BOTTOM FAUNA PRODUCTION AND PHYSICAL NATURE OF THE SUBSTRATE IN A NORTHERN COLORADO TROUT STREAM [1]

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INTRODUCTION

The great majority of stream bottom fauna studies are concerned with production of organisms in streams as a whole, with little regard to the differential productive capacities of the various types and proportions of substrates. In a few papers, however, such as those of Pate ('32, '34), Needham ('29, '38), Behney ('37), and Smith and Moyle ('44), there is evidence of decreasing production in the substrate series: silt—rubble—bedrock—clay—gravel—sand. The investigation here reported was undertaken primarily to find out whether this principle applies to a typical, unpolluted, northern Colorado trout stream. In addition, it was desired to establish the general qualitative and quantitative composition of the bottom fauna, as compared with stream faunas in other parts of the United States.

DESCRIPTION OF SAMPLING AREA

All observations and collections were made at a station on North St. Vrain Creek, located in the foothills zone at an altitude of 1,677 meters, about two miles northwest of the town of Lyons, in the northern part of Boulder County, Colorado. The section of the stream studied was 50 meters long and approximately 20 meters wide, with a mean depth of 0.5 meter. Measurements and samples were taken at weekly intervals between June 18 and August 6, 1945. The average stream flow during this period was 6.4 cubic meters (226 cubic feet) per second, and current velocity averaged 0.8 meter per second. Water temperatures ranged from 9.4 to 17.8° C. The water remained clear throughout the period of study.

Four distinct types of substrate predominated: (1) the bare rock surfaces of very large boulders (comparable with the "bedrock" of other studies), (2) rubble, consisting of rocks and pebbles ranging from one to eight inches in diameter, (3) coarse gravel, consisting chiefly of particles measuring between one-fourth and one inch in diameter, and (4) very coarse sand, mostly between one-sixteenth and one-eighth inch in diameter, and especially abundant near the margins of the stream. The greater portion of the bottom consisted of riffles. There were no deep pools and no silt or clay substrates.

METHODS

Bottom samples were taken with a modification of the square-foot sampler of the Fish and Wildlife Service; the lower edge of this sampler encloses 0.1 square meter of the substrate. Three samples (aggregating 0.3 square meter) were taken from each of the four types of substrates each week for eight weeks, making a total of 96 samples. A special effort was made to take samples from representative scattered spots along the whole 50-meter section and over the entire width of the stream in order to eliminate errors caused by different productive capacities of the stream bed in the center as contrasted with the edges of the stream (Needham, '29, '38; Behney, '37). The contents of the sampler net were sorted in a white pan, and all organisms were removed and preserved in 70 per cent alcohol.

In the laboratory, organisms were counted and identified to genus where

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possible, otherwise to family or subfamily (especially early larval and nymphal stages). Wet weights were then determined after absorbing excess moisture from the organisms on filter paper for about 15 seconds. Results were converted to numbers of organisms per square meter and grams of organisms per square meter.

Results and Discussion

As shown in table I, the great majority (98.7 per cent) of the bottom organisms belonged to five orders of insects, that is, Plecoptera, Ephemeroptera, Trichoptera, Coleoptera, and Diptera. Furthermore, the Ephemeroptea and Diptera accounted for 91.6 per cent of all specimens collected. The Naididae, Hydracarina, and Odonata formed only a negligible part of the total population. Except for the comparatively small numbers of Trichoptera and Plecoptera, these results are in general agreement with most other comparable investigations.

Ephemeroptera nymphs were by far the most abundant organisms occuring on rubble, with an average of 449.6 specimens per square meter, and Diptera larvae were second most abundant, with 89.6 per square meter. Bedrock had about equal numbers of Ephemeroptera and Diptera (259.9 and 253.8 specimens per square meter, respectively). Even though bedrock supported more Trichoptera larvae than the other substrates, it averaged only 35.3 specimens per square meter. No stonefly nymphs were found on bedrock. About 53 per cent of all organisms on gravel were Ephemeroptera nymphs, and 39 per cent were Diptera larvae. The smallest populations occurred on sand bottoms, the average being only 202.2 organisms per square meter. About 74 per cent of these were Diptera, and 20 per cent were Ephemeroptera.

