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Aquatic Macroinvertebrates in a Small Wisconsin Trout Stream Before, During, and Two Years After Treatment with the Fish Toxicant Antimycin[1]

by

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Abstract

Benthos and benthic drift were sampled periodically in Seas Branch Creek (Vernon County, Wisconsin) for 5 months before and for 2 years after the stream was treated with antimycin, and over the same period in nearby untreated Maple Dale Creek. During treatment on 4 October 1972, antimycin concentrations varied from 17 to 44 μg/l at the two sampling stations in Seas Branch Creek. Populations of macroinvertebrates were drastically reduced 2 days after treatment, but all common taxa identified before treatment were present in the stream 1 year later. Estimated biomass reductions of living organisms 2 days after treatment were as high as 50% for one caddis fly, *Hydropsyche* sp., and 75% for another, *Brachycentrus americanus;* 70% for a crane fly, *Antocha* sp.; and nearly 100% for a mayfly, *Baetis cingulatus*, and a scud, *Gammarus pseudolimnaeus*. Summer biomass of *Antocha* and *Brachycentrus* did not regain pretreatment levels during the second year. The mortality of the riffle beetle, *Optioservus fastiditus*, was approximately 20% 9 days after treatment. A crayfish, *Orconectes propinquus*, was not affected by the treatment. The biomass of *Gammarus, Prosimulium* (a black fly), *Baetis*, and *Hydropsyche* was high during both summers after treatment. After 1 year, and continuing into the second year, total benthic biomass approached or exceeded that before treatment.

The piscicide antimycin is used for several purposes in fishery management, including eradication of nongame fish species that are suspected of competing with game fish. Antimycin and rotenone are the only two chemicals registered for such use by the Environmental Protection Agency.

In 1972 the Wisconsin Department of Natural Resources, in rehabilitating Seas Branch Creek, used antimycin to eradicate populations of catostomids and cyprinids. After removal of the nongame species, the stream was restocked with brown trout *(Salmo trutta)*. This project afforded us the opportunity to observe the reactions of fish food organisms to antimycin.

The purpose of our study was to observe and document changes in nontarget aquatic macroinvertebrate populations in this small trout stream after the application of antimycin. Short- and long-term effects of treatment were shown by quantitative and qualitative variations in benthic biomass and changes in the composition and abundance of drift organisms.

The effects of antimycin on the invertebrate fauna have been previously investigated in lakes or ponds, but not (to our knowledge) in a natural trout stream. Callaham and Huish (1969) and Rabe and Wissman (1969) reported that 5.0 μg/l applications of antimycin severely reduced populations of zooplankton in lakes and ponds, whereas Walker et al. (1964), Gilderhus et al. (1969), and Houf and Hughey (1973) found that fish-killing concentrations of antimycin had no significant effect on lake plankton and benthos. Snow (1974) observed no gross long-term detrimental effects on zooplankton and benthos 6 years after antimycin treatment in Rush Lake, Wisconsin.

Study Area

Seas Branch Creek is in central Vernon County, in the hilly, unglaciated area of southwestern Wisconsin (Fig. 1). It is an 8-km-long tributary of the West

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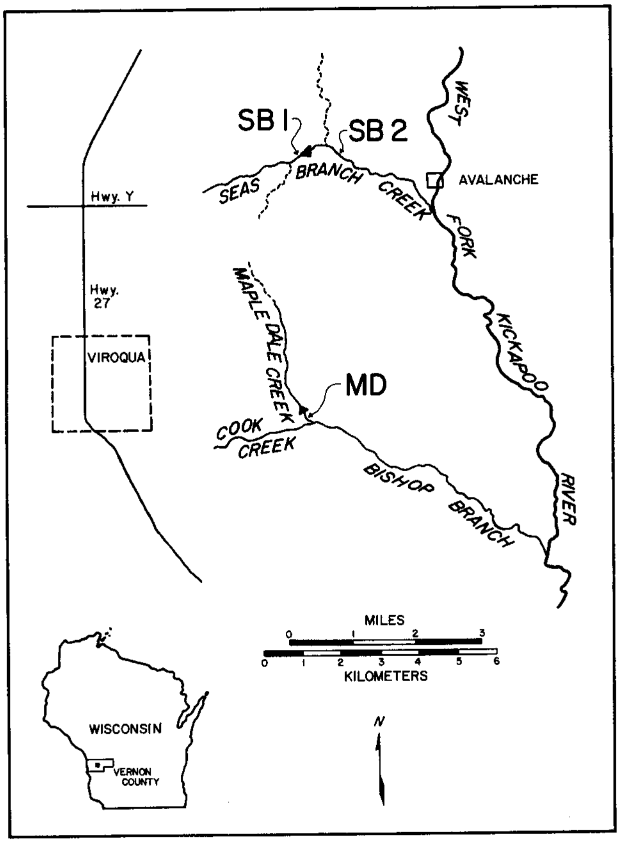

Fig. 1. Locations of study stations SB1 and SB2 on Seas Branch Creek, which was treated with antimycin on 4 October 1972, and control station MD on untreated Maple Dale Creek. The triangles near SB1 and MD indicate flood control reservoirs.

Fork of the Kickapoo River. A 5-ha permanent impoundment on the stream, 4 km above its mouth, serves as a flood control reservoir.

Because Seas Branch Creek was treated with antimycin at its source, a nearby stream, Maple Dale Creek, which has similar physical, chemical, and biological characteristics, was selected as a control. This stream, 4 km long, is a tributary of Bishop Branch Creek, which is also a tributary of the West Fork of the Kickapoo River. The confluence of Bishop Branch Creek with the Kickapoo is 9 km downstream from that of Seas Branch Creek. A flood control structure, with no permanent pool, is about 300 m above the sampling station on Maple Dale Creek.

The upstream Seas Branch Creek station (SB1) was 50 m above the impoundment, in the middle of a riffle 70 m long. At this station the stream averaged 1.5 m in width and 12 cm in depth, and had a mean annual discharge of 0.11 m^3/s. The downstream Seas Branch station (SB2) was 800 m below the impoundment and was at the lower end of a riffle 130 m long. The stream here was 3.3 m wide and 18 cm deep, and had a mean annual discharge of 0.17 m^3/s. The Maple Dale Creek control station (MD) was 6 m above the confluence of Maple Dale and Cook Creeks at the lower end of a riffle 40 m long. The stream here was 2.5 m wide and 15 cm deep, and had a mean annual discharge of 0.15 m^3/s.

Water quality data were taken at each station throughout the study period (Tables 1, 2, and 3). Temperatures ranged from 0 to 20 C; average temperatures at SB1 were 2 to 4 C lower than at SB2 or MD, or both, during the summer before and the two summers after treatment. Water chemistry differed little at the stations before, during, or after treatment. Dissolved oxygen concentrations were high (8.5 to 15.1 mg/l; 81 to 126% saturation). The calcareous composition of the numerous bluffs along both streams is reflected in the average water quality values: pH, 8.3; total alkalinity, 215 mg/l; and conductivity, 434 μmhos. Turbidity was low, averaging 0.29 Jackson Turbidity Unit (JTU) during periods of normal flow (Tables 1, 2, and 3). Average discharge at all stations was about twice as high in 1973 as in 1972 or 1974. Slow release of cold groundwater after high precipitation in 1973 may have been responsible for the lower water temperatures in 1973 and 1974.

The stream bed at all three stations was composed largely of rough, angulate stones, mostly 5 to 10 cm in diameter (some up to 30 cm). Small amounts of gravel and sand were present; interstitial organic litter was primarily autochthonous plant material. The stones at SB2 and MD were loose, but at SB1 many were imbedded in clay. Water crowfoot *(Ranunculus aquatilis)*, the dominant stream vegetation, covered 8 to 50% of the stream bed throughout the year at all three stations. Limited amounts of pondweed (*Potamogeton* sp.) were present in the control stream, and watercress *(Nasturtium officinale)* along the water's edge in the treatment stream.

Methods

Antimycin (Fintrol-concentrate formulation) was applied to Seas Branch Creek from 0000 to 0920 h on 4 October 1972, under the direction of the Cold Water Research Group of the Wisconsin Department of Natural Resources. Errors in calculating dosages and equipment failure resulted in treatment values much higher than the intended concentrations of 10 μg/l. The concentration was 25 μg/l for the first 3 h and 40 μg/l for the next 6-1/3 h at SB1 and 17 μg/l for 2 h and 44 μg/l for 7 h at SB2. Antimycin drip sites were about 270 m above each of the two stations.

Table 1. *Physical and chemical data from the upper treatment station (SB1) of Seas Branch Creek, 1972-74.*

Date	Temp (°C)		Dissolved O_2		pH	Total alkalinity (ppm)	Turbidity (JTU)	Conductance (μmho/cm)	Discharge (m^3/s)
	Air	Water	ppm	Percent saturation					
1972									
15 May	21	16	11.7	122	8.8	186	0.16	ND	0.08
15 June	15	12	10.1	96	8.5	194	0.27	440	0.08
15 July	32	17	9.2	98	8.1	186	0.12	440	0.08
15 Aug	25	14	10.0	100	8.5	203	0.30	420	0.07
3 Oct	18	11	10.1	95	8.3	215	0.27	520	0.09
6 Oct	10	10	10.2	94	8.4	223	0.57	500	0.08
13 Oct	10	10	11.0	102	8.5	213	0.36	480	0.08
1 Nov	8	8	10.6	93	8.3	215	0.19	420	0.10
1 Dec	-6	4	13.0	102	8.2	207	0.35	400	0.08
1973									
15 Jan	-12	1	14.3	104	8.3	203	0.30	400	0.08
15 March	1	6	13.4	111	8.2	210	0.21	380	0.15
15 May	15	8	12.8	112	8.6	218	0.11	450	0.17
16 July	24	14	11.4	115	8.3	203	0.22	460	0.19
15 Sept	10	9	9.9	90	8.0	198	0.27	440	0.16
6 Oct	11	9	10.3	95	8.1	236	0.17	450	0.14
10 Oct	1	5	12.4	100	8.1	209	0.20	410	0.13
1974									
20 April	10	9	10.2	90	8.1	210	0.20	350	0.11
17 May	16	11	10.4	97	8.2	215	0.50	420	0.04
30 July	21	14	9.8	98	8.0	233	0.07	400	0.09
2 Oct	6	9	10.0	90	7.4	207	0.16	410	0.10
Mean	11.8	9.9	11.0	100	8.2	209	0.25	430	0.11

On 16 August 1972 the gate of the impoundment on Seas Branch Creek was opened and the reservoir drained to an area of 1 ha, where it was maintained until after treatment to reduce the amount of antimycin needed. When the gate was closed 2 days after treatment, the impoundment refilled in about 2 weeks. This refilling reduced the water flow at SB2 by about one-half for most of that period.

