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The macroinvertebrates and fish of a Colorado stream during a period of fluctuating discharge

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SUMMARY. 1. During a 2-year study of the fish and macroinvertebrates of a third-order montane stream, a severe drought in the first year resulted in a temporary cessation of surface flow. Flow was continuous during the second year.

2. Some taxa (e.g. *Ophiogomphus severus*) exhibited higher density during the drought year, others declined in abundance during low flow (e.g. *Baetis* spp.), whereas a few (e.g. *Tricorythodes minutus*) appeared unaffected. Total macroinvertebrate density decreased by 50% during the low flow year compared to the normal flow year. Mayflies were most severely affected, but also exhibited the most dramatic recovery.

3. The collector-gatherer functional feeding group was abundant only during the normal flow year, whereas shredders and predators exhibited increased relative abundance during low flow.

4. Fish populations were severely reduced in the low flow year. However, fishes rapidly invaded the area following resumption of normal flow.

Introduction

Severe fluctuations in flow can have adverse effects on the biota of normally permanently flowing streams. Reduced discharge has been shown to affect macroinvertebrates through loss of riffle habitat, reduced periphytic food and desiccation (Hynes, 1958; Larimore, Childers & Heckrottle, 1959; Kamler & Reidel, 1960; Iversen *et al.*, 1978; Ladle & Bass, 1981). Reduced flow usually occurs during late summer and early autumn, a period of rapid growth for many of the organisms inhabiting permanent streams, such as mayflies, stoneflies and caddisflies (Hynes, 1970). In general, invertebrates are better able to withstand the effects of drought than fish because of egg, nymphal or pupal diapause; emergence as aerial adults; or by burrowing into the stream bed. Recolonization is rapid following resumption of flow (Hynes, 1975; Larimore *et al.*, 1959; Townsend & Hildrew, 1976; Williams & Hynes, 1976a, b, 1977).

Reduced stream flow adversely affects fish populations by restricting them to shallow pools, which often become too warm, stagnant or crowded to sustain normal populations and growth rates (Hynes, 1958; Larimore *et al.*, 1959), but after flow resumes, fish return to affected reaches quickly, primarily due to the movements of young fish (Larimore *et al.*, 1959; Williams & Coad, 1979).

This paper summarizes research on the invertebrate and fish populations of Trout Creek, a small stream in central Colorado, during a 2-year period with marked differences in stream discharge.

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Site description

Trout Creek is a small third-order stream in the upper South Platte River basin of central Colorado, U.S.A., on the east slope of the Rocky Mountains. It flows roughly south to north through the Manitou Experimental Forest of the U.S. Forest Service. The 1.4 km study area is a low gradient segment at 2235 m elevation lined with willows (*Salix* spp.). The substrate is primarily gravel and coarse sand in the riffles. The green alga *Cladophora glomerata* (L.) Kuetzing was abundant throughout the study area during summer. Small beds of the aquatic macrophyte *Veronica* sp. were sporadically abundant by late summer. Three sections (upper, middle and lower) were sampled in the study area and were 650, 390 and 400 m long, respectively.

Methods

Mean daily discharge was determined at the upper end of the study area using a Parshall flume. Water temperature was also continuously monitored at this site.

Macroinvertebrates were collected monthly from June to October, 1978 and 1979, using a core sampler which enclosed 477 cm^2. Organisms were removed by stirring the substrate and straining the water with a hand net (mesh size 250 μm). Substrate was then placed in a bucket and the remaining organisms were thoroughly elutriated into the net. Four sample units were taken from each of the upper, middle and lower sections of the study area on each occasion. In addition, drift samples were taken at the middle and lower sections. Drift nets with 250 μm mesh were placed in the stream overnight once each month. Water depth and current speed at the net mouth were measured when the nets were set and prior to removal. The initial and final discharge values were averaged to determine the volume of water sampled assuming a linear decrease over time (Hemsworth & Brooker, 1979). Organisms were preserved in the field with 80% ethanol and returned to the laboratory where they were sorted from the debris, identified and counted. Identifications were made to the lowest practical taxonomic level using available keys. Statistical analysis of the invertebrate data was run on $\log_{10}$ transformed data to 'normalize' the data allowing the use of parametric tests (Elliott, 1977). Functional analysis was conducted by assigning taxa to one of five functional feeding groups (collector-gatherer, collector-filterer, scraper, shredder, and predator) using the designations in Merritt & Cummins (1978).

