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EFFECTS OF CONTROLLED FLOW REDUCTIONS ON AQUATIC INSECTS IN A STREAM RIFFLE

by

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VITA

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ABSTRACT

A study was conducted on Blacktail Creek in southwestern Montana from May, 1966, to September, 1967, to determine the effects of controlled flow reductions on the ecology of aquatic insects. Two riffles were selected for study: one served as a control, and the other, the test riffle, was subjected to flow reductions of 75 and 90% during the summers of 1966 and 1967, respectively. Four samples of aquatic insects were collected with a Surber sampler along a transect in each riffle on each sampling date. Samples were collected bimonthly during the periods of dewatering and monthly during the period of natural flow. Physical and chemical data were collected on each sampling date. Average depth, average water velocity, and water volume were the physical parameters most affected by flow reductions. During the period of 75% dewatering, aquatic insect populations in the control riffle increased, while those in the test riffle remained stable. Insect densities in the test riffle, relative to those in the control riffle, were higher during the period of 75% dewatering than during the full-flow period. A decline in the numbers of aquatic insects/m^2 in the test riffle was associated with the resumption of natural flow conditions. Total numbers of insects in the test riffle did not reach their initial high value until two months after the initial high was reached in the test riffle. Trichoptera were affected most by flow reductions.

INTRODUCTION

The summer flows of many streams in the western United States are reduced by the diversion of water for irrigation. In 1965, the Montana Fish and Game Department sponsored studies on Blacktail Creek in southwestern Montana to determine the effects of reduced flows on fish populations. Water was diverted from a portion of the stream to simulate conditions that might occur from dewatering for irrigation. During the first summer of the study some aquatic insects were stranded by dewatering and sedimentation increased in some areas. My study was initiated to determine the effects of reduced flows on the habitat and dynamics of aquatic insect communities. Field work was conducted from May 6, 1966, through September 1, 1967.

Populations of aquatic insects are affected by stream flows. Surber (1936), Tarzwell (1937), and Logan (1963) showed an inverse relationship between numbers of insects and flow, and suggested a scouring effect. Irving and Culpin (1956) showed that diurnal water level fluctuations below a dam in Idaho reduced the production of aquatic bottom invertebrates. Powell (1948) compared aquatic insect populations below a power dam in Colorado with those above the impoundment. In the area below the dam, subjected to large diurnal and reduced minimum flows, weights of populations were less, individual organisms were smaller, and there were severe reductions in the numbers of mayflies, stoneflies, and caddisflies. Briggs (1948) reported the numbers and weights of bottom organisms to be much greater below a percolation dam in California than above and attributed this to the stabilization effect of the dam on water flows.

METHODS

The test riffle was selected in the uppermost section (A, Fig. 1) of the 52 m portion of the stream used for the fish population studies conducted by Wipperman (1966, 1967) of the Montana Fish and Game Department and Kraft (1968). A dewatered state was maintained throughout a three month summer period by diverting a percentage of the calculated base flow of 0.90 m^3/sec. The base flow in Section A was reduced 75% to 0.22 m^3/sec from May 23 to August 23, 1966. Flow was decreased 90% to 0.09 m^3/sec from July 3 to September 3, 1967. Another riffle, the control, was selected upstream in an area free from dewatering influences (Fig. 1).

Three 0.3 m^2 samples of the stream bottom were collected along a transect in each riffle with a Surber sampler. Material was collected to a depth of about 7.5 cm in the test riffle, but only to 5 cm in the control riffle due to the presence of bedrock. The samples from each riffle were dried and put through a series of Tyler soil screens to separate them into seven size categories. The volume of each size category was determined by displacement of water and its percent of the total volume calculated.

Aquatic insect samples were taken with a Surber sampler. The lower end of each riffle was sampled first so upstream areas, to be sampled later, would not be disturbed. Four 0.3 m^2 samples, spaced 0.6 m apart along a transect, were collected in each riffle on each sampling date. Areas with large amounts of aquatic vegetation or large rubble were avoided. Succeeding samples were taken in a similar manner on transects established about 0.6 m upstream from the preceeding one. After seven months of