Benthic samples were collected a total of 20 times during the 28-month study. On each sampling date, four samples were taken at SB1 and five each at SB2 and MD with a modified Hess circular 0.05-m^2 bottom sampler (with a net of 7.5 meshes/cm), similar to that described by Waters and Knapp (1961). At each station one sample came from vegetation and the rest from the rubble substrate. The biomass of benthos in the vegetation samples was prorated into the total benthic biomass according to the estimated percentage of the riffle area covered with vegetation at each sampling period. This percentage was assigned subjectively on the basis of the estimated change in vegetative cover in each riffle area from one sampling period to another.

Drifting organisms were collected in vertical nets of 7.5 meshes/cm supported by a 0.1-m^2 square frame attached to a board placed on the stream bottom. Three nets were used at SB2 and MD, and two at SB1 to collect samples for 10 min, four or five times in each 24-h period before treatment. Sampling times included sunrise, sunset, midday, and midnight, which represented times of major drift (Waters 1972). Drift samples were taken every 3 h for 24 h during treatment (starting 3 h before application of antimycin) and then every 6 h for 36 h thereafter. Total drift was calculated by the methods of Waters (1962). Current velocities were measured with a Gurley pigmy current meter, no. 625. Velocities were used to calculate discharge, which was then used to calculate drift rates.

Samples of invertebrates were strained with a 0.5-mm mesh soil screen and stored in 70% isopropyl alcohol. Organisms were separated from detritus and

Table 2. *Physical and chemical data from the lower treatment station (SB2) of Seas Branch Creek, 1972-74.*

Date	Temp (°C)		Dissolved O_2		pH	Total alkalinity (ppm)	Turbidity (JTU)	Conductance (μmho/cm)	Discharge (m^3/s)
	Air	Water	ppm	Percent saturation					
1972									
15 May	18	14	11.7	115	8.7	186	0.11	ND	0.10
15 June	17	15	9.8	100	8.6	199	0.16	420	0.11
15 July	32	20	10.0	114	8.0	190	0.73	420	0.12
15 Aug	24	18	11.6	125	8.5	201	0.44	400	0.10
3 Oct	17	12	10.3	98	8.3	220	0.52	500	0.16
6 Oct	10	11	10.8	102	8.5	220	0.30	500	0.15
13 Oct	10	10	13.0	119	8.5	240	0.42	520	0.05
1 Nov	8	8	11.6	102	8.5	203	0.20	440	0.20
1 Dec	-6	4	12.5	100	8.1	215	0.19	420	0.15
1973									
15 Jan	-12	1	14.3	103	8.0	224	0.40	460	0.12
15 March	1	6	14.1	117	8.3	185	7.20	320	0.22
15 May	15	12	13.1	125	8.5	197	0.58	425	0.24
16 July	24	17	11.1	118	8.1	204	0.51	420	0.26
15 Sept	10	12	9.1	85	8.0	220	0.42	420	0.29
6 Oct	11	11	10.0	95	8.1	214	0.21	440	0.31
10 Nov	0	4	12.2	98	8.0	214	0.31	420	0.28
1974									
20 April	10	9	9.6	85	7.8	202	0.16	350	0.18
17 May	16	12	10.3	100	8.1	217	0.20	400	0.06
30 July	20	17	8.9	95	8.2	220	0.10	410	0.08
2 Oct	7	10	10.4	95	7.7	232	0.35	400	0.16
Mean	12.1	11.2	11.2	105	8.3	210	0.35	425	0.17

identified, and body length was measured. Identifications were verified by the museum staff of the Smithsonian Institution, Washington, D.C. In estimating the biomass of individual organisms from the length, we followed Hynes (1961), Hynes and Coleman (1968), Hamilton (1969), and Jacobi (1969) in assuming that an insect's shape is that of a cylinder five times as long as wide, that its volume increases by the cube of the length, that its specific gravity is 1.05, and that 3.3×10^{-5} g is the weight of a 1-mm length unit. Insects were not weighed because weight loss varies widely after preservation (Howmiller 1972). Crayfish were wet-weighed after surface water had been removed by blotting.

Additional specimens from some of the major taxa were nonquantitatively collected from the treatment and control stream on 6, 13, and 19 October and 4 November 1972, and the percentages of dead organisms noted (Table 4). We used these values to estimate the percentages of dead organisms in the benthic samples for these periods; biomass was adjusted to show only the weight of living organisms. The taxa collected are given in Table 5; average monthly values for water temperature, discharge, vegetative cover, and total benthic biomass before and after treatment in Table 6; and the estimated biomass (g/m^2) for each organism at each station on each collection date in Tables 7-9.

Results

Total Benthos and Drift

The aquatic macroinvertebrates collected included 33 identified to genus or genus and species, 5 to family, and 2 to order (Table 5). The dominant forms on the basis of pretreatment biomass (in order of abundance) were *Hydropsyche* (caddis fly), *Orconectes propinquus* (crayfish), Chironomidae (midges), *Optioservus fastiditus* (riffle beetle), *Antocha* (crane fly), *Brachycentrus americanus* (caddis fly), *Gammarus pseudolimnaeus* (scud),

Table 3. *Physical and chemical data from the control station (MD) of Maple Dale Creek.*

Date	Temp (°C)		Dissolved O_2		pH	Total alkalinity (ppm)	Turbidity (JTU)	Conductance (μmho/cm)	Discharge (m^3/s)
	Air	Water	ppm	Percent saturation					
1972									
15 May	18	18	8.5	93	8.6	191	0.40	ND	0.09
15 June	15	13	11.6	113	8.6	216	0.23	420	0.08
15 July	28	20	10.2	116	8.6	219	0.23	470	0.10
15 Aug	28	20	11.0	124	8.5	213	0.13	420	0.07
3 Oct	16	13	10.1	98	8.4	238	ND	ND	0.13
6 Oct	13	11	8.6	81	8.5	235	0.47	560	0.11
13 Oct	6	10	11.0	101	8.5	226	0.30	540	0.09
1 Nov	9	8	10.9	95	8.5	222	0.60	450	0.15
1 Dec	-6	4	13.8	107	8.3	230	0.10	440	0.11
1973									
15 Jan	-11	0	15.1	106	8.2	223	0.30	500	0.10
15 March	1	5	14.5	117	8.4	229	0.21	420	0.33
15 May	15	15	12.4	126	8.7	210	0.21	440	0.25
16 July	24	19	9.9	105	8.1	238	0.55	460	0.16
15 Sept	15	10	10.4	95	8.1	228	0.30	450	0.20
6 Oct	11	10	11.8	108	8.1	206	0.17	480	0.17
10 Nov	1	5	13.1	105	8.1	230	0.19	440	0.17
1974									
20 April	16	13	10.1	98	8.4	224	0.10	345	0.17
17 May	18	13	11.2	110	8.3	223	0.35	420	0.06
30 July	21	17	9.7	102	8.3	247	0.10	425	0.12
2 Oct	7	7	12.3	105	7.6	248	0.20	385	0.10
Mean	12.3	11.6	11.3	105	8.3	225	0.27	447	0.14

Baetis cingulatus (mayfly), and *Prosimulium* sp. (black fly).

Drift rates increased noticeably during treatment at both stations, reaching 50 g/h at SB1 18 h after treatment and nearly 169 g/h at SB2 9 h after treatment (Fig. 2). Other increases in drift rates were associated with increased densities or emergence of the dominant taxa before and after treatment (Fig. 3). The high values for total drift at SB2 in July and October 1974 are attributed largely to scuds, which in these 2 months constituted 67% and 34% of the total benthic biomass.

Total benthic biomass decreased at SB1 and SB2 (as well as at MD) immediately after treatment but attained a peak in the treated stream later in the fall, resuming the generally increasing trend that began in early fall (Fig. 4). One year after treatment, total benthic biomass in Seas Branch Creek approached or exceeded that found before treatment. This trend also was suggested during the second year after treatment, although the order of dominating taxa differed between years.

The decrease in benthos at the control station (MD) during the time of treatment probably reflects a sampling error, rather than a true decrease in density of organisms; the samples were collected from a riffle area which had been disturbed during earlier sampling. Neither drift samples (Fig. 3) nor nonquantitative benthic samples (Table 4) indicated abnormally high values for dead or drifting organisms at MD during the time of treatment.

To compare the pretreatment and posttreatment data, we calculated the average biomass (without crayfish) of samples collected annually at each station in May, July, and October (Table 6). Biomass reached maximum levels during these months, which span the major growing season. Vegetative cover more than doubled during the year after treatment at SB2 and during the second year after treatment at SB1, but changed little at the control station. Benthic biomass also followed this general pattern in the treatment stream but, again, remained nearly constant in the control stream (Table 6).

Table 4. *Summary of total numbers of invertebrates collected and percentage dead at the three study stations on different dates after the antimycin treatment on 4 October 1972.* (Dashes indicate no sample taken; P = present, but not counted).