Fish were sampled on 12 September 1978 and 1979 by making one pass through the three sections of the study area with backpack electrofishing gear. All fish captured were identified, counted, weighed and the length measured. Narrow stream width, shallow water depth, good water clarity, and the relative paucity of overhanging riparian vegetation permitted reliable counts of those small fish which were not captured. These data were added to the number of captured fish for an estimate of number of fish 100 m^{-1}. Scales were taken from selected fish for age and growth analyses. In the laboratory, scales were dried, soaked in 10% NaOH and rinsed in distilled water prior to mounting on glass slides. Scales were magnified at 80× and measured according to the procedures of Bagenal & Tesch (1978). The condition factor, K, was calculated from the formula: $K=W10^5\ L^{-3}$, where W=weight in grams and L=length in millimetres.

Results

Discharge

Discharge measurements depict an overall pattern of low and high stream flow years (Fig. 1). Mean daily discharge values averaged 0.78 $m^3\ min^{-1}$ in 1978 the low flow year, in contrast with a more normal stream flow of 3.98 $m^3\ min^{-1}$ in 1979 the normal flow year.

During early summer (June and July), daily stream discharge values were much lower in 1978 (Fig. 1). During August and September, drought conditions reduced stream discharge to negligible levels in the upper and middle study section in 1978, and the streambed was dry throughout the lower section. Flow never ceased during the normal flow year. Despite these differences in discharge, the temperature did not differ between the 2 years of study, indicating the major influence of groundwater on this alluvial stream segment.

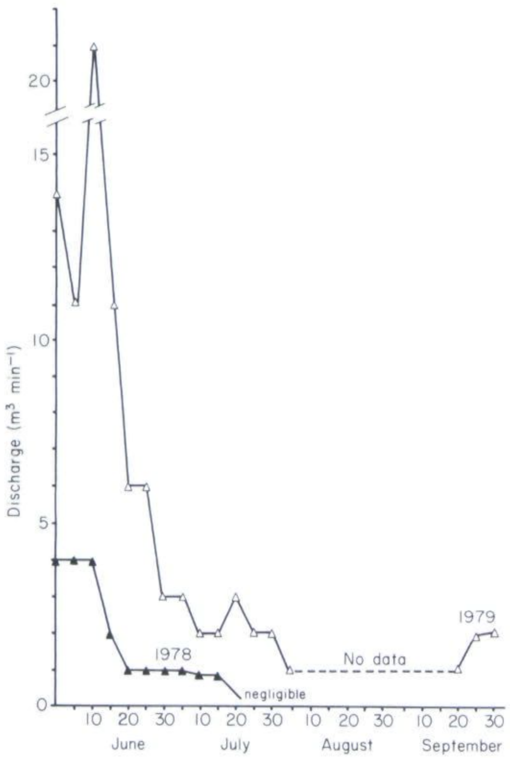

FIG. 1. Stream discharge for 5 day intervals based on average daily discharge values obtained at the upper end of the study area on Trout Creek, Colorado, 1978 and 1979.

Macroinvertebrates

During the 2 years of study, seventy-two invertebrate taxa were collected from Trout Creek in the study area although only twenty were common (Table 1). Many taxa exhibited higher densities during the low flow year of 1978 followed by reduced numbers after resumption of more normal flow in 1979 (e.g. *Hydroptila* sp., *Ophiogomphus severus* Hagen, *Cricotopus* sp., *Eukiefferiella* sp., *Palpomyia* sp. and *Tipula* sp.). Two species, *Cricotopus* sp. and *Palpomyia* sp., had statistically significant lower populations in the normal flow year, 1979 (ANOVA, P=0.008). Other taxa (e.g. *Baetis* spp. and *Glossosoma* sp.) exhibited the opposite pattern with significantly higher densities during the 1979 normal flow year (ANOVA, P=0.006). A few taxa (e.g. *Tricorythodes minutus* Traver and chloroperlid stoneflies) exhibited no significant change in density during the 2 years of study (ANOVA, P=0.17).