Although about 40 genera were identified during the course of this investigation, the great majority of individuals belonged to only a few genera. Thus, nearly half of the Plecoptera nymphs belonged to the genus *Pteronarcella;* more than half of the Ephemeroptera were *Pseudocloeon;* most of the Trichoptera were *Hydropsyche* and *Brachycentrus;* and *Simulium,* Diamesinae, and Tendipedinae accounted for most of the Diptera larvae.

In many instances the number of individuals in a particular genus and species varied widely from week to week. As some exceptional examples, the population of *Baetis* ranged from 7 per square meter

Table I. *Average numbers of organisms per square meter on different types of substrates in North St. Vrain Creek, Colorado, between June 18 and August 6, 1945*

Organisms	Rubble	Bedrock	Coarse gravel	Coarse sand
Naididae	3.9		0.8	11.1
Hydracarina (Hygrobatidae)	2.5	1.1	23.2	0.4
Odonata (Gomphinae) nymphs	0.9			
Plecoptera nymphs				
Atoperla	1.6		0.4	
Diploperla	0.4		0.4	
Isoperla	3.6			
Neoperla	2.6			
Paraperla	3.6		0.4	
Pteronarcella	10.4		1.6	
Pteronarcys	0.8		0.9	
Total	23.0		3.7	
Ephemeroptera nymphs				
Ameletus	2.0		0.4	0.4
Baetis	58.9	40.9	12.4	1.6
Cinygmula	22.1	1.6	4.3	
Ephemerella	48.2	3.0	49.0	1.9
Iron	23.3	2.0	1.3	
Paraleptophlebia	29.6		1.6	
Pseudocloeon	261.1	212.4	240.4	36.1
Rhithrogena	0.8		0.4	
Stenonema	3.6		1.8	
Total	449.6	259.9	311.6	40.0
Trichoptera larvae				
Agapetus	2.1		2.0	
Agapetus (pupa)	0.4			
Agraylea	1.1	2.0	1.3	
Athripsodes	2.1			
Brachycentrus	6.3	32.5	1.3	0.4
Hydropsyche	6.5	0.4	0.4	
Lepidostoma	0.4		2.5	
Micrasema	0.8			
Oecetis	0.4			
Psychomyia		0.4		
Total	20.1	35.3	7.5	0.4
Coleoptera (Elmidae)				
Larvae	12.4	0.4	4.5	
Adults	7.6	0.4	2.0	
Total	20.0	0.8	6.5	
Diptera larvae				
Atherix	2.9		0.4	
Culicoides			1.3	0.4
Deuterophlebia	3.6	38.8	3.8	0.4
Hexatoma	11.5		17.9	10.7
Palpomyia and ***Bezzia***	6.9	0.8	8.8	1.3
Simulium	6.9	195.0	6.1	2.8
Diamesinae	42.1	18.8	90.0	69.1
Hydrobaeninae	5.1		4.3	8.0
Tendipedinae	10.6	0.4	89.6	57.6
Total	89.6	253.8	222.2	150.3

on July 9 to 220 per square meter on August 6 on rubble bottom, *Simulium* ranged from no specimens late in July to 907 on July 25 on bedrock, and the Tendipedinae ranged from no specimens in the June samples to 457 per square meter on July 23. Although numerical variations were probably due in part to sampling errors, they were undoubtedly due chiefly to the seasonal course of the life histories of the various species, such as the time of egg deposition and hatching, rate of development, and the time of emergence of the adults from the water.

Table I also emphasizes the well known habitat preferences of the various taxonomic groups. Among the non-insect groups, the Naididae, being chiefly burrowers, were common only in sand and were absent from bedrock. The Hydracarina, on the other hand, were most abundant in coarse gravel where there is the greatest proportion of interstices whose dimensions are neither too small nor too large for their free movements and activities.