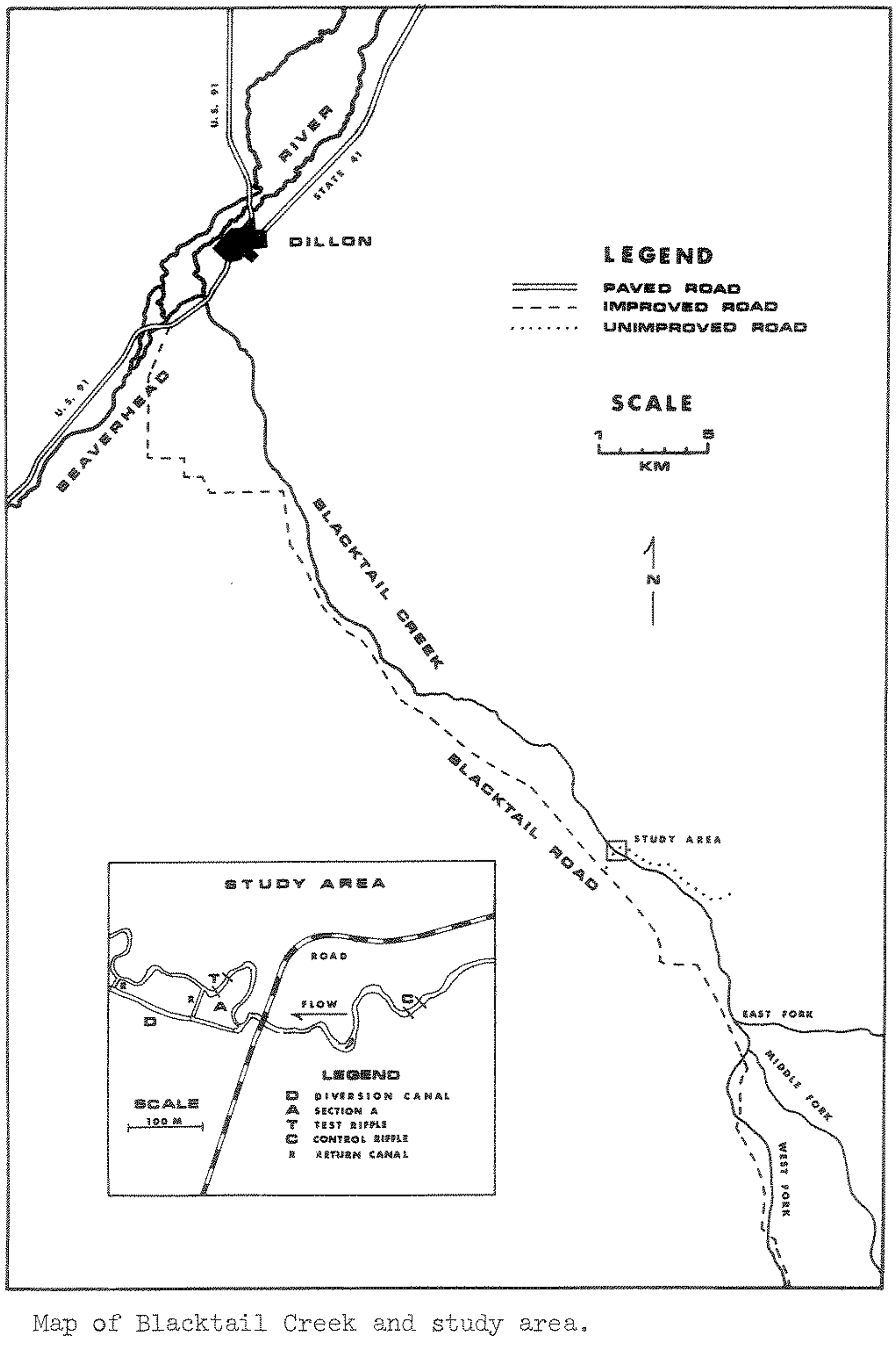

Figure 1. Map of Blacktail Creek and study area.

sampling, the upper ends of the riffles were reached and collections were taken at the downstream ends but were staggered so that sample sites in the second series fell between those of the first series (Fig. 2). Samples were collected every two weeks during the periods of dewatering and every four weeks during natural flows (August 26, 1966, to June 25, 1967) except in June, 1967, when high spring flows prevented sampling. Hereafter, the three above mentioned flow periods will be referred to as the period of 75% dewatering, 90% dewatering, and full-flow.

A total of 168 samples were collected (84 from each riffle) on 21 sampling dates. Samples were placed in plastic bags, preserved in 10% formalin, then later sorted to Order, counted, and preserved in 70% alcohol. Volumes of insects were determined to the nearest 0.1 cc by displacement in 70% alcohol. Trichoptera cases were not included in volumetric measurements. Numbers and volumes of insects from the test riffle were compared to those from the control riffle by flow period with an analysis of variance test. Significance is reported at the 1% level unless otherwise stated. Insects from three selected sampling dates (March 24, July 7, and September 1, 1967) were identified to species where practicable.

Physical and chemical data were collected on each sampling date. Flows were calculated from velocity and depth measurements taken with a Gurley current meter at 0.3 m intervals on a transect across the stream. Velocities were obtained at 0.4 the depth of the water. The velocity and

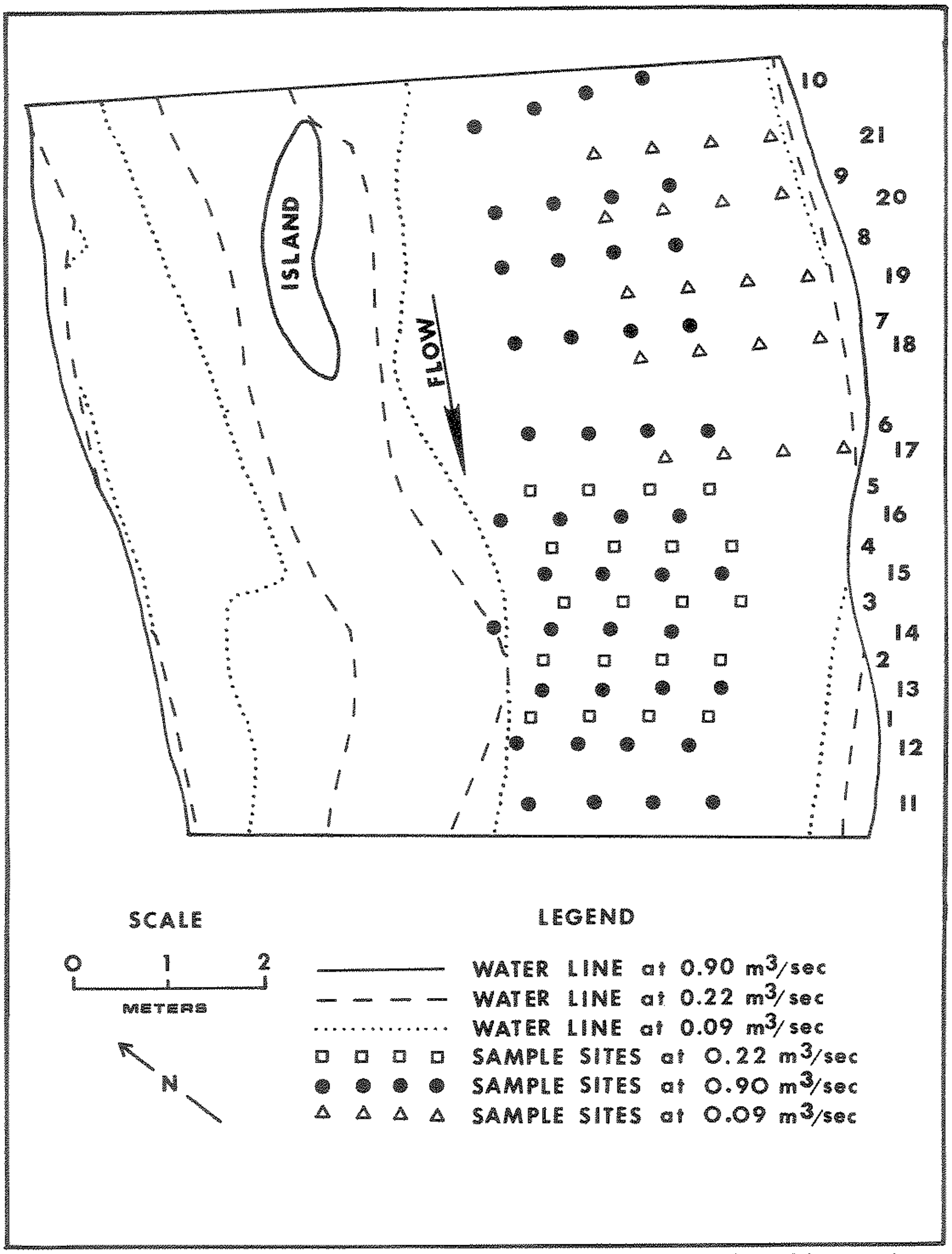

Figure 2. Map of test riffle showing sample sites and water lines at three flow conditions. Numbers indicate the location of transects and the sequence in which they were established.

depth at each sample site were recorded. Water temperatures were recorded on Taylor thermographs during the dewatered periods. Maximum-minimum thermometers were used throughout the full-flow period and were read on each sampling date. A model DR-EL Hach kit was used to determine dissolved oxygen, alkalinity, pH, and turbidity on each sample date.

