The Effect of Suspended Solids on Macroinvertebrate Drift in an Indiana Creek

David S. White, University of Oklahoma Biological Station,
Kingston, Oklahoma 73439 and James R. Gammon,
Zoology Department, DePauw University
Greencastle, Indiana 46135

Abstract

The addition of small amounts of suspended solids to a normally clear stream produced a marked change in the macroinvertebrate drift rate. As suspended solids were increased, the number of drifting organisms showed corresponding increases to more than double the normal rates.

Introduction

Sediment is a pervasive, ubiquitous pollutant reaching water courses in the United States in quantities estimated at three billion m^3 annually. Poor farming, logging, and mining practices were the major contributors in the past, but now these have been joined by road and bridge building, and the proportion of sediment from urban construction may overtake that from agriculture in the near future (Wolman and Schick, 1967).

Large amounts of silt and sediment can cause drastic reductions in the lotic invertebrate populations when introduced into normally clear waters. Tebo (1955) found benthos reduced up to 75% with silt loads of 261 to 390 mg/l. Herbert et al. (1961) recorded decreases greater than 90% in streams receiving 1,000 to 6,000 mg/l suspended solids. Bartsch (1960) noted almost no organisms present when turbidity from a glass manufacturing plant exceeded 5,000 mg/l. Gammon (1970) and White (1970), however, found that a 60% reduction in the macroinvertebrate fauna could be caused by as little as a sustained 50 to 80 mg/l increase in suspended solids. Suspended solids causing sediment buildup may eliminate benthic populations by covering them over or destroying favorable habitats (Cordone and Kelly, 1961), but even light amounts of sediment not causing buildup may have profound effects on the benthos and fishes (Gammon, 1970; Reis, 1969).

Studies in the past 20 years have proven the downstream drift of invertebrates to be a good indicator of environmental conditions and changes occurring in flowing waters. Pearson and Franklin (1968) analyzed eight factors affecting the rate of benthic drift. Among these was the effect of turbidity. In one sample, they noted a sudden increase in turbidity from 20 to 700 mg/l was coupled with an immediate rise in the drift rate of a baetid mayfly. In other invertebrate drift studies by Reisen and Prins (1972) and those summarized by Bishop and Hynes (1969) and Waters (1972), little more is known of the effect of suspended solids on drift. From this, a series of experiments was designed to measure the effect of varying concentrations of suspended solids upon the drift rate of macroinvertebrates.

Study Area

Deer Creek is a small stream in Putnam County, Indiana, draining approximately 233 km^2. Arising on the southern edge of the Tipton Till Plain, it flows southwesterly for most of its 40-km length. The middle third of the stream is situated on the Mitchell Plain which produces renowned building limestone, and the lower third cuts through the more deeply dissected Crawford Upland. The section used for this study lies within the Upland at T 1- N, R 5 W, Sections 23, 24, and 26 near the town of Manhattan, Indiana.

The waters of Deer Creek are enriched by runoff from agricultural lands and treated domestic wastes. Chemical characteristics are typical for most east-central Indiana streams. Normal suspended solids usually are less than 100 mg/l. Discharge ranges from 125 m^3/sec to 0 m^3/sec and averages 1.8 m^3/sec; but stable flows from July through November average less than 0.2 m^3/sec.

Along the study section of the stream is a limestone quarry producing rock used mainly in road construction. In its operation, the quarry draws water from Deer Creek to be used in washing and sorting the crushed rock. The rock/water slurry containing the finer particles of limestone is then pumped to a series of two settling basins after which the waste water re-enters Deer Creek. The effects of the quarry washings on the stream biota have been presented by Gammon (1970) and White (1970).

A riffle above the quarry outfall was chosen for this experiment to eliminate any bias from previous sediment inputs. The riffle was characteristic of the stream, consisting of a mixture of large and small rubble on a bed of sand with a limestone base. Two large stands of water willow (*Justicia americana*) flanked the head of the riffle which was 25 m long, 8 m wide, and averaged 18 cm in depth. Previous studies have shown that this riffle had greater density and diversity of benthic forms than other riffles located directly above the quarry outfall (White, 1970).

