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Macroinvertebrate community structure of four special lotic habitats in Colorado, U. S. A.

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With 2 tables in the text

Introduction

The number of streams regulated by dams is increasing more rapidly than our understanding of the ecological consequences. Studies of regulated streams in Colorado show that macroinvertebrate communities may be useful indicators of ecological conditions because they integrate the unique combination of physical and chemical variables below each dam. A fuller understanding of why certain taxa are affected in a given way would contribute not only to knowledge of ecological requirements of species, but ultimately would provide data of predictive value in assessing impacts and desirable modification of future stream regulation projects.

The purpose of this paper is to compare the macroinvertebrate communities of four regulated streams and to identify taxa potentially useful as indicators of regulation.

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Study sites and methods

The Joe Wright Creek (JWC) site, below an irrigation reservoir (Chambers Lake) in northern Colorado, exhibits widely-fluctuating discharge. JWC was sampled on 14 occasions (June—November 1975) as a control site for a study of effects of highway construction on a mountain stream ecosystem (WARD & CARLSON unpubl.). The springbrook (SB) site, 1 km north of Horsetooth Reservoir in northern Colorado, was sampled monthly (January 1974—January 1975) as part of a study of longitudinal changes in a springbrook-pond system (WARD & DUFFORD unpubl.). SB is included because it had constant conditions similar to some sites below dams yet lacked an upstream source of limnetic seston. The Trout Creek (TC) site, below a surface-release reservoir (Manitou Lake), was sampled monthly (June—October 1976) as part of a survey of the waters of the Manitou Experimental Forest (WARD & SHORT unpubl.). The South Platte River (SPR) site, below a deep-release reservoir (Cheesman Lake) which dampens major flow fluctuations, was sampled monthly from June 1972—May 1973 (WARD 1974).

SB and SPR exhibited winter warm and summer cool conditions, whereas ice formed in winter at JWC and TC and summer temperatures were somewhat elevated (especially TC).

The streams range in size from a small rheocrene (SB) to a large stream (SPR). All sites were essentially unimpacted except by dams, and data from unregulated locations on the same streams were available for comparison.

Macroinvertebrates were collected from rubble riffles with a SURBER sampler. The SHANNON index was used for diversity calculations. Epilithic algae and physicochemical data were collected, but will be referred to only briefly.

Due to space limitations, only occasional reference will be made to results of other investigators. See WARD (1976 a, b) for reviews of effects of dams on the stream ecosystem.

Results and discussion

A summary of macroinvertebrate parameters and the relative abundance of epilithon and rooted plants is presented in Table 1. The relatively high diversity at JWC may actually be caused by the fluctuating environmental conditions which, within limits, may create conditions alternately favoring different species, thus allowing a degree of niche overlap not possible under more constant conditions (WARD 1976 c). Compared with unregulated streams, standing crop was enhanced at all sites except JWC. Rooted aquatic plants, not normally present in Colorado mountain streams, are favored by the relative flow constancy at TC and the springbrook. Although absent at the SPR site, dense beds occur a short distance downstream.

Table 1. Macroinvertebrate parameters and environmental conditions of four regulated and an unregulated Colorado stream. Symbols are as follows: R = rich, M = medium, P = poor, A = absent.

	TC	SPR	JWC	SB	NF[a]
Shannon index	1.7	2.3	2.8	1.8	3.7
Org/m^2	12,903	1,988	1,259	2,512	406
g/m^2 (wet wt.)	95.5	15.3	2.5	48.3	7.6
Epilithon	R	R	P	M	M
Rooted plants	R	A	A	R	A

[a] North Fork, a tributary of the South Platte River, unregulated by dams (WARD 1976 b).

Ephemeropterans exhibited a high relative abundance at all locations except TC; trichopteran populations were well-developed only at TC; plecopterans were absent below dams with relatively constant discharge (TC and SPR), were rare in the springbrook, but a relatively abundant stonefly fauna occurred in the stream with fluctuating discharge (JWC); dipterans were numerically important at TC, SPR and JWC, less so in the springbrook; non-insects were numerically insignificant except in the springbrook. Except for the poor development of trichopterans, the relative abundance of major groups at JWC came closest to the macroinvertebrate communities on rubble riffles in Colorado mountain streams (WARD 1975 a, 1976 b). The species composition was, however, modified at all locations when compared with unregulated streams.