Maps were constructed of both riffles when flow was near the calculated base of 0.90 m^3/sec and of the test riffle when the flow was reduced by 75 and 90%. A polar planimeter was used to determine the area of the watered zones under each flow condition.

DESCRIPTION OF STUDY AREA

Blacktail Creek originates from three major tributaries in southeastern Beaverhead County, Montana (Fig. 1). The tributaries head at an elevation of about 2400 m in the snowfields of the Snowcrest Range, a series of mountains composed of folded and faulted sedimentary rock from the Precambrian to Upper Cretaceous Periods (Klepper, 1950). Blacktail Creek is formed where the East Fork joins the combined flows of the Middle and West Forks at an elevation of about 1900 m. Blacktail Creek flows northwesterly 45 km through coniferous forests which merge with sagebrush and grassland hills. It drains an area of about 808 km^2 and empties into the Beaverhead River, about 3 km southeast of Dillon, Montana.

This creek flows through a broad valley capped with coalescent alluvial fans which head at the mouths of the many gulches (Alden, 1953). It meanders through a well defined channel of Tertiary deposits of glacial outwash, sand, and gravel (Alden, 1953) that is lined with willow (*Salix* sp.) interspersed with groves of cottonwood (*Populus* sp.).

Blacktail Creek is characterized by high spring runoffs with low flows the remainder of the year (Fig. 3). The United States Geological Survey operated a gage station about 13 km below the study area from January, 1947, through September, 1966. The highest mean monthly flow (6.6 m^3/sec) for the 19 year period 1947 through 1965 was recorded in June, 1964. The lowest mean monthly flow (0.4 m^3/sec) was recorded in January and February of the same year.

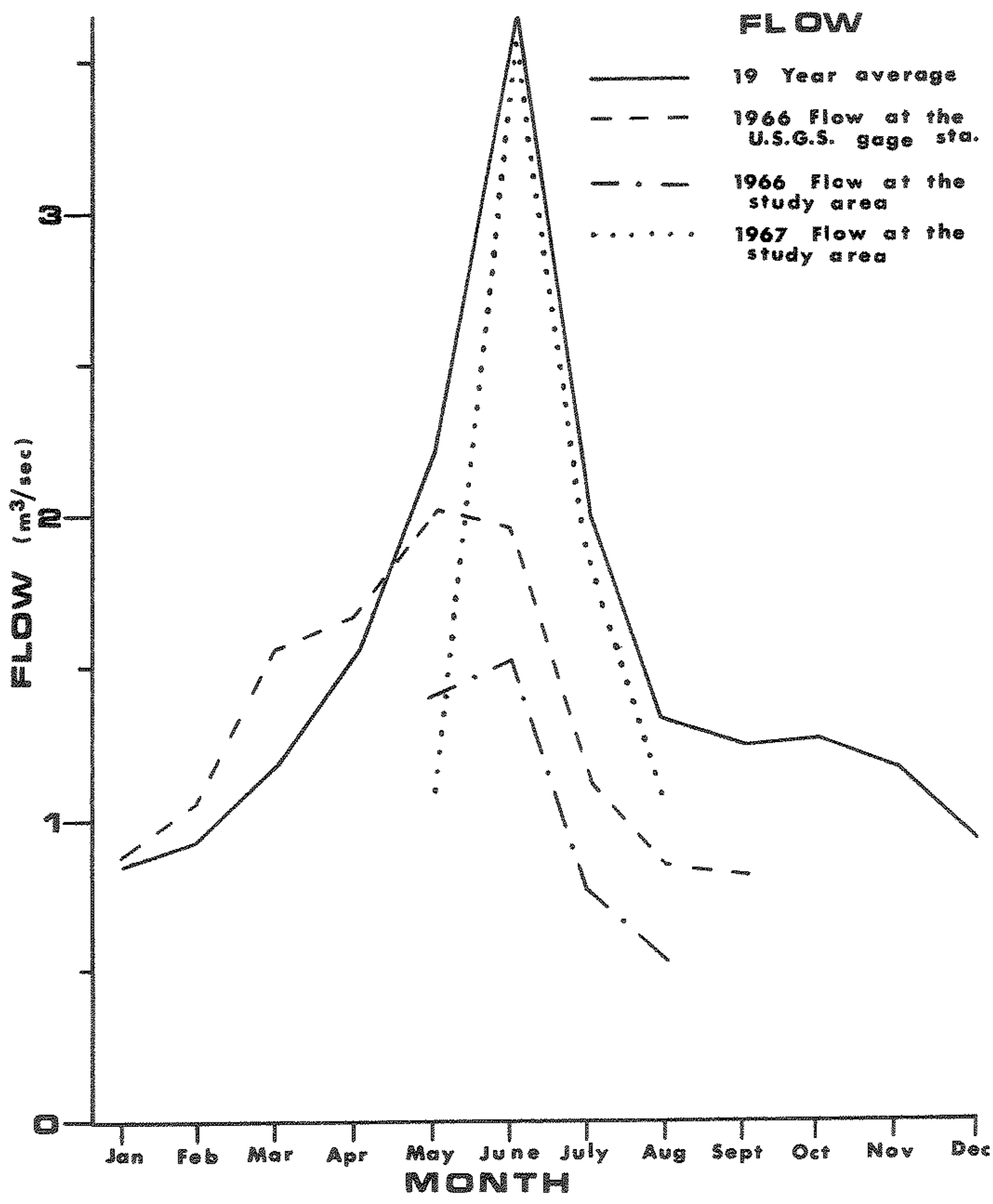

Figure 3. Mean monthly discharges for 1966, 1967, and the 19 year average.

In 1966 flows at the gage station were below the 19 year average. Total precipitation, measured at the Dillon WMCE Recording Station in Dillon, was 13.8 cm below the 1947-1965 average.

No USGS flow data were available for 1967, but a comparison of flows obtained from a water stage recorder in the study area to the 19 year average at the gage station indicated above average flows for that year. Flows in the study area from June through August, nearly paralleled the 19 year average obtained 13 km downstream. Total precipitation at Dillon for the first nine months of 1967 was 5.4 cm above the 19 year average.

The study area (Fig. 1) was located above irrigation diversions and about 35 km southeast of Dillon on the upper half of Blacktail Creek (T.10S., R.7W., Secs. 11 & 13). The elevation at this site is about 1840 m and the stream gradient is 7 m/km. The major land use consisted of livestock grazing and haying of native meadows. Kraft (1968) listed the dominant plant species in the area. The test riffle was located about 150 m (stream distance) below the headgate controlling flows in the section. The control riffle was situated about 625 m above the test riffle (Fig. 1).

The physical and chemical characteristics of both study riffles under natural flows are presented in Table I. On the average, the test riffle was wider but shallower than the control, and contained 23% less volume. Average flows were about 0.08 m^3/sec higher in the test riffle than in the

Table I. Average values (ranges) of physical and chemical characteristics of study riffles.