Methods

To minimize other factors affecting drift rates, all tests were conducted during the early afternoon on clear days when the discharge of Deer Creek was less than 1.5 m^3/sec and the natural suspended solids load was less than 30 mg/l.

Placed at the foot of the riffle was a nylon drift net 1.83 m long with mouth dimensions of 30.5 cm x 61 cm and a mesh size of 253 μ. Metal stakes were driven into the substrate and fixed such that the net and frame could be removed quickly at the end of each timed period. A modified garbage can, which proved to be an adequate sediment dispenser, was placed near the head of the riffle. A large, square hole was cut on one side of the can near the bottom with a smaller hole being cut on the opposite side so that both openings would be below the waterline of the stream. A vertical baffle placed perpendicular to the direction of flow was then soldered to the bottom. When mixed thoroughly with the incoming water, sediment measured into the upstream chamber maintained a fairly constant load of suspended solids. The suspended solids could be regulated by increasing or decreasing the rate at which sediment was placed in the dispenser. Between the can and the net, the area of the riffle subjected to suspended solids was approximately 6 m^2. Prior to the first experimental runs, tests were conducted to determine if the operation of the dispenser caused any mechanical dislodgment of the benthos. Four 15-min simulated test periods were run without introducing sediment and each resulted in no increases to the normally occurring drift rate.

Material to be used as suspended solids was taken directly from the limestone quarry's settling basins. Particle sizes, determined by bottom withdrawal tube (Subcommittee on Sedimentation 1943, 1953), were generally less than 30 μ in diameter, with the garbage can being efficient in trapping most larger particles.

Experiments consisted of collecting benthic drift at the downstream end of the riffle for 15-min as a control followed by a 15-min collection during which solids were added continually at a given rate. The first control run was used to establish the naturally occurring drift rate before the riffle was disturbed. The alternation of conditions was repeated through several cycles with an attempt to maintain the same concentration of suspended solids in any day's test runs. The cycle was stopped at the first sign of sediment beginning to accumulate in the riffle; thus, the riffle usually was subjected to test runs for less than an hour on any particular day. The examination of higher or lower concentrations usually was separated by a period of days or weeks to prevent any cumulative reactions to the suspended solids.

Water samples were taken half way between the dispenser and net during each control and test. Suspended solids were measured using the methods of Banse et al. (1963) and Wyckoff (1964). Aliquots of 100 ml were filtered through tared Gelman Type-A glass fiber filters and oven dried at 105°C for 24 hours. The dried filters were then desiccated for 24 hours and weighed on a Cenco No. 1581 balance to the nearest 0.1 mg.

At the end of each drift period, the net was changed, and all material including debris was preserved in 70% ethanol. In the laboratory, macroinvertebrates were separated, identified, and counted. Identifications were made using the keys of Edmondson (1959) and Usinger (1963). To determine if the test and control runs were statistically significant, *t*-tests for paired comparisons were calculated following the methods of Sokal and Rohlf (1969).

Benthic collections, taken with a Surber square-foot sampler (0.3 m x 0.3 m), were used to compare the actual macroinvertebrate composition with the drift. The bottom samples were not taken on the same days as the drift; therefore, they are presented for comparison only.

Results

Table 1 summarizes the results of the drift experiments. The average amount of added suspended solids ranged from 18.6 to 271.3

TABLE 1. *Summary of alternating controls and tests; mean suspended solids ± the standard error; means number of drifting organisms per 15 min ± the standard error; and values for t-test comparisons between periods of control and test drift. Number of trials in parentheses*

	Suspended Solids (mg/l)			Drifting Organisms			
Run	Controls	Tests	Mean Added Solids	Controls	Tests	t_s	P
A	9.7±1.7 (4)	28.3± 2.2 (3)	18.6	32.0±4.3	40.3± 4.4	0.77	0.500
B	11.0±0.8 (4)	65.3± 9.7 (3)	54.3	25.0±6.2	33.0±10.0	3.03	0.100
C	24.0±1.2 (3)	108.3±13.0 (3)	84.3	19.7±5.2	28.7± 8.4	0.83	0.500
D	20.3±1.3 (2)	125.0± 4.0 (2)	104.7	62.0±6.4	117.5±25.0	37.48	0.025
E	27.7±1.3 (3)	162.0± 2.8 (3)	135.5	62.0±2.0	135.5±41.0	4.33	0.050
F	19.0±1.0 (4)	173.5±38.2 (4)	154.5	30.0±9.0	60.5±26.7	2.86	0.050
G	20.2±8.6 (6)	291.5±46.5 (6)	271.3	51.0±2.5	96.3±33.2	3.08	0.050