Date (1972) and taxon (L = larvae)	Station					
	SB1		SB2		MD	
	Total no.	Dead (%)	Total no.	Dead (%)	Total no.	Dead (%)
6 October[a]						
Baetis	77	13	13	85	32	0
Brachycentrus	47	53	31	74	100	1
Gammarus	49	37	19	100	27	4
Hydropsyche	51	12	6	33	48	0
Optioservus (L)	32	16	2	0	27	0
Antocha (L)	41	63	—	—	4	0
Stenonema	11	9	4	0	1	0
Orconectes	0	0	10	0	0	0
13 October						
Baetis	1	100	0	0	16	0
Brachycentrus	12	50	50	98	31	3
Gammarus	17	18	4	50	50	2
Hydropsyche	58	40	100	89	50	0
Optioservus (L)	33	15	35	20	25	0
Antocha (L)	7	43	8	100	25	12
Stenonema	4	25	6	83	4	0
Orconectes	3	0	4	0	3	0
19 October						
Baetis	9	0	0	0	28	0
Brachycentrus	5	40	20	100	55	2
Gammarus	9	0	3	0	69	2
Hydropsyche	19	58	7	100	55	2
Optioservus (L)	26	4	25	0	53	2
Antocha (L)	9	33	2	100	41	7
Stenonema	3	0	2	50	10	0
Orconectes	10	0	4	0	3	0
4 November						
Baetis	0	0	0	0	—	—
Brachycentrus	10	80	P	0	—	—
Gammarus	4	25	P	0	—	—
Hydropsyche	5	0	P	0	—	—
Optioservus (L)	2	0	P	0	—	—
Antocha (L)	2	50	P	0	—	—
Stenonema	2	0	P	0	—	—
Orconectes	0	0	P	0	—	—

[a] Data for SB2 on 6 October were obtained from observations on organisms placed in small containers before treatment.

Amphipoda (Scuds)

Immediately after treatment, *Gammarus pseudolimnaeus* decreased in the benthic samples (Fig. 4), and increased markedly in the drift (Fig. 2). The number of drifting dead and dying organisms reached a maximum 12 h after treatment at SB2 and 18 h after treatment at SB1 (Fig. 2). By the second day after treatment the mortality of scuds was apparently 100% at SB2 but only 37% at SB1 (Table 4). Estimated benthic biomass of scuds at both treatment locations remained low during the winter after treatment but increased in the following summer to values far exceeding those of the previous year (Fig. 4). Scuds were abundant in the benthos during the summer after treatment; they were also dominant in July 1974 at both treatment stations, making up 56% and 67% of the biomass (without crayfish) at SB1 and SB2. A drift rate at SB2 of 5 g/h in September 1973 and about 25 g/h in July and 24 g/h in October 1974 reflected this increased density of organisms (Fig. 3).

In the control stream, the biomass of scuds never varied significantly from one sample period to another (Fig. 4), and drift rates were low throughout the year (Fig. 3).

Diptera (Crane fly, Midges, Black fly)

Benthic biomass of the crane fly *Antocha* was reduced sharply by the treatment at both SB1 and SB2 (Fig. 4), and no live specimens were collected in the drift immediately after treatment. The drift of dead crane flies reached a peak 18 h after treatment at SB1 and 12 h after treatment at SB2 (Fig. 2). No living crane fly larvae were taken in benthic samples for 2 weeks at SB2 (none were found 2 days after treatment), whereas the maximum mortality of 63% at SB1 2 days after treatment decreased gradually to 50% (one of two specimens collected) 1 month later (Table 4). Benthic biomass of crane flies was about four times greater at SB2 than at SB1 before treatment but remained low for 1 year after treatment at both stations. The estimated biomass was high in the samples collected at SB1 in November 1973, but was again low in April and May 1974. Emerging adults were not found at SB1 during May 1974, but were present in drift samples at SB2 and MD. Despite the large numbers of larval crane flies in the samples collected at SB1 in November 1973, the population did

Table 5. *Macroinvertebrate taxa collected in the treatment stream, Seas Branch Creek, and the control stream, Maple Dale Creek.*[a]

- Arthropoda
  - Insecta
    - Diptera
      - Chironomidae (midges)
      - Tipulidae (crane flies)
        - *Antocha*
        - *Hexatoma*
      - Simuliidae (black flies)
        - *Prosimulium*
      - Empididae (dance flies)
        - *Hermerodromia*
      - Rhagonidae (snipe flies)
        - *Atherix variegata*
      - Stratiomyidae (soldier flies)
        - *Hedriodiscus*
      - Tabanidae (horseflies)
        - *Tabanus*
        - *Chrysops*
    - Ephemeroptera (mayflies)
      - Baetidae
        - *Baetis cingulatus*
      - Heptageniidae
        - *Stenonema*
      - Ephemerellidae
        - *Ephemerella*
    - Trichoptera (caddis flies)
      - Brachycentridae
        - *Brachycentrus americanus*
      - Hydropsychidae
        - *Hydropsyche*
        - *Cheumatopsyche*
      - Hydroptilidae
        - *Ochrotrichia*
      - Helicopsychidae
        - *Helicopsyche borealis*
      - Glossosomatidae
        - *Protoptila*
        - *Glossosoma*
      - Limnephilidae
    - Plecoptera (stoneflies)
      - Perlodidae
        - *Isoperla*
      - Nemouridae
    - Coleoptera (beetles)
      - Elmidae (riffle beetles)
        - *Optioservus fastiditus*
        - *Stenelmis sandersoni*
      - Dytiscidae (diving beetles)
    - Odonata
      - Zygoptera (damselflies)
    - Hemiptera (bugs)
      - Corixidae (water boatmen)
        - *Sigaria mathesoni*
      - Belostomatidae (giant water bug)
        - *Lethocerus*
      - Gerridae (water striders)
        - *Gerris*
        - *Trepobates*
  - Crustacea
    - Amphipoda
      - Gammaridae (scud)
        - *Gammarus pseudolimnaeus*
    - Decapoda (crayfish)
      - Astacidae
        - *Orconectes propinquus*
  - Arachnoidea
    - Hydracarina (water mites)
- Mollusca
  - Gastropoda (snails)
    - Basommatophora
      - Physidae
        - *Physa obrussoides*
  - Pelecypoda (clams)
    - Heterodonta
      - Sphaeriidae
        - *Pisidium*
- Annelida
  - Hirudinea (leeches)
    - Rhynchobdellida
      - Glossiphoniidae
        - *Glossiphonia complanata*
    - Arhynchobdellida
      - Erpobdellidae
        - *Erpobdella punctata*
  - Oligochaeta (worms)
    - Pleisopora
      - Tubificidae
- Platyhelminthes
  - Turbellaria (flatworms)
    - Tricladida
      - Planariidae
        - *Dugesia*
- Nematomorpha
  - Gordiida (horsehair worms)
    - Gordiidae
      - *Gordius*

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[a] All forms shown were collected in both the treatment and control stream, with four exceptions: *Erpobdella, Helicopsyche,* and *Nemoura* were only in the treatment stream and *Pisidium* only in the control stream.

Table 6. *Average monthly (May, July, and October*[a]*) water temperature, discharge, vegetative cover, and benthic biomass at Seas Branch Creek stations SB1 and SB2 and control station MD before (1972) and after (1973, 1974) the antimycin treatment of Seas Branch Creek.*

Station and year	Water temp (°C)	Discharge (m^3/s)	Estimated vegetative cover (%)	Benthic biomass (g/m^2)
SB1				
1972	15	0.08	10	56.5
1973	10	0.17	10	49.7
1974	11	0.08	23	114.8
SB2				
1972	15	0.13	11	61.1
1973	13	0.27	27	105.6
1974	13	0.10	17	111.0
MD				
1972	17	0.11	11	96.0
1973	15	0.19	9	93.2
1974	12	0.11	7	100.3

[a] Before treatment on 3 October 1972 for all stations.

not recover from the treatment—as indicated by the sharp (nearly complete) overwinter decline, the lack of adults in the succeeding summer drift, and the near absence of the organisms in October 1974 (2 years after treatment).

The rate of emergence of crane flies was high in spring and decreased from May through September at the control station; the sharp decrease in biomass between March and May 1974 (Fig. 4) was presumably a result of emergence. Larval drift rates were low throughout the year at both treatment stations, except for the increase at the time of treatment (Fig. 3).

Drift rates of Chironomidae at SB2 increased sharply 21 h after treatment, peaked 12 h later, then declined gradually into the next week; drift at SB1 increased slightly 15 h after treatment (Fig. 2). The biomass at both SB1 and SB2 decreased slightly during treatment, then increased sharply in December 1972 (Fig. 5). At this time, midges dominated the biomass (without crayfish) at both treatment stations, contributing 57% at SB1 and 63% at SB2. Apparently the larvae rapidly occupied habitats vacated by more sensitive organisms. Biomass then decreased throughout the year to low levels that approached pretreatment values. High drift rates of midges at SB2 in the year after treatment (Fig. 3) were attributed to overlapping hatches of the various species present.

Benthic biomass values of Chironomidae were low and fluctuated throughout the year at station MD; an increase in biomass similar to that at SB1 and SB2 occurred here after the treatment date, but never reached the levels found at the treated stations (Fig. 5). Drift rates were low throughout the year at MD; the nearly 5 g/h in May 1974 (Fig. 3) reflected the slightly higher benthic biomass present then (Fig. 5).

Antimycin had no direct effect on *Prosimulium* sp. because black flies had emerged before treatment. Biomass at SB2 remained low through November; an increase began in January that reached a maximum of 98 g/m^2 in July 1973 (Fig. 5), or 65% of the benthic biomass (without crayfish). Drift rates, which previously were low (not illustrated) increased with this large increase of *Prosimulium*. Biomass at SB1 also peaked in July. A residual population was present at MD, throughout the year, but never made up a significant portion of the total benthic biomass (Fig. 5).

The dance fly *Hemerodromia* sp. which was present at all three stations in small numbers (but ranging up to 8 g/m^2 at station MD in January 1973) throughout the year (Tables 7-9) appeared to be unaffected by the treatment; few specimens were in the drift, and no dead ones were found.

