

# SPECIES DIVERSITY OF BENTHIC MACROINVERTEBRATES IN THREE MOUNTAIN STREAMS

B. J. MATHIS  
*Bradley University, Peoria*

ABSTRACT.—Species diversity of benthic macroinvertebrates in three unpolluted mountain streams was determined by using information theory methods. Results were compared with previous studies of a lowland, non-polluted stream, and two lowland, polluted streams. Maximum diversity was greater in mountain streams than in a grossly polluted stream but compared favorably with the furthest downstream station in a stream receiving oil field brines.

Indices derived from the field of information theory have been utilized in the analysis of benthic macroinvertebrate community structure by a number of investigators. Wilhm and Dorris (1966) utilized this approach in their study of a stream receiving sewage and industrial wastes. Mathis and Dorris (1968) utilized the methods in a study of an oil field brine polluted stream while Harrel and Dorris (1968) utilized information theory methods in a study of an unpolluted stream within one drainage basin. In each case, estimates of community structure were obtained with Patten's (1962) equations:

$$(1) \quad \bar{H} = \sum_{i=1}^m \frac{n_i}{N} \log_2 \frac{n_i}{N}$$

(Diversity per individual)

- $$(2) \quad H_{\max} = \log_2 N! - m \log_2 \times (N/m)!$$
- (Maximum diversity)
- $$(3) \quad H_{\min} = \log_2 N! - \log_2 \times [N - (m-1)]!$$
- (Minimum diversity)
- $$(4) \quad R = \frac{H_{\max} - H}{H_{\max} - H_{\min}}$$
- (Redundancy)

where (N) is the total number of organisms, (ni) number of individuals per species and (m) number of species in a unit area. Calculations were performed on an IBM Type 1620 data processing machine at the Bradley University Computing Center.

In using these equations, diversity and information are considered to be synonymous and calculations are made directly from numbers of individuals. Diversity, or information, is expressed in bits (short for binary digit), one bit being the amount of information required to specify one of two equally probable states. Information theory indices do not attempt an explanation of observed phenomena. Rather, they estimate the amount of information required to define community structure (Hairston, 1959).

Polluted streams should have less diversity than non-polluted streams

since some species are unable to survive. The remaining species encounter less competition and are able to produce large numbers of individuals if sufficient nutrients are available. The decreased numbers of species and increased numbers of individuals in the polluted community represent fewer bits of information.

A natural community, on the other hand, tends toward a more complex assemblage. Because spring fed mountain streams in remote and sparsely populated areas are relatively free of harmful effluents, they provide extremely stable habitats. Thus, benthic macroinvertebrate communities found in streams of this type reflect an increased ecological stability in terms of high  $\bar{H}$  and low R.

Although streams exhibit an almost infinite variability, certain habitats such as riffles, runs, and pools are characteristically present. Species extant in these habitats are different throughout the world, but the main taxa, or their ecological equivalents, are similar (Harrel and Dorris, 1968). With the use of information theory indices, an investi-

gator is able to make objective comparisons of community structure between different streams in different parts of the world.

In the present study, species diversity of benthic macroinvertebrates was determined during the summer of 1966 for three unpolluted mountain streams in southwest Virginia. The results were compared with previous studies of a lowland, non-polluted stream and two lowland, polluted streams in Oklahoma, Otter Creek, and Black Bear Creek and Skeleton Creek, respectively. Black Bear Creek was polluted with oil field brines; Skeleton Creek was polluted with domestic and oil refinery effluents.

#### DESCRIPTION OF STUDY AREA

Three small mountain streams, White Rock Branch, Spruce Run, and Little Stony Creek located in Giles County, Virginia were selected for study. They were typical mountain streams with long riffles and short pools. All three streams were spring-fed and maintained an almost constant flow during the study. Stream width ranged from 3.6 m to 1.8 m (Table 1). Sampling sites ranged from an altitude of 533 m to 834 m.

Physico-chemical conditions were measured only once on 2 August 1966

TABLE 1.—Station Characteristics.

