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THE RECOVERY OF STREAM MACROBENTHOS FROM LOW pH STRESS

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ABSTRACT

The effects of short term low pH stress was studied in relation to recovery and restoration of aquatic macrobenthic communities. Experimental acid additions were made to a healthy productive stream, reducing pH to 4.0 from 8.0 for 15 minutes. Diversity and density were decreased ($\bar{d}$ 3.91 and 74 organisms/ft^2 before acid vs. $\bar{d}$ 2.79 and 43 organisms/ft^2 after acid). Recovery was related to downstream drift of recolonizing organisms; full recovery occurred within 19 to 28 days with density and diversity equaling or exceeding pre-stress values. A second study was made to observe drift borne recolonizing organisms.

Baetis sp. dominated drift collections, and was the most abundant taxon in bottom fauna collections indicating a relationship between drift and recovery.

Average drift rate was 10 organisms or less during one 15 minute drift sample, drift rates were calculated to be in excess of 5000 organisms/day.

INTRODUCTION

Recovery and restoration of bottom fauna communities from the effects of stress may be rapid or slow depending on several factors such as: 1) severity and duration of the stress, 2) recolonization of the damaged area by appropriate aquatic organisms, or 3) the residual effect of the stress or associated materials. Stress severity is probably most closely related to discharge characteristics (e. g. toxicity and volume), although receiving water conditions (e. g. temperature, discharge, water quality, or overall assimilative capacity) may significantly influence impact on the biotic system. Damage is a function of both stress severity (i. e. toxicity) and duration. Greatest damage occurs when the stress is highly toxic'although a chronic stress of low toxicity may also cause significant damage. After damage has occurred the recolonization of the damaged area varies depending on several factors such as seasonal influence (HOFFMAN and DROOZ, 1953), in stream sources of recolonizing organisms such as drift (WATERS, 1964 or HERRICKS and CAIRNS, 1974) or stress survivors (LARIMORE, *et al.*, 1959), and ovipositing adults (STEHR and BRANSON, 1938, or MULLER, 1954). The residual effects of a discharge may be due in part to discharge constituents (e. g. heavy metals, residual pesticides, etc.), but may also include damage to energy resources which limit recovery until trophic stability has been re-established. To gain a better understanding of the processes of restoration and recovery of damaged bottom fauna communities, an experimental program was undertaken to simulate a stress which leaves no residual toxicity. Damage was produced by an acute acid stress and changes in the bottom fauna through time were studied to determine mechanisms and rates of recovery.

PHYSIOGRAPHY AND DESCRIPTION OF SAMPLING LOCATION

The experimental site located on Mill Creek a tributary to the North Fork of the Roanoke River in Montgomery County, Virginia. The stream (intermittent for most of its 5.6 km length) drains a small valley, flowing southeast from Brush Mountain. Maximum total relief is (171 m). As the stream nears elevation of the North Fork valley floor, several springs feed the stream, and continuous flow was maintained for approximately 1.6 km to its confluence with the North Fork. Average width in the downstream region was .8 to 3 m.

METHODS AND PROCEDURES

The physical site selected for the experiment was 30 m straight riffle section with an average width of 2.4 m. This reach was divided along its length by a partition producing two stream sections approximately 1.2 m wide. The divider created an experimental area with two comparable habitats side by side with similar fauna, and subject to similar natural environmental fluctuations. Two studies were carried out. The first involved only monitoring recolonization by sampling bottom fauna in the treated and reference sections through time. The second study was similar, but included sampling of drift borne recolonizing organisms.

While stress was applied, the flow was alternately reduced on both sides of the divider for fifteen minutes. This substantially increased the flow on the opposite side. As the flow was reduced in the experimental side, concentrated technical grade sulfuric acid was poured along the length of the experimental area. Tht pH in the experimental area was reduced to well below 4.0, and maintained at that level for fifteen minutes. As the water left the experimental section it was neutralized to pH 7.0 with sodium hydroxide.

In the initial study macro-invertebrate bottom fauna samples were collected in both treated (experimental), and reference (control) sections four weeks before as well as immediately before acid addition. Samples were also collected immediately after acid addition (day 0), and on day 2, 6, 13, 19, 28, and 34, following with additional samples at 14 to 60 day intervals. Each sample represents a composite of five Surber square foot (.1 m^2) bottom samples from both treated and reference sections on each date. Diversity was calculated from the composite fauna of all five samples. Density was the average number of organisms in five square feet of bottom. Water quality analyses were performed each time invertebrate collections were made with a Hach engineer's kit.