Plecoptera nymphs were confined to the under and lateral surfaces of rubble and gravel where they were protected from abrasion and the swiftest current; neither exposed bedrock nor shifting sands are suitable environments for most species in this order.

As a group, the Ephemeroptera are adapted to a wider range of current speed and exposure in stream habitats. Nine genera were found on both rubble and gravel, with *Pseudocloeon, Ephemerella,* and *Baetis* being especially abundant. *Baetis* and *Pseudocloeon* were also abundant on bedrock, but the latter was the only common genus found on sand.

The Trichoptera population was surprisingly low. *Brachycentrus* and *Hydropsyche,* both common swift-water forms, were most abundant of the nine genera collected. The former averaged 32.5 specimens per square meter on bedrock and 6.3 per square meter on rubble, and the latter averaged 6.5 per square meter on rubble. Coarse sand and coarse gravel had only negligible populations of caddis larvae.

Adult and larval elmid beetles totaled 20.0 per square meter on rubble and 6.5 on gravel, but were negligible on bedrock and absent on sand.

Diptera larvae had an interesting distribution. The greatest average total population for this order for any one substrate was 253.8 specimens per square meter on bedrock. Of this number, however, 195.0 were *Simulium.* The only other common dipteran on bedrock was *Deuterophlebia,* the mountain midge, which averaged 38.8 specimens per square meter. These two genera, along with a few Diamesinae, were the only important forms inhabiting surfaces exposed to the full force of the current. Although coarse sand, coarse gravel, and rubble differed greatly in their average total populations, the same taxonomic groups (Diamesinae, Tendipedinae, and *Hexatoma*) were most abundant on all three of these substrates. These forms, along with the less abundant *Palpomyia, Culicoides,* and Hydrobaeninae, are characteristic inhabitants of protected surfaces and small crevices and may burrow more or less in the superficial debris and sand of the substrate. Unquestionably, the occurrence of a few *Deuterophlebia* and *Simulium* in sand was fortuitous, since these genera have no means of attachment on shifting substrates.

In any estimation of the abundance of stream bottom organisms, it should be borne in mind that "total numbers of organisms" is a relatively crude method of presentation and that it is simply a summation of many overlapping and waxing and waning populations of individual species representing many different but characteristic life cycles. Therefore such mixed data ought to be used chiefly to indicate only general population trends, with little emphasis on minor week-to-week changes. Data of this sort are shown for the four common groups of immature insects for all four types of substrates in table II.

TABLE II. *Seasonal abundance of common bottom organisms in North St. Vrain Creek, Colorado, between June 18 and August 6, 1945; expressed as organisms per square meter*

Substrate	Date	Organisms			
		Plecoptera nymphs	Ephemeroptera nymphs	Trichoptera larvae	Diptera larvae
	June 18	10	206	3	65
	June 25	7	112	13	29
	July 2	10	342	13	86
Rubble	July 9	17	763	30	96
	July 16	6	569	30	64
	July 23	23	493	10	126
	July 30	12	497	12	72
	Aug. 6	106	613	46	179
	June 18		327	83	524
	June 25		441	13	963
	July 2		110	40	50
Bedrock	July 9		303	66	263
	July 16		156	60	57
	July 23		270	13	126
	July 30		209		33
	Aug. 6		263	7	13
	June 18		13	3	6
	June 25		67	6	133
	July 2		129	7	43
Coarse gravel	July 9	17	418	17	203
	July 16		646	6	193
	July 23		550	3	784
	July 30	6	340	3	214
	Aug. 6	6	327	14	200
	June 18		3		23
	June 25		66		73
	July 2		10	3	64
Coarse sand	July 9		56		19
	July 16		16		26
	July 23		120		670
	July 30		26		263
	Aug. 6		23		63

Plecoptera were most numerous on rubble on August 6 when the population was 106 specimens per square meter. At other times and on other substrates they were present only in small numbers or absent.