Table 2 includes selected common taxa which, by their presence, absence, or differential abundance, distinguish between regulated and unregulated Colorado streams studied by the writers. Symbols refer only to effects on relative abundance at the taxonomic level indicated. For example, despite a very different species composition, the relative abundance of plecopterans is listed as unaffected

Table 2. Effects of regulation on selected macroinvertebrate taxa of Colorado mountain streams. Symbols (R = reduced, F = favored, A = absent, U = unaffected) refer to effects on relative abundance compared with unregulated stream locations.

Taxon	Regulated stream locations			
	TC	SPR	SB	JWC
Plecoptera	A	A	R	U
Filipalpia	A	A	F	R
Alloperla spp.	A	A	A	F
Isoperla patricia	A	A	R	A
Ephemeroptera	R	U	F	U
Heptageniidae	R	A	A	R
Baetis spp.	R	F	F	F
Ephemerella inermis	R	F	A	F
Tricorythodes spp.	F	A	A	A
Trichoptera	F	R	R	R
Limnephilidae	A	A	F	R
Hydropsyche spp.	A	R	A	A
Cheumatopsyche spp.	F	A	A	A
Brachycentrus spp.	A	A	A	A
Others				
Simulium spp.	F	R	R	F
Tipula spp.	R	R	F	A
Chironomidae	R	F	R	F
Amphipoda	F	F	F	A
Gastropoda	F	A	F	A
Eiseniella tetraedra	U	F	F	A

at JWC since stoneflies comprised a similar portion (15.6 vs 16 %) of the fauna at a site above the reservoir.

Unregulated mountain streams in Colorado generally contain from 5—10 genera of plecopterans, yet not a single stonefly was collected at SPR or TC. Only *Isoperla patricia* and *Amphinemura* occurred in the springbrook. Six genera were collected at JWC, with *Alloperla* comprising 97.8 % of the stonefly fauna. *Alloperla* was one of the few organisms able to tolerate large flow fluctuations below a hydroelectric dam in Maine (Trotsky & Gregory 1974), and Radford & Hartland-Rowe (1971) reported that *Alloperla* and *Paraleuctra* were the important plecopterans of an Alberta River with widely-fluctuating flow. These small, slender stoneflies apparently are able to tolerate extremes of high and low flow by moving into substrate interstices, and their predominance seems indicative of streams with rapid flow fluctuations.

Filipalpian stoneflies were absent or rare at all locations compared with unregulated streams. Although rare at SB on rubble, populations of a nemourid were well-developed in beds of moss and water cress at the spring source. Since filipalpian stoneflies are large-particle detritivores, the presence of decomposing vascular plant tissue undoubtedly influences their distribution. Dams eliminate upstream contributions of large particles; dams with widely-fluctuating discharge further reduce the possibility of leaf pack formation. Riparian vegetation was

well-developed at the springbrook, which combined with flow constancy, allowed accumulation of some detritus despite the lack of an upstream contribution. Other large-particle detritivores, such as Limnephilidae and *Tipula*, were also rare or absent below dams, but may exhibit relatively well-developed populations at SB (preliminary evidence indicates that the *Tipula* in Colorado may not be obligatory shredders). High summer temperatures below the surface-release dam may contribute to the absence of plecopterans at TC, and the relatively constant thermal regime at SPR may not supply the thermal signals essential for completion of various life cycle stages (WARD 1976 c). *Isoperla patricia*, a predator, is apparently an exception since it appeared in good numbers a short distance below SPR and was collected under the constant thermal conditions at SB.

Ephemeropterans exhibited relative numerical abundance values at SPR and JWC which are similar to unregulated streams, although diversity was greatly reduced and species composition was greatly modified. Ephemeropterans were much less abundant at TC, which is thought to partly relate to spatial competition since other species virtually covered every available substrate. In the springbrook, which lacked a supply of limnetic seston, *Baetis*, the sole mayfly, comprised over 70 % of the macroinvertebrate fauna. *Baetis* spp. were present at all four locations and were favored by conditions at all sites but TC. The ubiquitous nature of the genus offers potential as an indicator of ecological conditions below dams, but the confusing taxonomy must first be worked out (EDMUNDS, JENSEN & BERNER 1976). *Ephemerella inermis* occurred at all dam sites and was favored at SPR and JWC with their contrasting temperature and flow regimes, which suggests a euryokous nature. Perhaps the extreme thermal constancy accounts for its absence from the springbrook source, since it occurred farther downstream. *Tricorythodes* is a slow-moving sprawler poorly adapted to resist current. The presence of beds of aquatic angiosperms, likely serving as current refugia, is apparently necessary for this mayfly. *Tricorythodes* comprised 84 % of the mayflies at TC, which had well-developed aquatic plants, although not a single specimen was collected at a site above the reservoir which lacked angiosperms. Apparently dense masses of filamentous algae are not sufficient since *Tricorythodes* was not collected at SPR but was relatively abundant a short distance downstream where plant beds appeared.