Environmental Factors*		Control Riffle	Test Riffle
Physical			
Width (m)**		6.8 (6.4 to 7.2)	7.4 (7.0 to 7.9)
Depth (cm)**		20.7 (9.2 to 45.8)	15.9 (0.0 to 36.6)
Water Surface Area (m^2)		22.50	22.80
Water Volume (m^3)		4.61	3.57
Water Velocity (m/sec)		0.45(0.06 to 1.15)	0.47(0.05 to 1.35)
Flow (m^3/sec)		0.48(0.31 to 1.16)	0.56(0.39 to 0.84)
Temperature (C)		4.9 (-0.7 to 16.9)	4.9 (-0.7 to 16.6)
Turbidity (ppm)		11.8 (0.0 to 60.0)	13.1 (0.0 to 62.5)
Bottom Materials			
Class	Size (mm)	Percent of Total Volume	
Rubble		54	44
Large	>152	18	16
Small	76.0 -151.9	36	28
Gravel		44	55
Large	19.0 - 75.9	34	44
Small	4.7 - 18.9	10	11
Sand	<4.6	2	1
Chemical			
Dissolved Oxygen (ppm)		11.7 (8.2 to 15.5)	11.9 (8.5 to 15.0)
Alkalinity (ppm $CaCO_3$)			
Phenolphthalein		0.0	0.0
Methyl orange		173.0 (140 to 190)	178.6 (145 to 200)
pH		8.49(8.30 to 8.68)	8.45(8.30 to 8.57)

* All measurements except those of width, depth, and bottom materials are based on the 11 samples collected throughout the full-flow period (August 26, 1966 to June 25, 1967).

** Measurements based on flows of about 0.9 m^3/sec in each riffle.

control due to accretions from groundwater and the presence of a small spring creek which entered Blacktail Creek midway between the two study riffles. Average water velocity in the two riffles was nearly the same. The control riffle contained 10% more rubble and 11% less gravel than the test riffle, however, this may have been due in part to the fact that each riffle was sampled to a different depth. Turbidity, dissolved oxygen, alkalinity, and pH readings were similar for both riffles. Water temperatures in both riffles had the same seasonal trends with the lowest readings in December and the highest in July and August (Fig. 4).

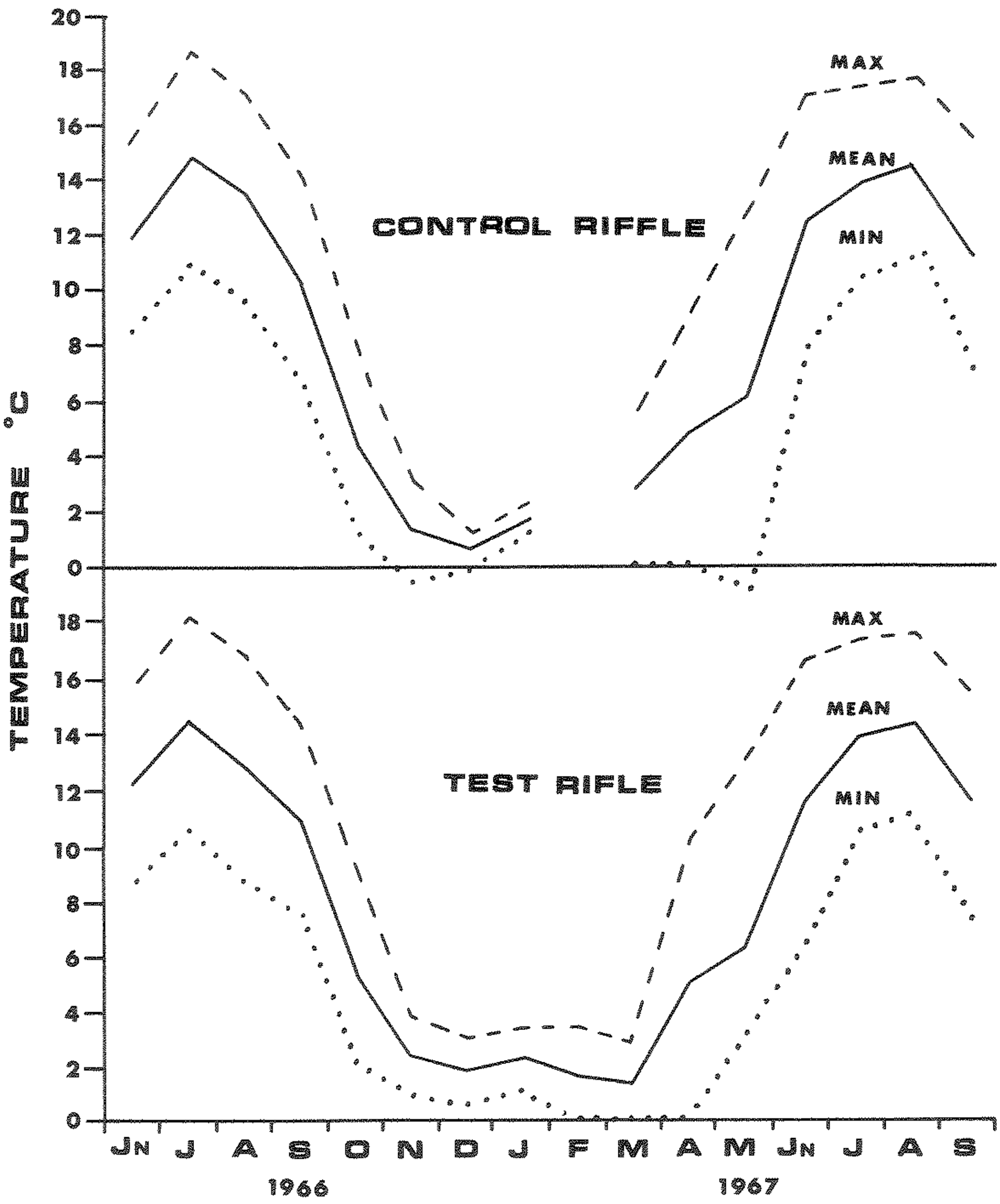

Figure 4. Monthly water temperatures in the study riffle.

RESULTS

Physical Changes in the Test Riffle

The effects of flow reductions on velocity, depth, width, water surface area, and water volume of the test riffle are shown in Figures 2, 5, 6, 7 and Table II. Flow reductions of 75 and 90% had the least effect on average width of the watered area and surface area of the water.

Table II. Physical characteristics of test riffle near base flow (0.95 m^3/sec) and flow reductions of 75% (0.22 m^3/sec) and 90% (0.09 m^3/sec).