Stream	Station	Width (m)	Depth (m)	Velocity (m/sec)	Discharge (m <sup>3</sup> /sec)
White Rock Branch	Upper	1.8	.09	.51	.06
	Lower	2.7	.08	.51	.12
Spruce Run	Upper	1.8	.08	.38	.08
	Lower	2.4	.15	.32	.10
Little Stony Creek	Upper	3.6	.13	.29	.11
	Lower	3.6	.20	.29	.17

(Table 2). The low pH in Little Stony Creek can be attributed to the presence of a bog located near the upper reach of the stream. The low pH reading is also reflected by the low alkalinity. Dissolved oxygen was near 100% saturation at all stations and ranged from 93% saturation to 105% saturation.

#### PROCEDURES

Ten bottom samples were taken with a Surber sampler from each station between 28 July 1966 and 10 August 1966. Five riffle samples were collected approximately one-half meter from the shore and five were taken from the middle of the stream. Pool samples were not taken. Rocks and gravel were removed from the sample area, placed in a large bucket and individually brushed with a paint brush. Samples were then washed in a sieve (U.S. standard soil series with openings of 0.420mm) and preserved in 70% isopropyl alcohol. Crayfish were not collected. Alkalinity and dissolved oxygen were measured in the field according to standard methods. The pH was measured by means of a portable Sargent pH meter. Stream discharge was estimated by the method of Robins and Crawford (1954).

#### DISCUSSION

The majority of species collected during the study were dipterans, caddisflies and mayflies (Table 3). These taxa dominated the fauna at

all stations. Most of the dipterans collected during the study were tendipedid dipterans. At most stations, tendipedids provided a disproportionate share of the species but few individuals per species.

Taxa represented by the greatest numbers of individuals included the caddisflies, mayflies and stoneflies (Table 4). Other taxa present in abundance included elmids larvae and tendipedid dipterans. The elmids larvae reached maximum density at the lower Station on Spruce Run where they comprised approximately 25% of the total numbers of individuals. Psephenid larvae were abundant only in Spruce Run. This stream exhibited the highest water temperature as well as the highest alkalinity and was located at a slightly lower altitude than the other two streams.

Spruce Run was the most productive mountain stream in terms of individuals per m<sup>2</sup> (Table 5). By comparison, Black Bear Creek was even more productive since large numbers of *Cheumatopsyche* sp. were present during the summer (Mathis

TABLE 2.—Physico-Chemical Conditions in Three Mountain Streams.

Stream	Station	Temp. C	pH	Alkalinity		Oxygen ppm
				HCO <sub>3</sub> <sup>-</sup> ppm	CO <sub>3</sub> <sup>=</sup> ppm	
White Rock Branch..	Upper.....	16	8.3	52	0	9.9
	Lower.....	16	7.8	58	0	11.0
Spruce Run.....	Upper.....	21	7.5	115	0	8.4
	Lower.....	19	8.4	128	0	9.9
Little Stony Creek...	Upper.....	16	5.0	12	0	9.3
	Lower.....	16	6.7	13	0	10.0

TABLE 3.—Species Distribution in Three Mountain Streams.

Stream	White Rock Branch		Spruce Run		Little Stony Creek	
	Upper	Lower	Upper	Lower	Upper	Lower
Diptera.....	13	29	24	23	14	22
Trichoptera.....	10	15	11	11	9	6
Ephemeroptera.....	10	17	14	13	5	9
Plecoptera.....	7	3	6	7	3	5
Colcoptera.....	3	4	6	6	3	5
Annelida.....		1	1	3	1	4
Pelecypoda.....		1	1		1	
Megaloptera.....		1	2	1	2	1
Odonata.....	1		2		1	
Gastropoda.....			3	2	1	
Turbellaria.....			1	1		
Crustacea.....			1			
Total Species.....	44	75	69	63	39	54

TABLE 4.—Relative Abundance of Dominant Benthic Macroinvertebrates in Three Mountain Streams.\*

Stream	White Rock Branch		Spruce Run		Little Stony Creek	
	Upper	Lower	Upper	Lower	Upper	Lower
Taxa						
Trichoptera.....	214	945	746	1,040	301	208
Ephemeroptera....	357	443	863	806	44	175
Plecoptera.....	493	305	210	128	281	75
Elmidae.....	34	72	684	1,179	513	8
Psephenidae.....			484	903		
Tendipedidae.....	11	76	232	56	409	79

\* Per m<sup>2</sup>

TABLE 5.—Species Diversity Range in Polluted and Unpolluted Streams During Summer.