Ephemeroptera (Mayflies)

Many dead nymphs of *Baetis cingulatus* were observed at the time of treatment at SB1, and drift rates doubled (Fig. 6). At SB2, where the water was warmer, a major emergence had taken place before the treatment. Benthic biomass of this species therefore declined at both stations after treatment (Fig. 5). The benthic biomass of *B. cingulatus* increased 20-fold 1 year after treatment at SB2 and also increased greatly at SB1 earlier in the year (Fig. 5). The decrease in biomass at all stations in November 1973 (Fig. 5) was apparently caused largely by earlier increased drift of late instar nymphs and subimagoes (Fig. 7). The very high biomass levels at SB2 during the second summer after treatment were related to increased vegetation and the larger population of the generation in the preceding year. The decrease in biomass in October 1974 at SB1 was presumably due to earlier emergence.

The two periods of maximum emergence of *B. cingulatus* at MD were in May to July and late September to November. Benthic biomass increased here for each generation (Fig. 5), and drift was high at the time of emergence, which coincided with the time of antimycin treatment (Figs. 6 and 7).

The mayfly *Stenonema* sp. was present at the three sampling stations throughout the study; biomass was highest in the second year after treatment.

Mortality during treatment appeared to be initially low or nil at SB2, but five of six organisms (83%) collected 10 days after treatment were dead (Table 4).

Another mayfly, *Ephemerella* sp., was not collected in 1972 or 1973 but appeared in 1974 at SB1 in April, May, and October and at SB2 and MD in May.

Trichoptera (Caddis flies)

Benthic biomass of the caddis fly *Brachycentrus americanus* was reduced immediately after treatment (Fig. 8), and drift increased sharply (Figs. 6 and 7). At SB1, drift did not occur until 12 h after treatment and reached a maximum 3 h later (Fig. 6). Mortality at this station was about 53% 2 days after treatment and 80% 1 month later (Table 4). Drift at SB2 doubled shortly after treatment (Fig. 6) and continued to be high for at least 2 days. Mortality was 74% on the second day after treatment and 100% 2 weeks after treatment (Table 4). This species seemed to become disoriented during the antimycin treatment. At SB2 many organisms moved about sluggishly and crawled onto stream vegetation and stones. About 50% then abandoned their cases and died.

Biomass of *B. americanus* remained low at both treatment stations during the first year after treatment, but increased considerably at SB1 (not at SB2) during the second year after treatment (Fig. 8).

This species overwintered as larvae and emerged in May through August in Maple Dale Creek. An early emergence in May 1973 preceded a rapid increase in biomass of the following generation (Fig. 8).

For the caddis fly *Hydropsyche* sp., the number of dead and dying in the drift at SB2 reached a maximum 9 h after treatment and decreased during the next week (Fig. 6). Mortality then increased gradually to 100% on 19 October (Table 4). Few drift organisms were taken after treatment at SB1, and the number increased only slowly into the next week (Fig. 6). Mortality here was initially low and reached a maximum of only 58% 2 weeks later (Table 4). Biomass of *Hydropsyche* was reduced at both stations during treatment and increased slightly during the months after treatment (Fig. 8). We attributed this increase to recolonization by drift. The population appeared to have recovered during the year after treatment. Biomass levels at both treatment stations during the second summer after treatment exceeded those before treatment.

In 1972, benthic biomass of *Hydropsyche* was markedly lower in samples taken at MD on 6 and 13 October than on 3 October or 1 November (Fig. 8). However, as mentioned earlier, this decrease was attributed to a sampling error as no increase in drift rates or die-off was observed during this period. Larvae in the 3 October and 1 November samples were in the same size group, indicating that no emergence had occurred.

Hydropsyche produced one generation per year; emergence extended from May through August. Drift rates increased at the times of emergence (Fig. 7). Benthic biomass at all three stations showed decreasing trends after emergence, followed by an increase as the new generation developed (Fig. 8). Samples contained a wide range of instars because of the prolonged hatching time, as was observed also by Hynes (1961). Biomass increased in the fall. Medium size specimens (5-10 mm long) dominated the October-November samples and large ones (10-13 mm long) the late winter and early spring collections.

Coleoptera (Riffle beetle)

No noticeable changes in benthic biomass or drift of *Optioservus fastiditus* occurred during treatment, although benthos collections 10 days after treatment suggested a 15% and 20% mortality at stations SB1 and SB2, respectively (Table 4). The biomass of *O. fastiditus*, represented by concurrent populations of larvae and adults, reached a peak at all stations at about the same time in 1972 and 1973 (Fig. 8). After the reduction or disappearance of organisms sensitive to antimycin, the larvae contributed significantly to the total benthic biomass—e.g., up to 70% at SB2 on 13 October 1972 (Table 8).

Decapoda (Crayfish)

No dead or dying *Orconectes propinquus* were observed during or after the antimycin treatment (Table 4). Because this organism is highly mobile, it was difficult to accurately evaluate its population density (Tables 7, 8, and 9). Many young of the year (1.2-2.0 cm long) were found at SB2 from May, June, or July through October in all years (Table 8).

Discussion

The application of high concentrations of antimycin (17-44 $\mu g/l$) resulted in an immediate increase in drift rates and a temporary reduction in populations of five of nine major taxa, *Gammarus pseudolimnaeus, Antocha, Baetis cingulatus, Brachycentrus americanus,* and *Hydropsyche. Orconectes propinquus* was not affected by the treatment. The biomass of other organisms, such as Chironomidae, *Optioservus fastiditus,* and *Prosimulium,* increased during the months after treatment. Total benthic biomass (all taxa combined) during the two summers after treatment approached or exceeded that of the summer before treatment.

Table 7. *Benthic biomass (g/m²) for station SB1 of Seas Branch Creek above the impoundment, before and after treatment of the stream with antimycin on October 4, 1972.*[a]

Taxon	1972								
	15 May	15 June	15 July	15 Aug	3 Oct	6 Oct	13 Oct	1 Nov	1 Dec
Diptera									
Chironomidae	11.5	4.0	8.1	2.3	2.2	T	0.4	6.7	102.1
Antocha									
larvae	4.3	1.7	4.6	2.3	3.2	0.9	0.2	0.1	0.3
pupae	2.9	0.8	0.5	0.4	0	0	0	0	0
Prosimulium									
larvae	T	0.3	0.7	0.5	0.1	0	0	0	0
pupae	T	0	T	T	T	T	0	0	0
Hemerodromia	0	0	0.2	0.1	3.7	1.2	1.0	1.1	1.5
Other	0.1	0.2	3.6	2.8	7.1	0.5	1.3	4.0	40.0
Epheremoptera									
Baetis	0.1	1.0	0.9	2.1	5.2	0.3	0	0	0
Stenonema	0	0	0	0.1	0.6	0.9	0	0.2	0.5
Ephemerella	0	0	0	0	0	0	0	0	0
Trichoptera									
Hydropsyche	17.4	17.0	7.0	11.7	54.7	28.3	12.6	9.0	16.9
Brachycentrus americanus	0	0.4	2.8	1.5	1.6	0.4	0.5	0.1	1.3
Ochrotrichia	0.3	0.3	0	0	0	0	0	0	0
Glossosoma	0	0	0	0	0	0	0	0	0
Other	0.2	0.2	0.6	0.1	0.1	0.5	0.2	T	0.1
Plecoptera									
Isoperla	T	0	0	0	T	T	0	0	0.2
Coleoptera									
Optioservus fastiditus									
larvae	1.1	2.4	3.9	7.4	13.4	5.3	7.0	12.7	15.8
adult	0.3	0.1	0.3	1.0	0.9	0.5	0.5	0.3	0.7
Stenelmis sandersoni	0.1	0.1	0.2	0.2	0.7	0.1	0.2	0.3	0.1
Amphipoda									
Gammarus pseudolimnaeus	0.6	6.9	1.9	2.8	1.3	0.4	0.4	0.4	0.1
Mollusca									
Physa obrussoides	0	0	0	0	0	0	0	0.1	0
Hirudinea									
Erpobdella punctata	0	0	0	0.3	0	0.9	0	T	0
Miscellaneous	0.3	T	0.2	0.1	0.1	0	0	T	T
Benthic Biomass without *Orconectes*	39.2	35.4	35.5	35.7	94.9	40.2	24.3	35.0	179.6
Decapoda									
Orconectes propinquus	4.2	0.1	16.7	11.9	0	1.4	0	0	4.0
Total Benthic Biomass	43.4	35.5	52.2	47.6	94.9	41.6	24.3	35.0	183.6

[a] T = less than 0.05 g.

Table 7—Continued

1973							1974			
15 Jan	15 Mar	15 May	16 July	15 Sept	6 Oct	10 Nov	20 April	17 May	30 July	2 Oct
23.7	9.9	9.8	11.8	7.1	0.2	0.1	1.1	0.5	8.8	0.1
0.3	0.2	0.1	0.1	1.6	0.4	7.5	0.3	0.2	0.7	0.1
0	0	0	0	0	0	0	0	0	0	0
0.2	0.1	0	24.5	3.5	2.1	10.3	T	T	8.9	0.6
0	0	T	0	T	T	0	0	0	0	0
3.9	0.1	T	0.2	2.2	0.2	0.4	0	0	T	3.2
14.8	15.2	4.8	0	0.5	0	9.0	0	0.5	0	4.0
T	3.9	6.3	1.3	1.6	1.4	1.2	0.3	T	2.5	0.1
0.1	0	1.0	0	0.4	0.4	0.6	0.5	2.9	2.4	0.9
0	0	0	0	0	0	0	4.8	11.4	0	T
25.8	19.1	1.7	0.4	44.8	58.2	13.1	49.7	68.8	17.8	35.5
0.8	0.6	0	1.6	1.4	2.3	11.0	3.0	0	14.3	15.4
0	0	T	0	0	T	0	0	0	T	T
0	0	0	T	0	T	0	3.3	4.7	3.1	4.0
0.4	0.3	1.6	0.2	2.0	0.2	0	1.9	4.5	0.1	T
T	0.7	0.9	0	T	T	0.3	2.1	0.2	0	0
12.2	1.6	1.4	0.8	16.4	6.6	20.1	4.6	6.3	6.6	9.1
1.0	0.2	0.3	0.2	1.8	0.6	0.4	1.0	0.9	1.3	1.1
0.1	0	0	0	0.1	0	0.2	0	T	0	0
0.2	0.2	1.6	0.6	5.6	4.3	9.2	5.2	7.6	86.4	11.2
0.3	0	0	T	T	T	0	T	T	0	0.1
T	0	0	T	3.4	0.4	0.4	0	0.6	0.5	0
T	0	0.3	0	0.1	T	T	0	0	0	0
83.8	52.1	29.8	41.7	92.5	77.3	83.8	77.8	109.1	153.4	85.4
3.6	0	0	0	0	25.9	0	0	39.1	13.2	82.6
87.4	52.1	29.8	41.7	92.5	103.2	83.8	77.8	148.2	166.6	168.0