Flow Condition	Average			Water Surface	Water
	Velocity	Depth	Width	Area	Volume
	m/sec	cm	m	m^2	m^3
Base Flow	0.61	15.9	7.4	22.8	3.57
75% Dewatered	0.44	7.6	6.0	18.8	1.42
90% Dewatered	0.16	5.5	4.8	15.4	0.84

Average width was reduced by 19 and 35% at the respective flows, while surface area decreased 18 and 32%, respectively. Average depth, water velocity, and water volume were the parameters most affected. Average depth was reduced by 52 and 65% at the respective flow reductions. The effect of a 90% flow reduction on the cross-section of the test riffle is shown graphically in Figure 7. Average water velocity was reduced 28% at a flow reduction of 75%, but was decreased 74% at a 90% flow reduction. Water volume (the product of average depth and surface area), was the parameter most affected by reduced flows. It was decreased by 60 and 76% at flow reductions of 75 and 90%, respectively.

Figure 5. Test riffle at base flow (0.90 m^3/sec), looking upstream.

Figure 6. Test riffle at 90% flow reduction (0.09 m^3/sec), looking upstream.

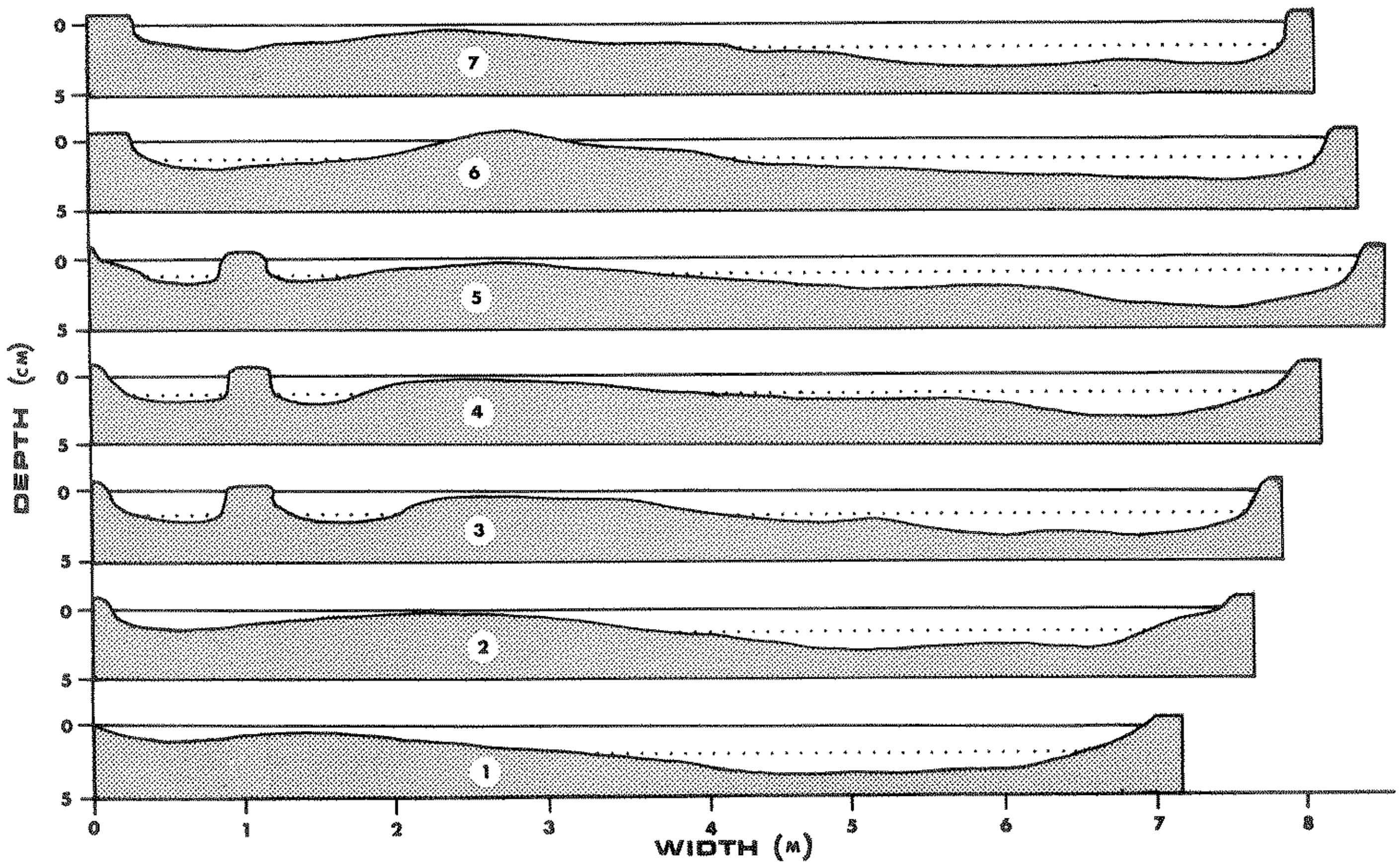

Figure 7. Cross-sections of test riffle at seven transects showing water levels at base flow (solid line) and 90% flow reduction (dotted line).

A comparison of the mean depths and mean velocities at all sample sites (where benthos samples were taken) during each of the three designated flow periods is presented in Table III. During the period of 75 and

Table III. Mean depths and velocities at sample sites during each flow period and results of statistical comparisons.

Period of Flow	Depth (m) Control Mean	Depth (m) Test Mean	Depth (m) F-Value	Velocity (m/sec) Control Mean	Velocity (m/sec) Test Mean	Velocity (m/sec) F-Value
75% Dewatered	0.18	0.08	36.16**	0.76	0.43	20.47**
Full-Flow	0.14	0.15	2.20	0.61	0.73	8.39**
90% Dewatered	0.24	0.09	54.70**	0.96	0.33	67.38**

** Significant at the 1% level.

90% dewatering, depths and velocities at sites sampled in the test riffle were significantly lower than those in the control riffle. Under conditions of full-flow, depths in both riffles were not significantly different, however, velocities were significantly larger in the test riffle, although the difference was only 0.12 m/sec.

Temperatures and oxygen readings in the test riffle were similar to those in the control riffle, both during periods of full-flow (Table I) and during dewatering in both years (Table IV). Average daily maximum and minimum water temperatures in the test riffle differed from those in the control by 1C or less during the period of reduced flows.

Table IV. Average daily maximum and minimum water temperature (C) and semimonthly dissolved oxygen concentrations (ppm).

	Period of 75% Dewatering		Period of 90% Dewatering	
	Control	Test	Control	Test
Maximum Temperature	16.9	16.5	15.7	15.9
Minimum Temperature	11.5	10.5	11.3	11.2
Dissolved Oxygen	9.8	9.7	9.3	9.7

Community Composition

Trichoptera, Diptera, and Coleoptera together comprised 84 and 88% of the numbers, and 73 and 84% of the volumes of all aquatic insects for the control and test riffle, respectively. Diptera constituted 31 and 67% of the volumes and Trichoptera composed 35 and 12% in the control and test riffle, respectively. Trichoptera, Diptera, and Coleoptera comprised 26, 37, and 25% of the numbers in the test riffle and 29, 29, and 26%, respectively, in the control riffle.