mg/l with corresponding increases in drift from 25.9 to 118.5%. The drift rate increased roughly linearly with the increasing suspended solids up to 135.5 mg/l added. Beyond this point, greater concentrations of suspended solids did not increase the drift to higher rates.

In those tests where the mean added solids were less than 100 mg/l, the increase in drift, although higher than in control runs, was not statistically different when *t*-tests were applied (Table 1). The four runs with greatest amounts of added solids did produce a significantly greater drift rate at least at the P=0.05 level.

All runs were made without stops between the cycles, control-test-control-test-etc. In each control that followed a test, the drift rate returned to the level of the first control, even during the runs with the greatest inputs of solids. Correspondingly, the drift response was immediate to the addition of suspended solids; and, at least at lower levels of input, did not proportionately increase throughout most runs. During the two series in which the greatest quantities of solids were added, there was a rather slow initial increase in drift and then a steady increase during subsequent test periods.

In order of abundance (Table 2), Chironomidae, *Simulium, Cheumatopsyche, Baetis, Caenis,* and *Stenelmis* comprised more than 95% of the drifting organisms. When compared with square-foot bottom samples, Chironomidae and *Simulium* were relatively more numerous in the drift than in the riffle while the other groups were either the same or less abundant in the drift. As the drift rate increased through higher concentrations of suspended solids, the numbers of Chironomidae, *Cheumatopsyche*, *Baetis*, and *Caenis* increased proportionally. The genus *Simulium* (mainly *Simulium vittatum* Zetterstedt) showed a decrease in drift during test runs until more than 100 mg/l of suspended solids were added, with higher concentrations more than doubling the drift rate over the control periods. The riffle beetle (*Stenelmis sexlineata* Sanderson) showed no reaction to the suspended solids either as adults or larvae.

TABLE 2. *Percentage composition of macroinvertebrates from ft^2 bottom samples and from control and test drift trials.*

	Ft^2 Samples		All Control Runs		All Test Runs	
	Range	Median	Range	Median	Range	Median
Chironomidae	10-89	43	44-91	77	55-92	74
Cheumatopsyche	0-47	20	0-9	5	3-13	7
Baetis	1-10	8	0-14	4	0-15	6
Stenelmis	1-8	4	0-3	1	0-8	1
Simulium	1-17	3	0-28	6	0-16	7
Caenis	1-10	1	0-8	1	0-9	2
Others	1-30	4	0-9	1	0-9	1

Discussion

In previous drift studies, such as that by Pearson and Franklin (1968), the effect of suspended solids could not be separated from the effect of flow. Data from our experiments show that an increase in daytime drift rates can be related to increases in suspended solids without corresponding increases in flow. Up to a certain point, greater amounts of suspended solids produce a proportionate rise in drift rates.

Waters (1965, 1972) suggests that drift may be divided into the categories of constant, behavioral, and catastrophic. Drift also may be classified as active or passive (Müller, 1963). From our data, we cannot be sure how suspended solids influences the drift rate; but, at first glance, it seems to be an active-behavioral response. Additionally, it is difficult to state if the changes in drift rates are a reaction solely to the suspended solids or to other factors, such as light penetration, etc., that may change with the amount of solids added.

Most invertebrate taxa reacted similarly in relation to the increased suspended solids. The most notable exception was *Stenelmis sexlineata*. Even though this elmid is subject to distinct periods of diurnal drift (observations of the authors), it seems quite tolerant of suspended solids. *S. sexlineata* previously has been found to be indifferent to both turbidity and siltation (Sinclair, 1964; White, 1970); therefore, it would have been surprising to observe any reaction to the suspended solids.