Table 8. *Benthic biomass (g/m²) for station SB2 of Seas Branch Creek, below the impoundment, before and after treatment of the stream with antimycin on October 4, 1972.*[a]

Taxon	1972								
	15 May	15 June	15 July	15 Aug	3 Oct	6 Oct	13 Oct	1 Nov	1 Dec
Diptera									
Chironomidae	13.8	31.0	15.4	28.6	0.8	2.3	5.2	20.0	111.4
Antocha									
larvae	3.4	1.3	2.9	16.1	12.3	6.7	0	0.3	0.3
pupae	0.5	0.9	0.2	0.4	0	0.1	0	0	0
Prosimulium									
larvae	0	0.5	0.2	T	0.2	0	0	0	0.1
pupae	0	0.1	T	T	T	T	T	0	0
Hemerodromia	0	T	0.5	0	0.3	3.0	0.1	1.2	1.2
Other	0.6	0.2	T	0.2	0	0.4	0.1	16.3	1.8
Ephemeroptera									
Baetis	0.1	1.3	1.5	0.4	T	0	0	0	0
Stenonema	0	0	0	0.1	0.2	0.1	0.1	0.2	0.3
Ephemerella	0	0	0	0	0	0	0	0	0
Trichoptera									
Hydropsyche	6.7	12.1	17.4	30.1	34.2	19.7	4.1	7.2	10.4
Brachycentrus americanus	0	12.4	12.4	11.0	17.0	11.5	0.9	1.6	2.6
Ochrotrichia	T	0.1	0	0.1	0	0	0	0	0
Glossosoma	0	0	0	0	0	0	0	0	0
Other	1.1	0.6	0.3	T	T	0.1	0.3	0.5	0.2
Plecoptera									
Isoperla	0	0	0	0	0	0	0	0	0
Coleoptera									
Optioservus fastiditus									
larvae	0.4	5.4	8.6	7.3	12.3	17.7	40.5	45.7	43.3
adult	T	0.1	T	0.1	0.1	0.1	0.3	0.2	0.2
Stenelmis sandersoni	T	0.1	0.5	0.5	0.6	0.5	1.2	0.5	0.8
Amphipoda									
Gammarus pseudolimnaeus	4.9	4.9	1.7	2.4	2.3	0	0.1	T	0
Mollusca									
Physa obrussoides	0	0.1	0	T	0	0	T	T	0.4
Hirudinea									
Erpobdella punctata	4.6	13.0	0	3.5	3.5	0	4.3	0.4	0.1
Nematomorpha	0	0	0	0	T	T	0	0	T
Miscellaneous	1.8	0.4	T	0	0.1	0.1	0.1	0.3	3.1
Benthic Biomass without *Orconectes*	37.9	84.5	61.6	100.8	83.9	62.3	57.3	94.4	176.2
Decapoda									
Orconectes propinquus	23.3	6.0	7.1	34.0	52.7	21.4	5.3	49.1	0
Total Benthic Biomass	61.2	90.5	68.7	134.8	136.6	83.7	62.6	143.5	176.2

[a] T = less than 0.05 g.

Table 8—Continued

1973							1974			
15 Jan	15 Mar	15 May	16 July	15 Sept	6 Oct	10 Nov	20 April	17 May	30 July	2 Oct
50.5	39.3	55.3	13.9	8.8	0.1	0.1	0.6	3.2	0.4	0.1
0.1	T	0.5	0.1	0.6	0.5	0.5	0.3	1.1	0.4	1.5
0	0	0	0	T	0	0	0	0	0	0
0.7	3.4	1.9	97.8	0.4	0.1	0.1	T	3.1	1.3	T
0	0	0.1	T	T	T	0	0	0	0	0
2.9	T	0	T	2.2	0.6	1.1	0	0	T	0
3.6	11.0	0.3	0	0.4	0.2	0	1.3	0.4	1.2	9.2
T	0.9	3.4	6.1	13.9	14.0	1.3	23.5	37.7	6.0	7.6
0.1	0.1	0.1	T	1.5	2.6	2.3	8.9	8.4	1.1	1.4
0	0	0	0	0	0	0	0	1.5	0	0
4.7	4.5	3.8	2.5	39.1	39.1	11.9	10.9	50.9	6.6	18.7
0.3	0.5	0	1.1	1.2	0.5	0.3	0.1	0	2.4	3.3
0	0	0	T	T	T	0	0	0	0	0
0	0	0	T	0	0	0	0	0.3	0	0.3
3.0	1.6	0	T	0	0	9.0	0	0.1	0.3	0
0	0	T	0	T	0	0	1.1	0.2	0	0
18.5	9.4	1.5	10.5	33.2	18.9	20.6	7.3	8.2	10.2	14.3
0.1	0.2	0.2	0.2	0.3	0.1	T	0.2	0.4	0.6	0.8
0.2	0.1	T	T	0.1	T	T	T	0.3	0	0
0	T	0.1	11.6	24.0	16.3	14.5	19.7	20.8	71.4	29.3
0.4	T	T	0.2	0.1	T	T	T	0	0.3	0.2
0.1	2.8	20.6	1.0	0.9	1.0	1.6	12.7	2.9	5.1	T
0	0	0	0	0	0	0	0	0	0	0
2.0	0.7	0.4	0	0	T	0	0	0	0	0
87.2	74.5	88.2	145.0	126.7	94.0	63.3	86.6	139.5	107.3	86.7
12.6	8.9	5.3	25.0	45.2	80.7	15.4	15.3	16.7	27.9	13.1
99.8	83.4	93.5	170.0	171.9	174.7	78.7	101.9	156.2	135.2	99.8

Table 9. *Benthic biomass (g/m²) for control station MD of Maple Dale Creek, before and after treatment of Seas Branch Creek with antimycin on October 4, 1972.*[a]

Taxon	1972								
	15 May	15 June	15 July	15 Aug	3 Oct	6 Oct	13 Oct	1 Nov	1 Dec
Diptera									
Chironomidae	5.0	10.7	3.6	6.3	1.0	0.7	1.6	2.0	21.9
Antocha									
larvae	1.6	0.4	12.7	10.9	11.9	13.0	7.1	13.1	7.9
pupae	0.7	0.2	0.3	1.8	0	0	0	0	0
Prosimulium									
larvae	0	0	0.2	0.3	0.1	T	T	0.2	0.2
pupae	0	0	T	T	T	T	0	0	0
Atherix	0	0	0	6.3	4.9	2.3	2.1	2.0	8.3
Hemerodromia	0.4	0.2	0	0.4	1.1	0.9	0.5	2.2	3.4
Other	0	0.7	T	T	0.1	0.2	0.9	0.1	T
Ephemeroptera									
Baetis	T	0.2	0.4	0.2	0.7	0.5	0.1	0.2	0.5
Stenonema	0.4	0	0	T	0.3	T	T	0.2	0.1
Ephemerella	0	0	0	0	0	0	0	0	0
Trichoptera									
Hydropsyche	9.8	6.3	14.7	60.3	172.9	40.2	6.0	164.9	40.3
Brachycentrus americanus	0.1	1.0	1.8	3.3	6.9	6.1	3.9	13.1	2.8
Ochrotrichia	0.1	T	0	0	0	0	0	0	0
Glossosoma	0	0	0	0	0	0	0	0	0
Other	0.8	0.3	T	0.1	0.6	0.4	0.6	0.1	0.1
Plecoptera									
Isoperla	0.3	0	0	0	T	T	0	0.2	0.4
Coleoptera									
Optioservus fastiditus									
larvae	1.4	4.0	4.6	4.2	21.2	13.6	17.8	19.7	11.4
adult	0.1	0.2	0.2	0.4	1.1	0.4	0.2	0.1	0.1
Stenelmis sandersoni	0.1	0.5	0.3	0.4	0.5	0.8	0.6	0.4	0.2
Amphipoda									
Gammarus pseudolimnaeus	0.7	2.3	0.8	0.4	0.5	0.1	0.5	0.2	1.3
Mollusca									
Physa obrussoides	0.3	0.2	T	0	T	0	0	0.1	0
Hirudinea									
Erpobdella punctata	0	7.7	2.6	0	0.1	0	0	0	0
Nematomorpha	0	0	0	0	0	0	T	T	0
Miscellaneous	0.1	0.4	0.1	0.1	0.2	T	T	0.1	0
Benthic Biomass without *Orconectes*	21.9	35.3	42.3	95.4	224.1	79.2	41.9	218.9	98.9
Decapoda									
Orconectes propinquus	26.3	32.4	7.2	41.6	30.0	0.2	1.1	0	16.0
Total Benthic Biomass	48.2	67.7	49.5	137.0	254.1	79.4	43.0	218.9	114.9

[a] T = less than 0.05 g.