Twenty-two families and 34 genera of insects were identified from 24 samples — 12 from each riffle (Table V). Thirty of the same genera were found in both riffles. The mayfly *Rhithrogena* was found only in samples from the control riffle. The caddisflies *Helicopsyche* and *Neophylax*, and the stonefly *Capnia* were taken only in samples from the test riffle. Eleven taxa accounted for 89% of the numbers and volumes in the control riffle. These same taxa made up 93% of the numbers and 87% of the volumes in the test riffle. The 11 taxa were: *Hydropsyche*, *Rhyacophila*, *Brachycentrus*, and *Lepidostoma* (Trichoptera); *Ephemerella inermis*, *E. grandis*, and *Baetis bicaudatus* (Ephemeroptera); *Tipula* and

Table V. List of insects identified from Blacktail Creek, Montana.

Trichoptera
  Hydroptilidae
    Ochrotrichia sp.
  Helicopsychidae
    Helicopsyche borealis (Hag.)
  Hydropsychidae
    Hydropsyche sp.
    Cheumatopsyche sp.
    Arctopsyche grandis (Bks.)
  Rhyacophilidae
    Rhyacophila acropedes Bks.
    Glossosoma sp.
    Protoptila sp.
  Leptoceridae
    Athripsodes sp.
  Brachycentridae
    Brachycentrus sp.
    Micrasema sp.
  Lepidostomatidae
    Lepidostoma pluviale (Milne)
  Limnephilidae
    Neophylax sp.

Ephemeroptera
  Baetidae
    Ephemerella inermis
    E. grandis
    Paraleptophlebia memorialis
    Baetis bicaudatus
  Heptageniidae
    Rhithrogena sp.
    Heptagenia spp.

Diptera
  Tipulidae
    Tipula sp.
    Antocha monticola
  Psychodidae
    Pericoma sp.
  Simulidae
    Simulium spp.
  Chironomidae
  Rhagionidae
    Atherix variegata
  Empididae
    Hemerodromia sp.

Plecoptera
  Pteronarcidae
    Pteronarcella badia
  Nemouridae
    Nemoura sp.
    Capnia sp.
  Perlidae
    Acroneuria pacifica
  Perlodidae
    Arcynopteryx sp.
    Isoperla fulva
  Chloroperlidae
    Alloperla sp.

Coleoptera
  Elmidae
    Narpus sp.
    Lara sp.

Chironomidae (Diptera); *Acroneuria* (Plecoptera); and *Narpus* (Coleoptera).

Community Dynamics

Total Numbers and Volumes

Trends and fluctuations in numbers and volumes of aquatic insects during the study are shown in Figure 8. Numbers of insects increased in

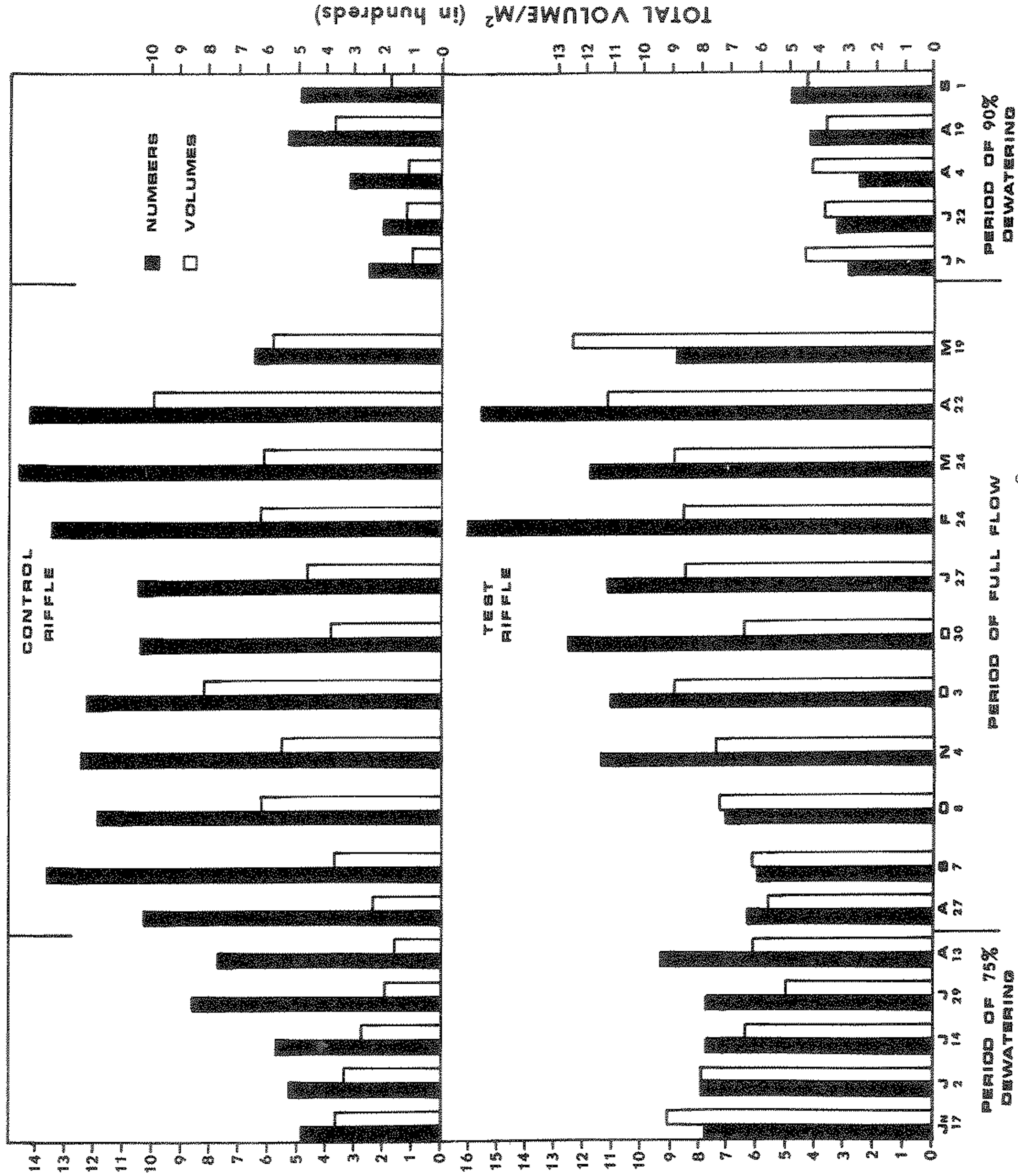

Figure 8. Numbers and volumes (cc) of aquatic insects/m^2.

the control riffle during the period of 75% dewatering, while numbers in the test riffle remained stable. Insect numbers continued to increase in the control riffle while numbers in the test riffle declined with the resumption of normal flows. High numbers in the test riffle did not occur until November, two months after high values were reached in the control riffle. During the period of 90% dewatering, numbers in the control and test riffle did not show distinct differences in trends.