Source	Sampling Sites	Individuals/M <sup>2</sup>	Number of Species	$\bar{H}$ Bits/Ind.	R
<u>Unpolluted</u>					
White Rock Branch, Va., (Present Study).....	Riffles.....	1,149-1,990	44-75	4.14-4.33	.25-.30
Spruce Run, Va., (Present Study).....	Riffles.....	3,571-4,248	63-69	3.60-4.12	.33-.41
Little Stony Creek, Va., (Present Study).....	Riffles.....	679-1,660	39-54	3.71-4.61	.17-.29
Otter Creek, Okla., (R. Harrel, personal communication)	Pools and Riffles...	280-2,633	23-43	2.66-3.53	.32-.58
<u>Polluted</u>					
Black Bear Creek, Okla., (Mathis and Dorris, 1968).....	Pools and Riffles...	213-6,748	13-41	2.30-3.93	.20-.58
Skeleton Creek, Okla., (Wilhm and Dorris, 1966).....	Pools and Riffles...	150-3,022	5-16	0.55-3.09	.19-.89

and Dorris, 1968). While a few taxa dominated the community to some extent in the mountain streams, other species were not excluded as is the case in polluted streams. As a result, maximal values for  $\bar{H}$  were greater in mountain streams than in the polluted lowland streams. Maximal  $\bar{H}$  in Black Bear Creek, however, exceeded minimal  $\bar{H}$  in two of the mountain streams. The high  $\bar{H}$  in Black Bear Creek was found at the extreme downstream station where brine concentration was lowest.

The range in values for  $\bar{H}$  in Otter Creek, the only unpolluted lowland stream that has been subjected

to information theory methods to date, closely paralleled those of Black Bear Creek. The range reported for Skeleton Creek, on the other hand, was considerably greater. This is an indication that oil field brines in Black Bear Creek were less restrictive to populations of bottom organisms than domestic and oil refinery effluents in Skeleton Creek (Mathis and Dorris, 1968).

R, a measure of faunal repetition, was minimal at the lower Station in Little Stony Creek but it was also the least productive in terms of individuals per m<sup>2</sup>. The bottom fauna extant in this stream was more equitably distributed among the species, thus R was low and  $\bar{H}$  was high.

Highest R, on the other hand, was found in Spruce Run where large numbers of riffle beetles, caddisflies and mayflies were found.

Minimal R in the polluted streams was comparable to minimal R in all other streams. The low values for R in the polluted streams were obtained at extreme downstream stations where clean water conditions were present. Maximal R in polluted lowland streams exceeded maximal R in all three mountain streams. R in both Black Bear Creek and Otter Creek was 0.58. The similarity of values for this parameter lends support to the contention that faunal compositions in the two streams are not extremely dissimilar, despite the presence of oil field brines in Black Bear Creek.

Maximum values for  $\bar{H}$  exceeded 4.00 in all three mountain streams. On the basis of this investigation, it would appear that maximum  $\bar{H}$  for benthic macroinvertebrates in habitats of this type lies somewhere between 4.00 and 5.00, at least dur-

ing summer. Comparative data from other seasons is lacking.

#### ACKNOWLEDGMENTS

This study was supported by an NSF post-doctoral research grant GB-3439 administered by the University of Virginia.

#### LITERATURE CITED

- HAIRSTON, N. G. 1959. Species abundance and community organization. *Ecology* 40:404-416.
- HARBEL, R. C., and T. C. DORRIS. 1968. Stream order and community structure of benthic macroinvertebrates and fishes in an intermittent stream. *Amer. Midl. Nat.* (In press).
- MATHIS, B. J., and T. C. DORRIS. 1968. Community structure of benthic macroinvertebrates in an intermittent stream receiving oil field brines. *Amer. Midl. Nat.* (In press).
- PATTEN, B. C. 1962. Species diversity in net phytoplankton of Raritan Bay. *J. Mar. Research* 20:57-75.
- ROBINS, C., and R. W. CRAWFORD. 1954. A short accurate method for estimating the volume of stream flow. *J. Wildl. Mgmt.* 18:363-369.
- WILKIN, J. L., and T. C. DORRIS. 1966. Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluents. *Amer. Midl. Nat.* 76 (2):427-449.

*Manuscript received October 7, 1967.*