Continued

Table 9. *Benthic biomass (g/m²) for control station MD of Maple Dale Creek, before and after treatment of Seas Branch Creek with antimycin on October 4, 1972.*[a]

1973							1974			
15 Jan	15 Mar	15 May	16 July	15 Sept	6 Oct	10 Nov	20 April	17 May	30 July	2 Oct
16.8	18.6	5.6	1.6	2.7	0.8	0.2	11.4	24.6	9.4	0.1
7.1	14.9	4.3	5.9	8.8	9.9	6.1	6.6	6.5	13.3	2.1
0	0	0	0	T	0	0	0	0	0	0
0.3	T	0	0.3	1.5	0.4	T	0.4	0.4	2.6	0.2
0	0	0	0	0	0	0	0	0.3	0	0
1.6	2.0	0	0	1.3	0	0	0	0	0	0
8.0	2.0	0.1	0.3	1.5	2.6	1.6	0	T	0	0
0.4	3.4	0.2	0.6	0	0	0	0.4	0	0	0
0.4	5.6	0.5	1.3	3.6	3.3	0.4	0.1	0.3	3.7	7.3
T	0.4	T	0	0.1	T	T	0	1.1	0.1	0
0	0	0	0	0	0	0	0	T	0	0
44.4	82.0	18.5	14.1	79.7	128.2	56.5	62.3	32.4	13.7	94.3
10.4	9.5	0	11.1	32.9	25.6	31.9	3.4	0	2.5	42.5
0	0	0	0	0	0	0	0	0	0	0
0	0	0	T	0	0	0	0.1	0.1	T	0.1
T	1.7	0.3	0.1	0	T	0	0.1	0	0.4	0
0.9	0.4	0.3	0	0	T	0	1.5	0.4	0	0
29.9	2.6	1.5	16.3	50.6	20.7	27.0	9.3	7.9	12.4	17.1
0.1	0.3	0.2	1.0	0.4	1.2	0.4	0.6	0.9	0.5	0.5
0.6	0.1	0	T	T	T	T	0.1	0.3	0.2	0
0.6	1.9	0	1.0	1.6	1.4	2.0	0.3	0.3	1.4	1.0
T	T	0	0.1	T	T	0	0	T	T	0
0	0.8	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0.1	0.1	0	0	T	T	0	0	0	0	0
121.6	146.3	31.5	53.7	184.7	194.1	126.1	96.6	75.5	60.2	165.2
1.2	14.7	0	8.8	42.7	22.8	0	6.6	22.6	128.0	1.0
122.8	161.0	31.5	62.5	227.4	216.9	126.1	103.2	98.1	188.2	166.2

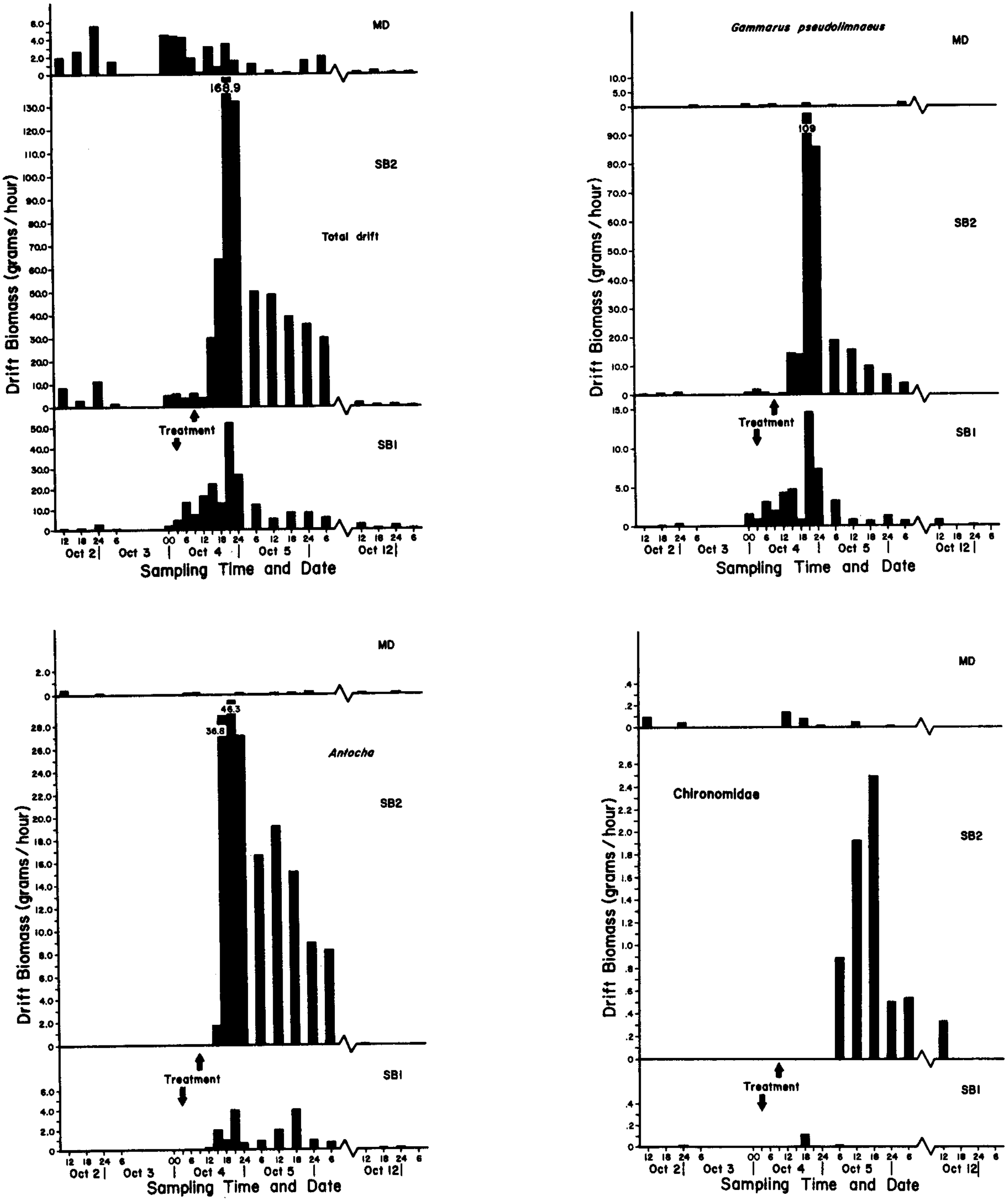

Fig. 2. Drift of benthic macroinvertebrates (total, scuds, crane flies, and midges) at sampling stations in treated Seas Branch Creek (SB1, above impoundment; SB2, below impoundment), and in untreated Maple Dale Creek (MD), October 1972. Numbers along the baseline show sampling times (6 = 0600 h, 12 = 1200 h, . . .) and arrows show time when antimycin reached the station.

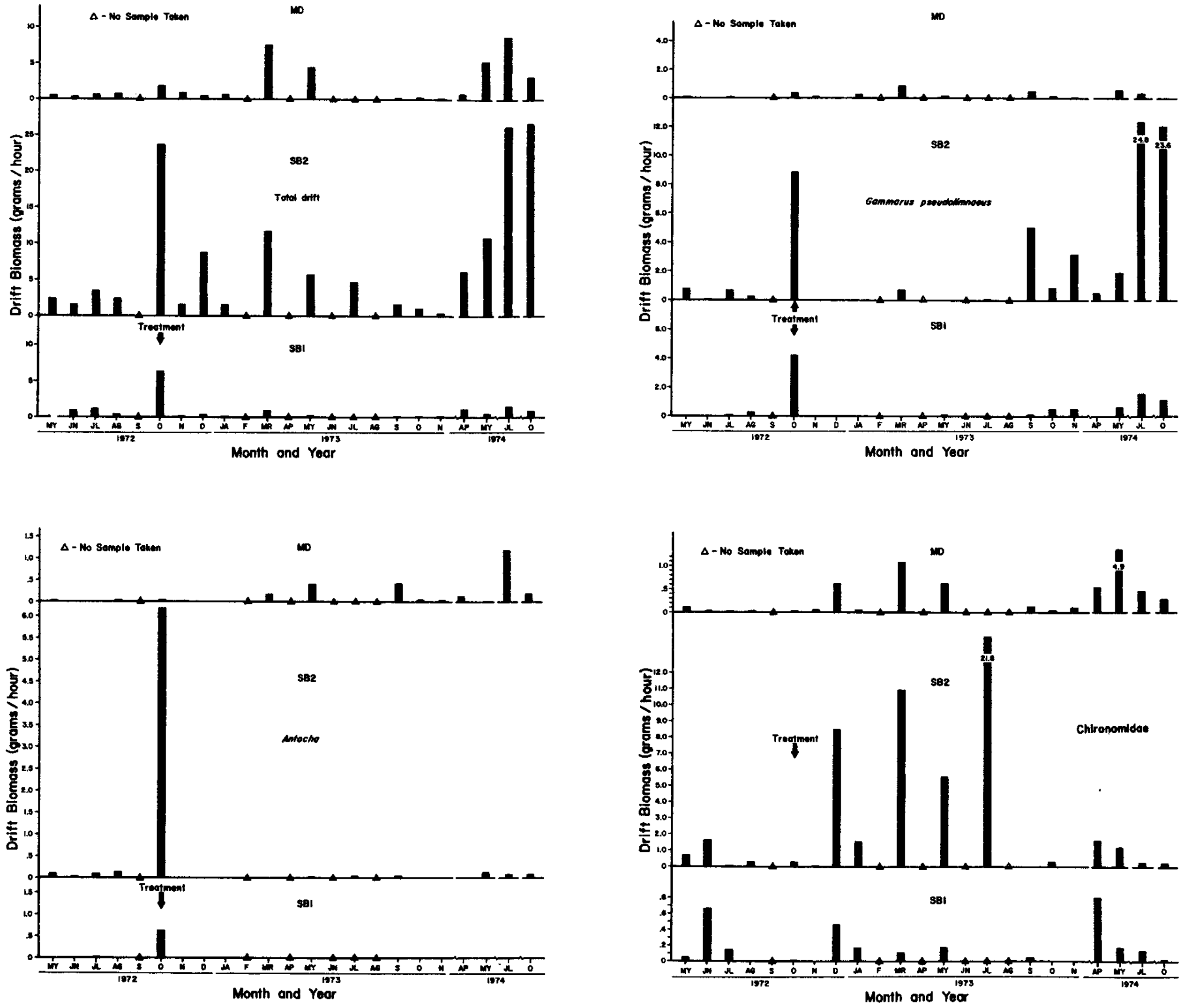

Fig. 3. Drift of benthic macroinvertebrates (total, scuds, crane flies, and midges) in treated Seas Branch Creek (SB1, SB2), and in untreated Maple Dale Creek (MD), 1972-74.