Mean numbers and volumes of all insects/m^2 collected during each flow period in the test and control riffles were compared statistically (Table VI). During the period of 75% dewatering, total numbers from the test riffle were significantly greater than those in the control riffle. There was no significant difference in numbers from the two riffles during the period of full-flow or during the period of 90% dewatering. Volumes were significantly greater in the test riffle during all flow periods, however, the F-value was greatest during the period of 75% dewatering and least during the 90% dewatering period.

Ordinal Numbers and Volumes

Throughout the study, numbers and volumes of aquatic insects/m^2 in each order, except Trichoptera, showed the same general increases and decreases for both the test and control riffles (Table VII). Ordinal numbers and volumes of insects in the test riffle were compared statistically to those in the control riffle for each flow period (Table VI).

Table VI. Mean numbers and volumes of aquatic insects for flow periods and results of statistical comparisons (volumes in parentheses).

	Period of 75% Dewatering			Period of Full-Flow			Period of 90% Dewatering		
	Control Mean	Test Mean	F-Value	Control Mean	Test Mean	F-Value	Control Mean	Test Mean	F-Value
Trichoptera	1,829.2 (12.8)	2,670.2 (12.8)	7.58** (0.00)	3,631.6 (19.5)	2,537.6 (7.3)	8.98** (66.91)**	835.6 (5.0)	770.4 (8.0)	0.06 (0.52)
Ephemeroptera	1,056.2 (6.9)	999.6 (9.4)	0.11 (1.04)	1,353.5 (6.3)	733.7 (4.4)	34.19** (8.55)**	941.6 (2.2)	649.6 (3.0)	6.98* (0.53)
Diptera	1,482.6 (3.3)	1,676.2 (39.1)	1.25 (100.05)**	3,790.7 (19.1)	4,951.1 (61.2)	3.69 (63.48)**	615.2 (7.6)	593.4 (23.8)	0.05 (9.17)**
Coleoptera	1,997.4 (2.4)	2,615.4 (2.7)	2.72 (0.53)	2,719.3 (3.7)	2,243.2 (3.2)	4.42* (2.48)	1,282.6 (1.8)	1,497.8 (2.0)	0.74 (0.09)
Plecoptera	87.2 (1.9)	146.4 (4.8)	5.57* (6.72)*	366.5 (8.8)	270.7 (7.1)	7.78** (2.24)	32.6 (2.1)	98.8 (4.5)	14.72** (6.32)*
Total	6,452.6 (27.3)	8,107.8 (68.8)	7.63** (50.71)**	11,861.6 (57.4)	10,736.3 (83.2)	1.56 (15.08)**	3,707.6 (18.7)	3,610.0 (41.3)	0.03 (11.17)**

* Significant at the 5% level.

** Significant at the 1% level.

Table VII. Numbers (per m^2) and volumes (cc/m^2) of aquatic insects for each sample period (volumes in parentheses).

Period	1966-67	Trichoptera Control	Trichoptera Test	Ephemeroptera Control	Ephemeroptera Test	Diptera Control	Diptera Test	Coleoptera Control	Coleoptera Test	Plecoptera Control	Plecoptera Test
Period of 75% Dewatering	June 17	1,512 (18.8)	3,562 (19.2)	1,383 (11.6)	1,181 (21.0)	982 (2.7)	1,622 (43.0)	979 (1.6)	1,321 (1.9)	86 (1.9)	118 (5.9)
	July 2	1,267 (14.2)	3,693 (24.2)	1,471 (14.2)	1,154 (15.9)	1,380 (2.7)	1,436 (35.0)	1,073 (1.6)	1,566 (2.2)	75 (1.6)	46 (1.6)
	July 14	1,934 (15.6)	2,128 (13.4)	947 (5.4)	847 (6.2)	1,084 (2.7)	1,805 (37.4)	1,722 (2.4)	2,889 (2.4)	59 (1.9)	81 (4.3)
	July 29	2,558 (8.4)	1,773 (4.5)	729 (1.6)	600 (1.6)	2,028 (5.9)	1,829 (36.3)	3,190 (3.2)	3,360 (3.0)	100 (0.9)	191 (3.8)
	Aug. 13	1,875 (7.0)	2,195 (2.7)	751 (1.6)	1,216 (2.2)	1,939 (2.4)	1,689 (43.9)	3,023 (3.2)	3,941 (4.1)	116 (3.2)	296 (8.6)
Period of Full Flow	Aug. 27	2,112 (7.7)	1,092 (3.2)	1,781 (3.4)	1,157 (2.4)	2,187 (3.2)	1,014 (41.7)	3,995 (4.1)	2,919 (3.4)	202 (5.6)	215 (4.8)
	Sept. 7	3,085 (15.1)	1,054 (3.2)	1,186 (2.7)	1,159 (3.4)	5,757 (7.5)	1,418 (45.4)	3,408 (3.0)	2,171 (3.0)	140 (8.8)	253 (6.7)
	Oct. 8	4,829 (25.3)	1,627 (5.9)	1,280 (7.3)	414 (2.7)	1,891 (13.1)	1,939 (52.9)	3,441 (5.4)	2,854 (3.4)	420 (10.5)	285 (7.7)
	Nov. 4	4,143 (24.7)	2,163 (5.6)	1,173 (7.7)	409 (2.7)	2,964 (4.8)	5,321 (54.0)	3,809 (5.9)	3,193 (3.4)	441 (11.8)	334 (8.8)
	Dec. 3	3,831 (27.8)	1,948 (8.8)	1,103 (5.4)	374 (3.4)	3,637 (35.5)	5,778 (59.0)	3,276 (4.3)	2,695 (4.5)	506 (8.6)	352 (13.1)
	Dec. 30	3,021 (13.8)	4,896 (7.7)	890 (4.5)	412 (3.2)	4,137 (10.5)	4,589 (45.0)	1,942 (2.4)	2,494 (3.8)	393 (7.5)	274 (5.6)
	Jan. 27	4,581 (24.2)	3,266 (7.0)	1,049 (5.6)	409 (4.3)	2,607 (11.3)	5,353 (64.8)	2,055 (2.7)	1,805 (2.7)	207 (4.3)	323 (5.9)
	Feb. 24	5,122 (20.4)	4,132 (9.9)	1,705 (7.7)	611 (4.1)	4,484 (20.2)	9,297 (59.2)	1,802 (3.2)	1,705 (3.2)	377 (11.6)	304 (9.5)
	March 24	4,576 (18.3)	2,968 (8.4)	1,660 (7.0)	449 (3.8)	5,878 (27.1)	6,744 (73.0)	2,058 (2.7)	1,488 (2.2)	551 (7.0)	156 (1.9)
	April 22	3,362 (21.7)	2,233 (9.9)	1,627 (8.4)	907 (7.5)	6,440 (56.5)	10,018 (88.8)	2,308 (4.3)	2,257 (3.2)	576 (9.5)	183 (2.7)
	May 19	1,286 (15.9)	2,539 (10.8)	1,434 (9.1)	1,770 (10.8)	1,716 (20.1)	2,991 (89.5)	1,818 (2.4)	1,194 (1.9)	218 (11.8)	299 (11.0)
Period of 90% Dewatering	July 7	194 (3.2)	785 (25.0)	831 (3.8)	788 (8.4)	691 (1.1)	640 (4.1)	936 (1.3)	640 (1.3)	24 (1.3)	56 (5.4)
	July 22	223 (1.1)	1,046 (5.9)	697 (1.9)	525 (2.2)	395 (7.5)	837 (25.6)	831 (0.9)	826 (0.5)	13 (1.6)	102 (4.1)
	Aug. 4	382 (1.6)	412 (1.3)	874 (1.6)	382 (0.9)	500 (5.2)	379 (34.6)	1,450 (1.3)	1,356 (1.6)	51 (3.0)	56 (4.1)
	Aug. 19	1,765 (9.1)	667 (3.2)	1,165 (2.2)	794 (2.2)	713 (22.4)	500 (24.2)	1,714 (3.2)	2,157 (3.2)	27 (0.9)	140 (4.5)
	Sept. 1	1,614 (9.9)	942 (4.5)	1,141 (1.6)	759 (1.3)	777 (1.6)	611 (30.3)	1,482 (2.4)	2,510 (3.4)	48 (3.8)	140 (4.3)
	Total	53,272 (303.8)	45,117 (184.3)	24,877 (114.3)	16,317 (110.2)	52,187 (264.0)	65,180 (195.6)	46,312 (61.5)	45,241 (58.3)	4,630 (117.1)	4,204 (124.3)