Heptageniid mayflies were absent or reduced at all locations. Their nearly complete absence at JWC is initially surprising since they are adapted to torrential conditions and may dominate the fauna below hydroelectric dams (RADFORD & HARTLAND-ROWE 1971). However, they are probably unable to tolerate the periods of very low flow at JWC.

Trichopterans were generally reduced at all locations except below the surface-release dam where *Cheumatopsyche* comprised 50 % of the total fauna. *Hydropsyche* was not collected at TC, although it was the only hydropsychid found at a site above the reservoir, and at SPR below the deep-release dam. It may be that *Cheumatopsyche* is a more obligatory filter-feeder than *Hydropsyche*, since plankton released from deep-release dams fails to provide a reliable enough food source for species depending solely on suspended particles (WARD 1975 b). *Hydropsyche* and *Cheumatopsyche* occurred sympatrically in a stream

in Georgia but fed on different-sized food particles (WALLACE 1975). Differences in the dominant particle size of seston at SPR and TC offer an additional explanation for the different hydropsychids at the two locations. *Cheumatopsyche* and another filter-feeder, *Simulium arcticum*, made up nearly 90 % of the fauna at TC. In addition, bryozoans at times comprised the majority of the epilithon. Below deep-release dams little seston is available, whereas a continuous supply of fine organic detritus of terrestrial origin was the predominant microseston component of a California mountain stream (MACIOLEK 1966). This undoubtedly accounts for the observed increase in *Simulium* and *Hydropsyche* with increasing distance below SPR (WARD 1975 b). *Simulium arcticum* was the predominant simuliid below all three dams and the only species (based upon pupal identifications) at TC and SPR. Simuliidae were more abundant at JWC than above the reservoir, perhaps because plankton-rich surface water is released as the reservoir level falls.

The absence of *Brachycentrus* at regulated sites may be explained by a predominance of fine seston particles, since later instars of *B. americanus* rarely capture particles smaller than 250 μm (GALLEPP 1974).

The ubiquitous chironomids were favored at some regulated locations and are potentially the best indicators of conditions below dams, but the taxonomy of lotic forms, especially in the western U. S., is poorly known.

Amphipods are rarely encountered in unregulated mountain streams in Colorado (PENNAK & ROSINE 1976), but occurred at all locations except JWC. They are apparently favored by flow constancy, but, unlike *Tricorythodes*, do not require aquatic angiosperms since *Gammarus lacustris* occurred at SPR.

Gastropods appear to require both flow constancy and aquatic angiosperms, since they were absent at SPR but appeared downstream concomitant with the appearance of plant beds.

Eiseniella tetraedra, an amphibious lumbricid earthworm, occurs commonly in the mud banks of Colorado streams (WARD 1976 d). The presence of permanent populations (not accidentals swept in by high water) is indicative of a relatively constant flow regime.

Conclusions

In summary, based upon the streams studied in Colorado, the majority of the macroinvertebrate fauna may be placed in one of the following groups: (1) Euryokous (tolerant) organisms which may be encountered in virtually any regulated or unregulated stream, and which may build up large populations under certain types of regulation (e. g. *Baetis*); (2) organisms present in unregulated streams which are favored by certain types of regulation (e. g. *Alloperla*); (3) intolerant organisms present in unregulated streams which are reduced or absent in regulated streams (e. g. *Brachycentrus*); and (4) indicator organisms not normally present in unregulated mountain streams which are indicative of regulation (e. g. amphipods). This classification scheme may be used with ecological categories (e. g. feeding strategies) as well. Other subdivisions are certainly possible. Category (4), for example, could be further divided based upon the type of regulation which favors certain taxa or ecological categories. It is hoped that the simple scheme presented will be broad enough to provide a useful framework for investigators in various regions with different fauna, and will be applicable to types of regulation not studied in Colorado.

The development of a systematic approach using macroinvertebrates as integrators of ecological conditions should ultimately provide information of predictive value in assessing impacts and desirable modifications of future stream regulation projects. Knowing, for example, that a hydropsychid with a given net mesh aperture is the predominant filter-feeder below one dam but is replaced by species with various mesh sizes in an adjacent regulated stream provides information which may be difficult or impossible to obtain by any other means. This should be an especially useful approach in regions such as eastern North America and Europe where the taxonomy and ecology of the fauna is relatively well known.

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