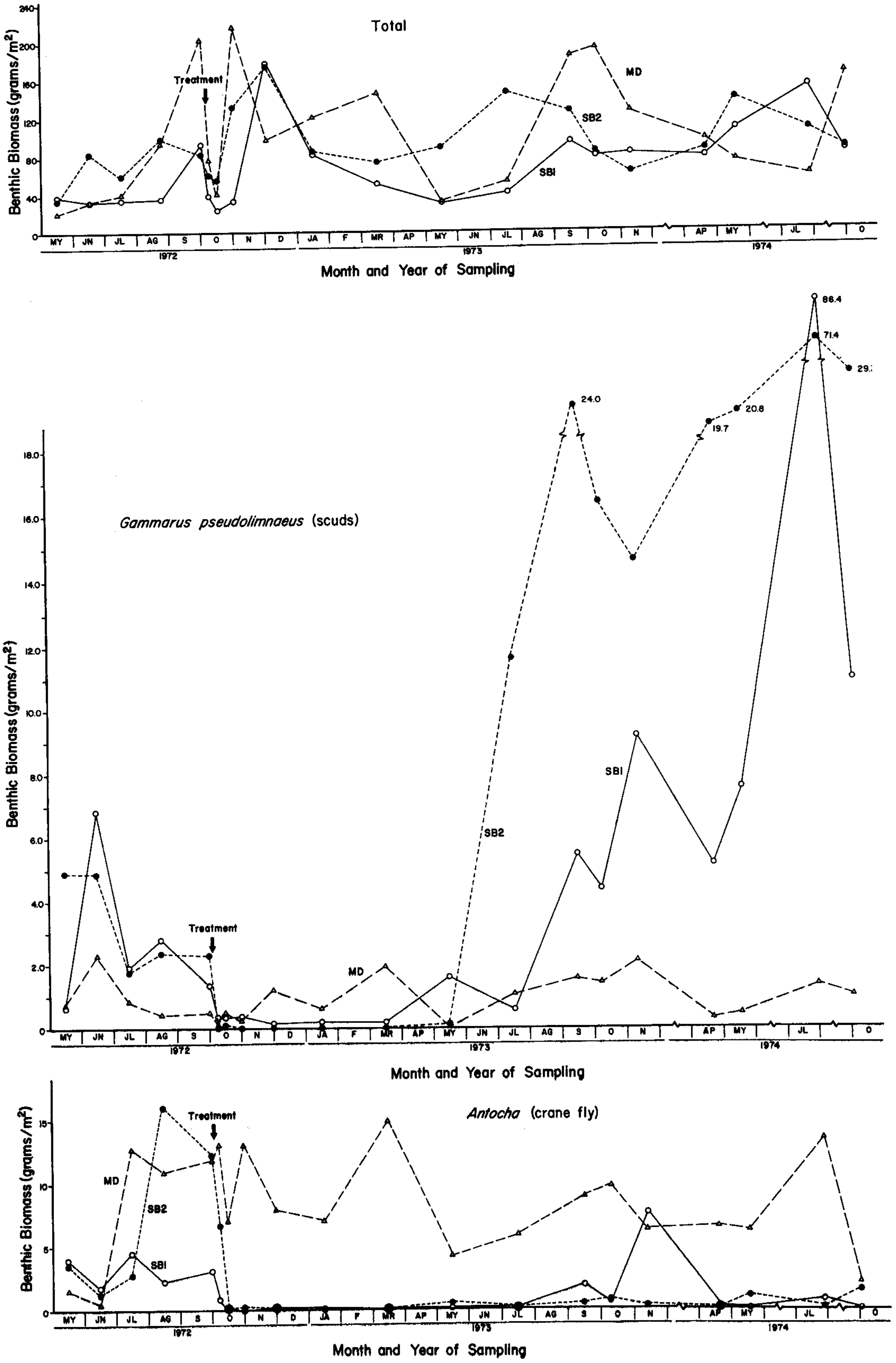

Fig. 4. Biomass of benthic macroinvertebrates (total, scuds, and crane flies) in treated Seas Branch Creek (SB1, SB2), and in untreated Maple Dale Creek (MD), 1972-74.

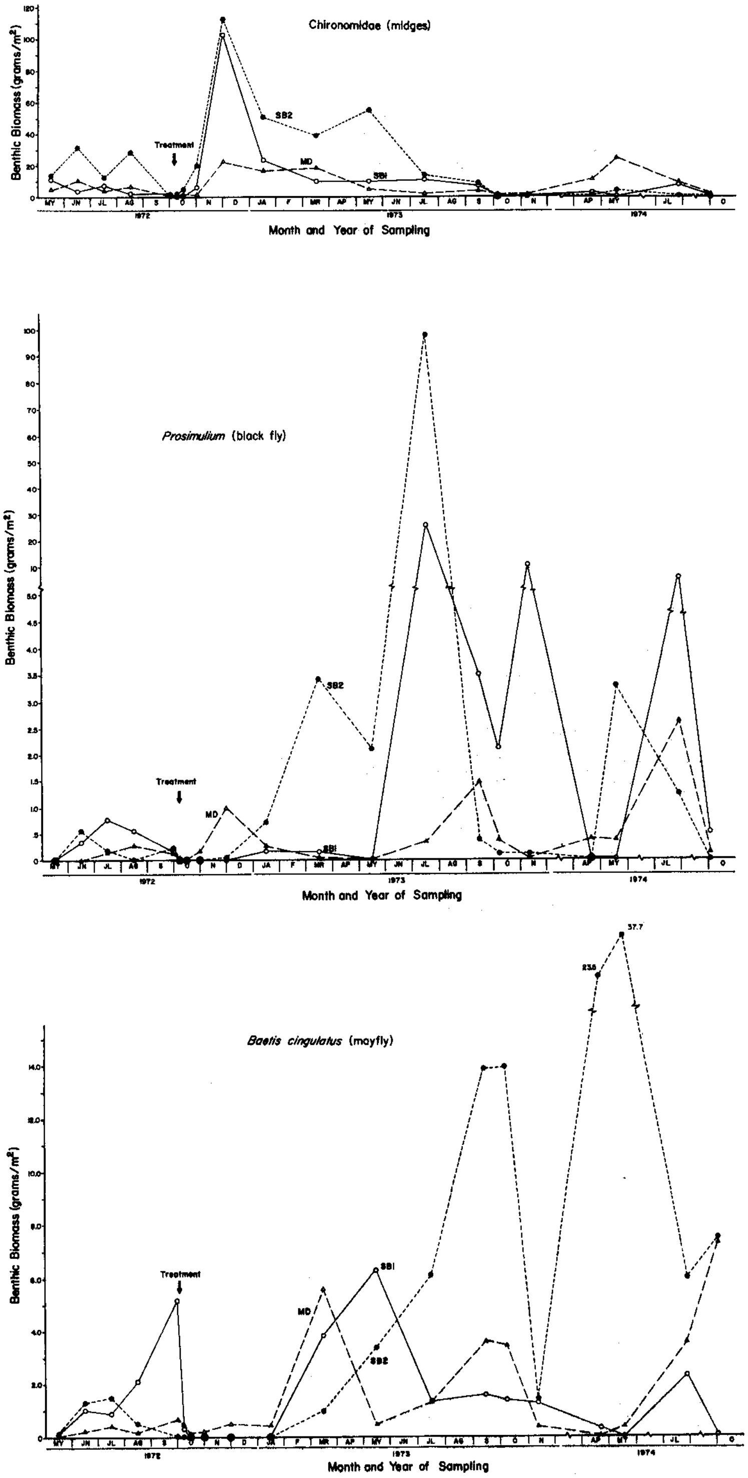

Fig. 5. Biomass of benthic macroinvertebrates (midges, black flies, and mayflies) in treated Seas Branch Creek (SB1, SB2), and in untreated Maple Dale Creek (MD), 1972-74. (Note the change in scale for biomass of black flies for values larger than 5 g/m²).

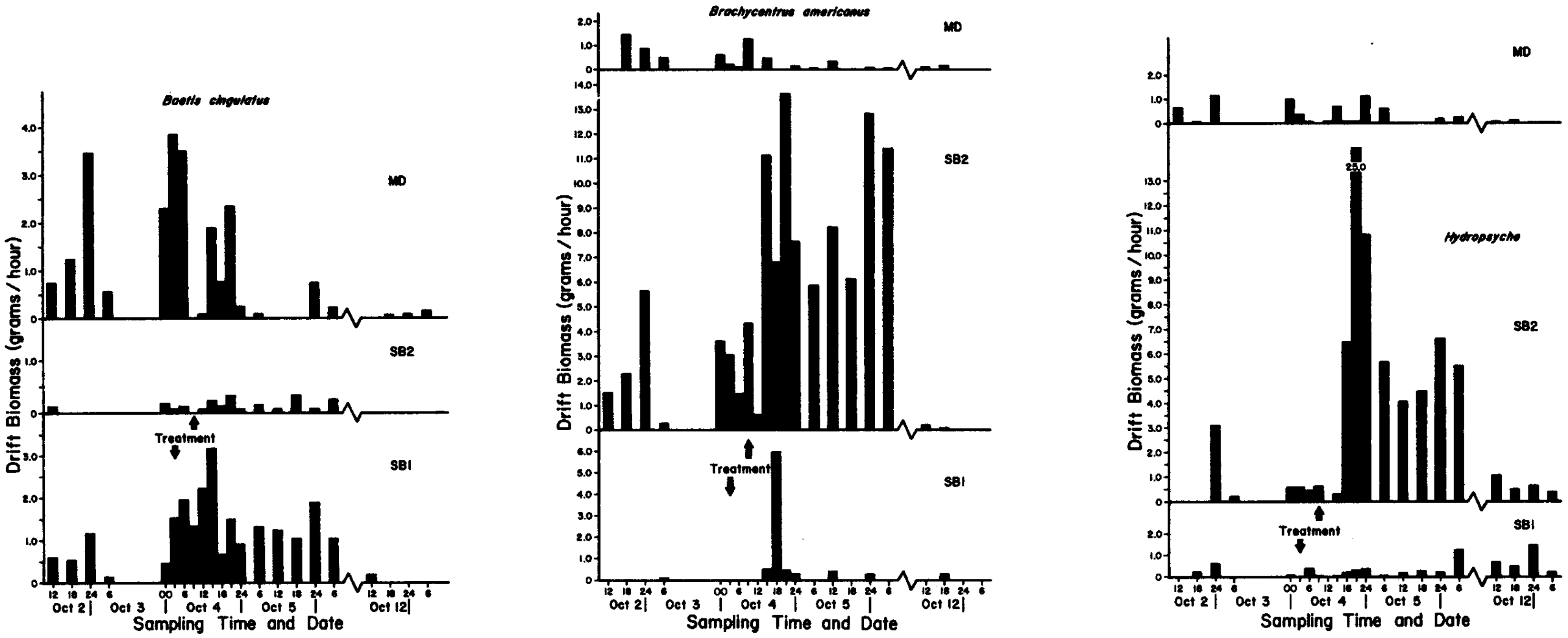

Fig. 6. Drift of benthic macroinvertebrates (a mayfly and two caddis flies) in treated Seas Branch Creek (SB1, SB2), and in untreated Maple Dale Creek (MD), October 1972.