Trichoptera

During the period of 75% dewatering, numbers in the control riffle increased, while those in the test riffle decreased. During the period of full-flow, numbers in the test riffle did not attain high values until late December, nearly three months after high values were reached in the control riffle. Volumes had similar trends in both riffles throughout the study.

During the period of 75% dewatering, numbers were significantly greater in the test riffle than in the control riffle. During the period of full-flow, numbers and volumes were significantly greater in the control riffle. There was no significant difference in volumes during either of the dewatered periods or in numbers during the period of 90% dewatering.

Ephemeroptera

There was no significant difference in either the numbers or volumes during either period of reduced flow, however, during the period of 90% dewatering, numbers were significantly greater at the 5% level in the control riffle. Both numbers and volumes were significantly greater in the control riffle during the full-flow period.

Diptera

There was no significant difference in numbers during each of the three flow periods. Volumes of Diptera were significantly lower in the control riffle during all flow periods.

Coleoptera

There were no significant differences in either numbers or volumes of beetles between the two riffles during any of the flow periods. However, at the 5% level of significance, numbers in the control riffle were significantly greater than those in the test riffle during the full-flow period.

Plecoptera

During the period of 75% dewatering, both numbers and volumes were significantly greater at the 5% level in the test riffle. During the period of full-flow, the numbers of stoneflies were significantly greater in the control riffle, however, volumes were not significantly different. During the period of 90% dewatering, numbers were significantly greater in the test riffle; volumes were significantly greater at the 5% level in the test riffle.

DISCUSSION AND CONCLUSIONS

Dewatering produced severe physical changes in the test riffle. Average depth, average water velocity, and water volume were the parameters most affected. Although average water velocity was reduced by only 28% during the period of 75% dewatering, average water depth and water volume decreased 52 and 60% respectively. During the period of 90% dewatering, average velocity was reduced by 74%, while depth and volume decreased 65 and 76% respectively. Needham (1928, 1934, 1938) considered water depth, current velocity, and bottom type, to be the major physical factors affecting the production of aquatic insects. Needham and Usinger (1956) found the cross-sectional distribution of aquatic insects in streams was linked with water depth and velocity.

Water temperature and dissolved oxygen in the test riffle were not affected by reduced flows, however, the dewatered portion of the stream was relatively short. Streams dewatered for greater distances might show higher temperatures and consequently less dissolved oxygen.

Four principal differences in the community dynamics of the test and control riffles were evident. First, during the period of 75% dewatering, numbers/m^2 in the control riffle increased while those in the test riffle remained stable. Trichoptera largely accounted for this difference as numbers/m^2 in the control riffle increased while those in the test riffle decreased.

Secondly, densities in the test riffle, relative to those in the control riffle, were higher during the period of 75% dewatering than during the full-flow period. Throughout the period of full-flow, there was no significant difference in total numbers between riffles, however, during the period of 75% dewatering, numbers were significantly greater in the test riffle than in the control riffle. The number of Trichoptera, Ephemeroptera, Coleoptera, and Plecoptera were significantly greater in the control riffle than in the test riffle during the period of full-flow. However, for the same orders during the period of 75% dewatering, there was either no significant difference in numbers, or numbers were significantly greater in the test riffle than in the control riffle. The increased densities in the test riffle may have been brought about by drift organisms settling out under reduced flow conditions or the emigration of insects from exposed areas. Denham (1938) showed that some aquatic organisms responded to receding water levels and became concentrated in the remaining watered areas. During my study many case-bearing Trichoptera (noteably *Brachycentrus*), were left stranded on exposed gravel bars and along stream margins.

Thirdly, the resumption of natural flow conditions apparently caused a decline in the numbers of Trichoptera, Diptera, Coleoptera, and Plecoptera in the test riffle. Surber (1936), Tarzwell (1937), and Logan (1963), all showed an inverse relationship between flow and abundance of insects in bottom samples and suggested high flows caused scouring. Maciolek and Needham (1952) reported high drift rates during the periods of peak flows.

Finally, total numbers of insects/m^2 in the test riffle did not reach their initial high value until November, two months after the initial high was reached in the control riffle. There were two to three times fewer Trichoptera in the test riffle than in the control for a period of three months after the resumption of natural flows.

During the period of 90% dewatering, there were fewer differences in numbers and volumes of insects from the two riffles than during the period of 75% dewatering. Extremely high flows during June, 1967, (average of 3.58 m^3/sec) probably reduced populations in both riffles to such low levels that differences were obscured. In the control riffle, average total numbers and volumes/m^2 during the second summer were 60 and 36%, respectively, lower than those for the first summer.

A comparison of the community dynamics of the two riffles prior to dewatering was not obtained since flow reductions were in effect one summer before this study was initiated. However, similarities in community dynamics of both riffles during the second half of the full-flow period indicate the principal differences cited above were caused by manipulation of flows.

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