Ephemeroptera were abundant throughout the summer on rubble, with peaks of abundance reaching 763 on July 9 and 613 on August 6. They were also abundant on bedrock and reached a maximum of 441 per square meter on June 25. Very few specimens were found on gravel early in the summer, the maximum of 646 not being reached until July 16. Relatively small numbers occurred on sand, the maximum being only 120 on July 23.

Trichoptera were never abundant, and poorly defined maximum populations of 46, 83, and 17 per square meter were found on rubble on August 6, on bedrock on June 18, and gravel on July 9, respectively.

Peaks of abundance were equally variable for Diptera. They occurred on August 6, June 25, July 23, and July 23 for rubble, bedrock, gravel, and sand. The minimum population occurred in August on bedrock but in June on the other three substrates.

Only a few scattered elmid beetle larvae and adults were found on bedrock and gravel; on rubble, however, they reached a maximum of 70 on August 6.

For the expression of standing crop and production, the use of "organisms per square meter" is inaccurate and misleading because of the wide variations in size of the organisms, some single individuals having a mass as much as 25 to 50 times that of others. A single large stonefly nymph, for example, may weigh more than 40 small mayfly nymphs. A much more significant index is the total weight of organisms per square meter. For purposes of comparison, corresponding numerical and weight determinations are summarized for North St. Vrain Creek in table III From the standpoint of total numbers of organisms, rubble, bedrock, and gravel were quite similar, with average populations of 610, 551, and 575 organisms per square meter, respectively. The corresponding average wet weights for these organisms, however, were 2.5, 1.7, and 1.3 grams per square meter. The discrepancy between these two sets of data is more evident when single pairs of figures are compared. On July 23, for example, the largest single population (1,393 organisms per square meter) was found on a gravel substrate; these specimens weighed only 1.3 grams. On July 2, however, 182 specimens taken on gravel weighed 2.9 grams.

TABLE III. *Standing crop of bottom organisms for different types of substrates in North St. Vrain Creek, Colorado, during the summer of 1945*

Date	Total number of organisms per square meter				Grams (wet weight) per square meter			
	Rubble	Bedrock	Coarse gravel	Coarse sand	Rubble	Bedrock	Coarse gravel	Coarse sand
June 18	298	934	28	59	2.5	2.9	0.3	0.5
June 25	168	1,417	216	186	0.9	3.5	0.1	0.4
July 2	468	203	182	80	2.9	0.8	2.9	0.4
July 9	933	635	699	75	3.5	1.7	1.6	0.3
July 16	693	279	877	42	3.0	2.2	1.3	0.04
July 23	695	409	1,393	793	1.9	1.1	1.3	1.7
July 30	609	242	602	289	1.7	0.8	1.3	0.5
Aug. 6	1,017	286	601	92	3.3	0.7	1.9	0.6
Average	610	551	575	202	2.5	1.7	1.3	0.6

The wide differences in the numbers and weights of organisms supported by the various substrates emphasize the necessity of basing a stream survey on an adequate number of samples taken from all substrates represented as well as on calculations of the relative percentages of substrate types comprising the stream bottom. Obviously a stream bed composed chiefly of large boulders will have a population which is very different from that of a rubble or gravel bed.

Viewing both the gravimetric and numerical determinations for all substrates collectively (table III), it should be pointed out that there do not appear to be any definite seasonal trends.

Although decreasing standing crop in the series rubble—bedrock—coarse gravel—coarse sand is in agreement with the findings of Needham ('29, '38), Pate ('32, '34), Behney ('37), and Smith and Moyle ('44), the population of bottom organisms in the portion of the North St. Vrain Creek studied is most disappointing as a potential source of trout food. The work of Needham, and Smith and Moyle on various substrates in New York, California, and Minnesota trout streams showed a productivity which was usually three to twenty times as great as the corresponding substrates in North St. Vrain Creek.