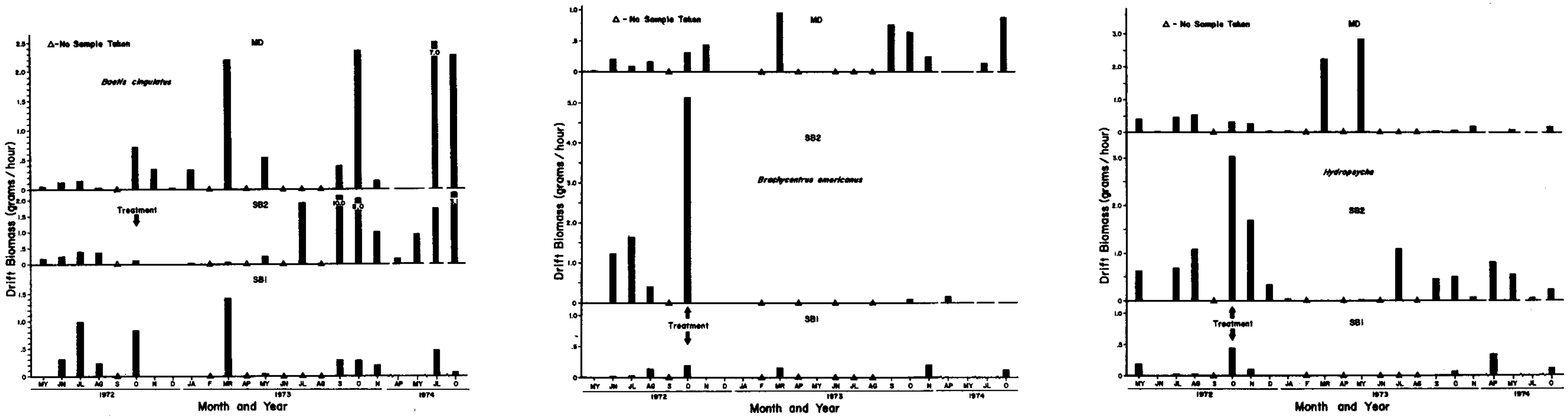

Fig. 7. Drift of benthic macroinvertebrates (a mayfly and two caddis flies) in treated Seas Branch Creek (SB1, SB2), and in untreated Maple Dale Creek (MD), 1972–74.

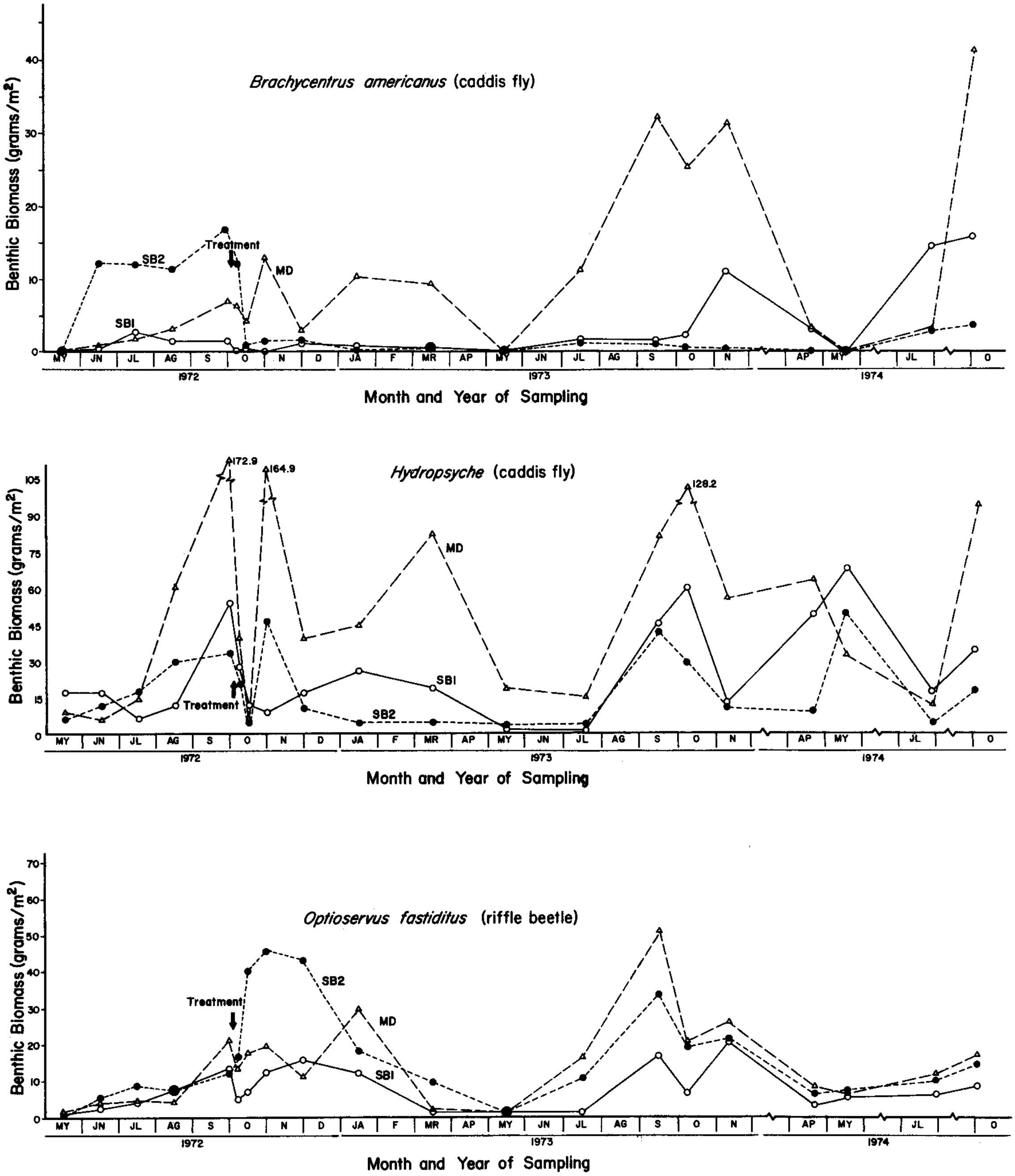

Fig. 8. Biomass of benthic macroinvertebrates (two caddis flies and a riffle beetle) in treated Seas Branch Creek (SB1, SB2), and in untreated Maple Dale Creek (MD), 1972-74.

Many benthic organisms are not specialized in food preference, and diets change according to the availability of algae (Chapman and Demory 1963). Additional food and space for Chironomidae, *O. fastiditus,* and *Prosimulium* could result from the reduction of other taxa of invertebrates, and of fish, and an increase in algae and in available plant surface area for attachment. The alga, *Vaucheria* sp., increased noticeably at SB2 1 week after treatment and reappeared in June 1973. *Ranunculus* present in July increased here also from a maximum of 15% stream-bed coverage before treatment to 50% in the year after treatment.

Recovery of invertebrates after treatment may have been hastened by the increase in stream vegetation. Particulate organic matter flushed downstream when the reservoir was draining may have been a source of nutrients. Nutrients also may have been made available by bacterial and fungal degradation of fish carcasses which littered the stream bottom after treatment. An increase in nutrients was observed by Richey et al. (1975) when kokanee salmon *(Oncorhynchus nerka)* died after spawning.

Chironomidae, *Gammarus pseudolimnaeus, Baetis cingulatus,* and *Prosimulium,* which had high turnover rates resulting from immature developmental periods of less than 1 year, returned more quickly than most other taxa to pretreatment biomass levels in the year following treatment. Populations of *Antocha* and *Brachycentrus americanus,* which have longer development times, had not recovered to pretreatment levels 1 year after treatment at the downstream station (SB2). Moffett (1936) observed a similar pattern in populations that were decimated by floods. Although both *Antocha* and *B. americanus* showed signs of recovery in November 1973, *Antocha* dropped back to low levels at SB1 during the second year.

Hildebrand (1971), who studied benthos disruptions by salmon spawning, believed that organisms with low drift rates in winter would not repopulate a stream until midsummer, when drift rates increased. Rapid recolonization in Seas Branch Creek could have taken place because treatment of areas adjacent to the mainstream was incomplete; e.g., mortality of *Hydropsyche* was high at SB2 but recovery was rapid after treatment. Repopulation could also have resulted from the insects' normal recolonization cycle which Mueller (1954) found to involve upstream flight of adults, ovoposition, population growth, and a later downstream drift of immatures in response to competition for food and space.

Because antimycin is short-lived, it would be desirable, although somewhat difficult, to treat a stream when adults of dominant or sensitive insects are mating. If ovoposition took place after treatment, survival and perhaps higher biomass levels might result, as observed in *Baetis cingulatus* at the downstream Seas Branch station.

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