Notably, one species, *Rhithrogena hageni* Eaton, was extremely rare in 1978, the drought year, and was not collected in 1979; although it was abundant in previous studies on Trout Creek (Short *et al.*, 1978). Other taxa (e.g. *Capnia* sp., *Ablabesymia* sp., Hydracarina and Oligochaeta), which were not abundant previously (Short *et al.*, 1978), appeared to have established populations in Trout Creek during the drought.

Nonetheless, for most taxa, density was much greater in 1979 than in 1978. Total density exhibited a significant increase (ANOVA, P=0.03) from 1978 to 1979 with mayflies exhibiting a highly significant increase (ANOVA, P=0.001) (Table 1). Among the major groups, only Odonata exhibited decreased density in 1979.

In addition to the structure of the benthic community, the functional aspects of the benthos were also examined. Collector-gatherers were most important in 1979 normal flow year (Table 2), primarily reflecting the increased abundance of mayflies during this year. Shredders and predators exhibited higher relative importance during the 1978 low flow year. Collector-filterers had greater abundance in the normal flow year (1979) as a result of significantly (ANOVA, P=0.02) higher number of *Hydropsyche* sp. and *Simulium arcticum* Malloch. Scrapers were never abundant.

During both years, drift density increased as discharge declined throughout the summer (Table 3). Mayflies and dipterans dominated the drift with other groups only occasionally abundant. Terrestrial organisms were never abundant in the drift. The peak in drift density occurred in August during both years although it was greater in 1979. The large number of exuviae in August suggests that the mayflies were beginning to emerge.

Fish

Three fish species were collected during the study: *Salvelinus fontinalis* (Mitchill) (brook trout), *Catostomus catostomus* (Foster) (longnose sucker) and *C. commersoni* (Lacepede) (white sucker). Notable differences were detected between the three stream sections samples (Table 4). In 1978, fish were virtually absent in the lower two sections of the study area. During this year, the lower 400 m section

TABLE 1. Mean numbers of organisms m^{-2} of selected invertebrate taxa, Trout Creek, Colorado, 1978–79 (standard error in parentheses)

Taxa	1978		1979	
INSECTA				
Ephemeroptera	2219	(587)	8906	(1995)
Baetis spp.	1096	(424)	6653	(1880)
Ephermerella inermis Eaton	—		34	(18)
Paraleptophlebia heteronea (McDunnough)	129	(51)	1282	(424)
Tricorythodes minutus Traver	854	(228)	875	(226)
Plecoptera	1232	(447)	1994	(760)
Capnia sp.	390	(313)	1098	(709)
Chloroperlidae	820	(240)	778	(127)
Trichoptera	553	(300)	920	(254)
Glossosoma sp.	12	(11)	196	(105)
Hydropsyche sp.	146	(122)	487	(174)
Hydroptila sp.	316	(141)	97	(16)
Diptera	5542	(1031)	9542	(2546)
Ablabesmyia sp.	527	(104)	1241	(183)
Cricotopus sp.	809	(244)	87	(39)
Eukiefferiella sp.	245	(54)	—	
Palpomyia sp.	339	(50)	68	(13)
Rheotanytarsus sp.	681	(160)	814	(320)
Simulium arcticum Malloch	853	(767)	3383	(1835)
Tipula sp.	828	(350)	11	(6)
Coleoptera	88	(52)	297	(84)
Optioservus castanipennis (Fall)	73	(31)	291	(84)
Odonata				
Ophigogomphus severus Hagen	271	(75)	82	(18)
HYDRACARINA	100	(54)	338	(72)
OLIGOCHAETA	105	(54)	223	(56)
Total	10824	(1604)	22876	(3577)
No. of taxa	58		53	

TABLE 2. Relative abundance (% of total density) of invertebrate functional feeding groups from Trout Creek, Colorado, 1978 and 1979

Functional group	1978	1979
Collector-gatherer	27	54
Collector-filterer	16	22
Scraper	7	4
Shredder	22	6
Predator	28	14

contained only eleven small exposed pools, which did not contain fish. The middle 390 m did have running water, but it was restricted to the centre of the channel with few pools. The majority of fish collected in 1978 were found in the upper 650 m reach where flowing water and pools were more prevalent. Densities of fish in 1979 were sharply higher than those in 1978 (Table 4), indicating rapid recovery from the drought. Suckers were well distributed throughout the study area in 1979, but the brook trout densities were still highest in the upstream portion.