Drift studies were conducted in conjuntion with a second experimental acid addition. Drift nets were constructed after WATERS (1962). Four nets were used, one placed above and below the divided section of the stream on both the experimental and reference sides. Drift samples were collected periodically before the experimental acidification to assess normal drift activity in the stream. Drift samples were collected immediately before and after acid addition, and additional samples were collected at two hour intervals for 66 hours. After this initial series of drift samples, additional samples were collected periodically at 6 to 12 hour intervals. In addition to drift sampling five Surber samples were collected from both reference and experimental section on day 4 and day 21 following the acid addition (day 0).

RESULTS AND DISCUSSION

Water quality was good throughout both experiments. The pH value was generally high, 8.0 to 8.5 and the total alkalinity was 260 to 280 ppm. Free acidity and total mineral acidity were generally 0. Total hardness ranged from 260 to 280 ppm. Temperature remained relativtly constant throughout the late summer months varying between 15 and 20 degrees Celsius. During late fall and winter collections water temperature dropped to 0 to 10 degrees Celsius. During drift sampling the water temperature fluctuated between 15 degrees Celsius in the late night and early morning to 20 degrees Celsius in late afternoon. Current velocity and stream depth remained relatively constant throughout the drift study.

ACUTE STRESS STUDY

Figures 1 and 2 show that both treated and reference sections were stressed as a result of the experimental procedure. Density declined over 30 % in both treated and reference sections after acid addition. The acid treated

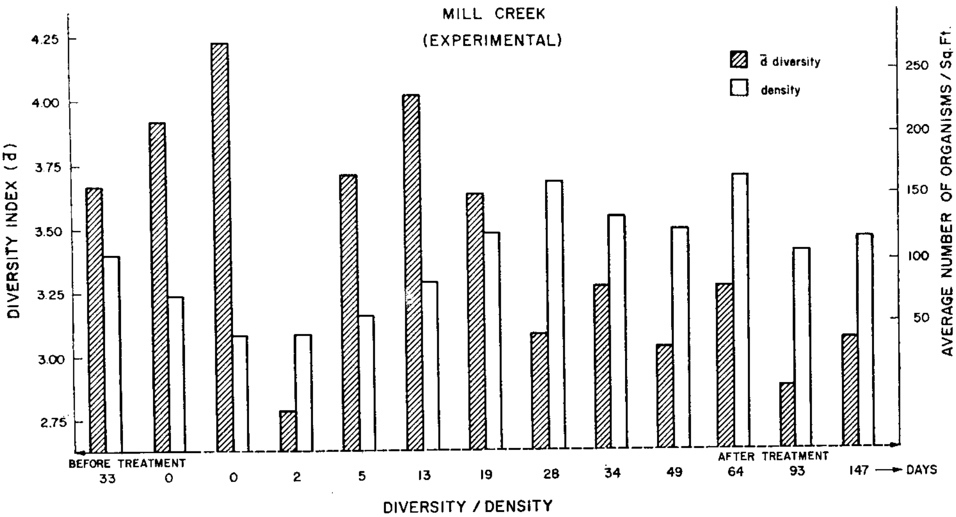

Fig. 1 — Density and diversity from Experimental section-Acute Stress Study.

area, however, showed a more dramatic alteration through time with marked changes in both diversity and density. Recovery trends were observed in density and diversity results, if rank-abundance data is also included, Table 1, these trends are shown to be shifts in dominant orders, and dominant taxa.

Immediately after treatment the diversity index in the experimental section showed a temporary rise while density remained low, Figure 1. This was probably due to a non-selective reduction of organisms in the treated community due to the low pH shock combined with an increase in downstream drift due to changes in flow (MINSHALL and WINGER, 1968). Two days after treatment the $\bar{d}$ value in the experimental section was very low, 2.79, as was the density, 43 organisms/ft^2. The reference collections showed little alteration in diversity, and had a very high density, 205 organisms/ft^2 This difference was probably due to the destruction of energy sources which made immediate recolonization of the experimental section unsuitable. Some of the surviving species had striking increases in numbers of individuals on day 2, becoming dominant in the community. Dominance was probably a function of survival of acid stress resulting in a lower diversity. Five days