Although repopulation occurs quite quickly through the natural drift from upstream riffles (Waters, 1972), high levels of suspended solids that increase drift rates over long periods could greatly affect the benthic fauna of a stream. In turn, this may reduce drastically the food supply available for stream fishes (Waters, 1969; Gammon, 1970).

Acknowledgments

We wish to thank all the members of the Zoology Department, DePauw University, for their help in this project and especially to Dr. Michael Baaske who aided in the drift collections. The research was supported through grant 18050 DWC from the Water Quality Office of the Environmental Protection Agency.

Literature Cited

BANSE, D., C. P. FALLS, and L. A. HOBSON. 1963. A gravimetric method for determining suspended matter in sea water using Millipore filters. Deep Sea Res. **10**:639-642.

BISHOP, J. E., and H. B. N. HYNES. 1969. Downstream drift of the invertebrate fauna in a stream ecosystem. Arch. Hydrobiol. **66**:56-90.

CORDONE, A. J., and D. W. KELLY. 1961. The influences of inorganic sediment on the aquatic life of streams. Calif. Fish Game. **47**:189-228.

EDMONDSON, W. T. ed. 1959. Fresh-water biology. 2nd ed. John Wiley & Sons, Inc., New York, New York. 1248 p.

GAMMON, J. R. 1970. The effect of inorganic sediment on stream biota. Water Poll. Cont. Res. Ser. 18050 DWC. 12/70:1-141.

HERBERT, D. W. M., J. S. ALABASTER, M. C. DART, and R. LLOYD. 1961. The effect of china-clay wastes on trout streams. Int. J. Air Water Poll. **5**:56-74.

MÜLLER, K. 1963. Diurnal rhythm in "organic drift" of *Gammarus pulex*. Nature. **198**:806-807.

PEARSON, W. D., and D. R. FRANKLIN. 1968. Some factors affecting drift rates of *Baetis* and Simuliidae in a large river. Ecology. 49:75-81.

REIS, P. A. 1969. Effects of inorganic limestone sediment and suspension on the eggs and fry of *Brachyodanio rerio*. Masters Thesis, DePauw U., Greencastle, Ind. 58 p.

REISEN, W. K., and R. PRINS. 1972. Some ecological relationships of the invertebrate drift in Braters Creek, Pickens County, South Carolina. Ecology. 53:876-884.

SINCLAIR, R. M. 1964. Water quality requirements for elmid beetles. Tenn. Dept. Pub. Health. 14 p.

SOKAL, R. R., and F. J. ROHLF. 1969. Biometry. W. H. Freeman and Co., San Francisco, Calif. 776 p.

SUBCOMMITTEE OF SEDIMENTATION, Federal Inter-Agency Basin Committee. 1943. A study of new methods for size analysis of suspended sediment samples. Rept. No. 7:1-102.

SUBCOMMITTEE ON SEDIMENTATION, Federal Inter-Agency Basin Committee. 1953. Accuracy of sediment size analysis made by the bottom withdrawal tube method. Rept. No. 10:1-115.

TEBO, L. B., JR. 1955. Effects of siltation, resulting from improper logging, on the bottom fauna of a small trout stream in the southern Appalachians. Prog. Fish Cult. 17:4-70.

USINGER, R. L. ed. 1963. Aquatic insects of California. U. Calif. Press. 508 p.

WATERS, T. F. 1965. Interpretation of invertebrate drift in streams. Ecology. 46:327-334.

WATERS, T. F. 1969. Invertebrate drift-ecology and significance to stream fishes, p. 121-134. *In:* T. G. Northcote ed. Symposium of salmon and trout in streams. H. R. MacMallian Lectures in Fisheries, U. Brit. Columbia.

WATERS, T. F. 1972. The drift of stream insects. Annu. Rev. Entomol. 17:253-272.

WHITE, D. S. 1970. The effect of inorganic limestone sediment on the macroinvertebrates of Deer Creek. Masters thesis, DePauw U., Greencastle, Ind. 135 p.

WOLMAN, M. G., and A. P. SCHICK. 1967. Effects of construction on fluvial sediment, urban and suburban areas of Maryland. Water Resour. Res. 3:451-464.

WYCKOFF, B. M. 1964. Rapid solids determination using glass fiber filters. Water Sewage Wastes. 1964:349-352.