Brook trout collected in 1978 were thin and moribund when handled. Average weight values for each age class were lower than expected on the basis of other North American studies (Carlander, 1969) and, as a result, the mean condition factor (K) value was lower in 1978 (1.10) than in 1979 (1.16), although these values were not statistically different (t-test, $P>0.05$). Fish collected in 1979 appeared normal.

Longnose suckers also displayed lower K values in 1978 (0.94) than in 1979 (1.03), although again this difference was not significant (t-test, $P>0.05$). Apart from having lower average length values than found in other North American studies (Carlander, 1969), fish appeared normal when handled.

Regenerated scales, which often indicate environmental stress, were found on many fish in 1979, after the drought year of 1978. In a few cases, especially on white suckers and brook

TABLE 3. Density (numbers 100 m^{-3}) of drifting invertebrates in Trout Creek, Colorado, June–October 1978 and 1979

	June		July		August		September		October	
Taxa	1978	1979	1978	1979	1978	1979	1978	1979	1978	1979
Ephemeroptera	3	+	28	8	26	1978		212	11	8
Trichoptera	–	–	2	+	3	10	N	1	4	+
Plecoptera	–	–	–	+	18	20	o	2	706	32
Diptera	6	2	34	68	118	168		24	118	8
Hydracarina	–	–	2	+	9	26	f	–	+	–
Gastropoda	–	+	9	2	5	36	l	21	81	2
Other	–	+	1	2	13	19	o	4	10	1
Exuviae (approx.)	1	2	54	6	40	172	w	36	18	6
Terr. organisms	13	13	81	14	18	82		5	6	9
Total	23	17	211	100	250	2511		305	954	68
No. of taxa*	12	12	17	22	27	19		21	26	19

+ = less than 1 100 m^{-3}.
* Excluding exuviae and terrestrial organisms.

TABLE 4. Estimated numbers 100 m^{-1} of salmonid and catostomid fishes for three sections of Trout Creek, Colorado, September 1978 and 1979

	Upper		Middle		Lower	
	1978	1979	1978	1979	1978	1979
Salvelinus fontinalis	3	17	0	4	0	3
Catostomus catostomus	1	3	0	6	0	3
Catostomus commersoni	<1	16	0	14	0	2
Catostomus spp.	0	0	0	0	0	14
Salmonidae and Catostomidae*	15	24	1	40	0	94
Total	19	60	1	64	0	116

* Fish not captured but counted.

trout, only regenerated scales were found. Regenerated scales were not observed in 1978.

Discussion

Marked year-to-year differences in the flow regime of Trout Creek had major effects on invertebrates and fishes. The large increase in total density in 1979 indicated a rapid recovery of the stream invertebrate community from the drought of the previous year. This recovery was probably a result of survival of eggs in moist substrate, subsequent oviposition by aerial adults and the drift of invertebrates from upstream reaches when flow resumed (Fisher *et al.*, 1982; Gray & Fisher, 1981; Williams & Hynes, 1976a, b, 1977). Mayflies appeared to be most severely affected by reduced discharge whereas Diptera were slightly favoured. Low discharge seemed to affect the invertebrates primarily through loss of habitat since temperature was not significantly affected.

Functional feeding group analysis showed that collector-gathers and collector-filters were relatively more important during the normal flow year whereas shredders and predators had greater importance during the low flow year. The lesser importance of gatherers and filterers during the drought year may be related to a combination of factors such as loss of habitat, decreased suspended matter and increased predation pressure. Invertebrate predators, such as the dragonfly *O. severus*, appeared to be favoured by the low flow, which would tend to concentrate prey into the remaining channel while reducing fish predation on the nymphs themselves.

Drift densities exhibited peak values in August during both years. Despite much higher benthic density in 1979, numbers of drifting organisms were greater in 1978 during three out of the five months of study and this may be attributable to the reduced flow conditions (Minshall & Winger, 1968).

Fish population densities were significantly reduced by the drought with no fish collected in most of the study area. After resumption of normal discharge, fish were abundant throughout the study area although the greater abundance of trout at the upper end of the study area suggests migration of trout from Manitou Lake downstream to the study area. This lake probably acted as a refuge for stream fish during the drought year. The rapid recovery of fish populations from drought has been noted in previous studies (Larimore *et al.*, 1959; Starrett, 1950; Stehr & Branson, 1938).

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