The station studied was composed of about 50 per cent rubble, 10 per cent bedrock, 30 per cent coarse gravel, and 10 per cent coarse sand, and weighted averages amount to 1.9 grams and 553 organisms per square meter. These figures may be used in comparing North St. Vrain Creek with other streams for which no distinction in the type of substrate has been made. In the Rocky Mountain Region, the studies of Madsen ('35) in Arizona, Durrant ('35) in Nevada, Brown ('35) in Utah, Simon ('35) in Wyoming, and Gilmore ('35) in Colorado all showed average bottom fauna populations which were numerically about one and one-half to nine times as great as those found for North St. Vrain Creek. Numerous studies on midwestern and eastern trout streams show even greater differences.

The standards of Hazzard ('35) have been widely used for grading stream productivity. By these criteria a Grade 1 (rich) stream has in excess of 22 grams of bottom organisms per square meter, Grade 2 (average) has between 11 and 22 grams, and Grade 3 has less than 11 grams. Madsen ('35), working on Arizona streams, graded them according to average numbers of bottom organisms; a "rich" stream contains more than 2,152 organisms per square meter, an "average" stream contains between 1,076 and 2,152 per square meter, and the "poorest" streams contain less than 1,076. By either of these methods, North St. Vrain Creek has a very poor fauna, and the statement of Feast ('38) to the effect that food grade of streams in the adjacent Roosevelt National Forest, Colorado, was not above "fair" to "average" is even more optimistic than the present results. In passing, it should be mentioned that superficial studies by the senior author on other stretches of North St. Vrain Creek, as well as on other streams east of the Divide in northern Colorado, present a similarly discouraging picture.

It is extremely difficult to explain the occurrence of a poor bottom fauna in North St. Vrain Creek on ecological grounds. It is well known that mountain streams are generally less productive than lowland streams because of their lower temperatures, lack of rooted vegetation, and softer waters. Nevertheless, if Rocky Mountain streams are considered as a group, it is seen that the productivity figures for North St. Vrain Creek are far below those which are available for other streams, even though the station studied consisted largely of riffles—the most productive type of bottom. Certainly North St. Vrain Creek does not have any obvious unusual qualities; such features as annual cycle of flow, streamside vegetation, the amount of encrusting diatoms and filamentous algae on the bottom, and water chemistry are all much the same as they are in scores of other western trout streams.

Summary

A 50-meter section of North St. Vrain Creek, a typical northern Colorado trout stream of the foothills zone, was studied between June 18 and August 6, 1945, with particular reference to the types of substrate and their bottom fauna populations. Riffles predominated, and the stream bed was composed of rubble, bedrock (large boulders), coarse gravel, and coarse sand. Qualitative and quantitative samples were taken on all four substrates at weekly intervals.

About 98.7 per cent of the bottom organisms were Plecoptera and Ephemeroptera nymphs, Trichoptera and Diptera larvae, and Coleoptera larvae and adults. Ephemeroptera and Diptera accounted for 91.6 per cent of the total. Thirty-nine per cent of all individuals belonged to the genus *Pseudocloeon* (Ephemeroptera).

Small numbers of stonefly nymphs and elmid beetles were found only on rubble and gravel. Mayfly nymphs occurred on all substrates but were most abundant on rubble where they averaged 450 individuals per square meter. Trichoptera averaged only 35 per square meter on bedrock and were much less common elsewhere. Diptera larvae were most abundant on bedrock and gravel where they averaged 254 and 222, respectively.

Depending chiefly on the details of the life histories, numbers of individuals in certain genera and species varied widely from week to week. The seasonal occurrence of maximum and minimum populations for particular forms were not concurrent from one substrate to another but widely variable.

Average numbers of organisms for rubble, bedrock, gravel, and sand were 610, 551, 575, and 202 per square meter, respectively. Corresponding wet weights were 2.5, 1.7, 1.3, and 0.6 grams per square meter. Compared with trout streams in other parts of the United States, these results are very low, and there does not seem to be any logical ecological explanation.

A stream survey ought to be based on an adequate number of samples taken from all substrates represented as well as on calculations of the relative percentages of substrate types comprising the stream bed.

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