	...	...	...	+	...	0	+
Chironomidae	-	-	-	0	+	-	-	-
Heleidae	-	...	...	+	...	-	+	...
Rhagionidae	-	...	...	-	...	...	+	...
Empididae	...	...	...	...	+	+	...	...
Other invertebrates:								
Annelida	-	...	...	-	+	...	-	...
Crustacea								
Isopoda	-	0	...	...	...	-	...	...
Amphipoda	...	-	...	...	...	...	...	-
Hydracarina	-	0	...	-	-	...	+	0
Mollusca								
Gastropoda	...	...	...	...	...	-	...	...
Pelecypoda	...	...	-	...	...	...	...	...
Increase	1	1	1	4	4	1	8	4
No change	0	3	3	3	2	0	3	1
Decrease	15	4	6	6	4	5	4	4

[1] Based on groups that contained five or more individuals per square foot (0.092 m.^{2}).

Table 11.--Percentage of pretreatment number of aquatic invertebrates in samples for various streams and substrates 1 week, 6 weeks, and 1 year after treatment and in control streams, Lakes Superior and Michigan, 1962-64

Stream and substrate	1 week	6 weeks	1 year
Treated streams:	Percent	Percent	Percent
Buck Bay Creek			
Riffle.....	93	137	-
Gongeau Creek			
Sand-detritus...	40	120	-
Iron River			
Riffle.....	64	-	108
Sand-detritus...	51	-	-
Sturgeon River			
Riffle.....	65	101	98
Sand-detritus...	25	56	110
Sunny Brook			
Riffle.....	60	39	-
Three Mile Creek			
Riffle.....	64	-	-
Wilson Creek			
Riffle.....	40	-	-
Control streams:			
Little Garlic River			
Riffle.....	104	-	-
Little Scarboro Creek			
Riffle.....	113	154	-

streams could act as hatcheries or reserves; and (3) upstream migrations could have occurred, because chemical concentrations were less in the lower reaches of streams and many organisms were probably affected little if at all in these areas. Downstream drift (Waters, 1961) may have been another factor that influenced reestablishment in this study; streams were not treated from their sources, so the unaffected populations of invertebrates were available from the headwaters of most treated streams.

In the three stations that were sampled 1 year after treatment, all showed complete recovery in total number of organisms, and all major groups present before treatment were well represented. Thus, aquatic invertebrates, although affected moderately by the selective lamprey larvicides, usually recovered substantially in 6 weeks and fully in 1 year.

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