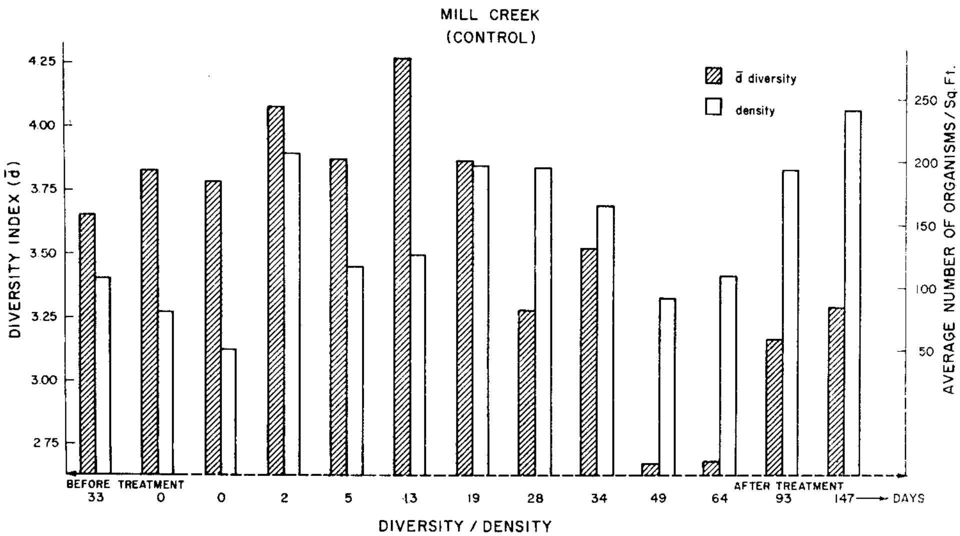

Fig. 2 — Density and diversity from Reference section-Acute Stress Study.

after treatment the community structure had regained some of its original complexity. The $\bar{d}$ value for day 5 was above 3.0, and density rose to 53 organisms/ft^2. During days 13 through 28 the community recovered from the low pH shock, re-establishing its former level of complexity as evidenced by high diversity and density values. Decreases in $\bar{d}$ and density during the late stages of the experiment were undoubtedly due to a number of factors. The most important was fall emergence of adult insects, and possibly a low grade stress produced by high suspended solids loading (CAIRNS, 1968).

The effect of higher than normal sediment loading was noted in diversity and density values for the reference section. Rainfall shortly before

TABLE 1 — **Dominant orders and dominant taxa Mill Creek acid stress study**

	8/20	8/20	8/20	8/22	8/26	9/3	9/9	9/18	9/24	10/9	11/6	12/4	1/23
Experi-mental Section	Order	C(62)*	C(34)	C(43)	C(35)	C(25)	C(35)	T(40)	E(32)	E(43)	C(34)	C(40)	T(41)
		D(13)	E(32)	P(21)	D(19)	E(19)	E(22)	E(24)	E(31)	C(32)	T(31)	E(32)	C(26)
		E(12)	T(15)	T(18)	E(19)	D(16)	T(15)	T(22)	C(28)	T(19)	C(24)	T(21)	E(18)
	Taxa	1	1	2	2	2	2	2	3	4	4	2	3
Reference Section	Order	C(41)	C(41)	E(48)	E(40)	E(36)	E(39)	E(33)	E(46)	C(41)	C(50)	E(37)	T(44)
		E(26)	E(23)	T(19)	C(30)	C(23)	C(27)	C(31)	C(24)	E(28)	E(23)	C(27)	E(22)
		D(12)	T(13)	P(10)	T(15)	T(19)	T(17)	T(28)	T(20)	T(25)	T(21)	T(27)	C(21)
	Taxa	2	2	5	5	5	4	4	4	2	2	4-5	6

* % of total collection

C — Coleoptra
D — Diptera
E — Ephemeroptera
P — Plecoptera
T — Trichoptera

1. *Rhizelmis* sp.
2. *Cleptelmis* sp.
3. *Hydropsyche* sp.
4. *Ephemerella* sp.
5. *Benetis* sp.
6. *Glossosoma* sp.

sampling on days 49 and 64 produced increased run-off, and higher stream discharge. Run-off from adjacent fields, and a dirt road along the right bank was channeled along the reference section by the divider. This run-off added heavy suspended solids loading to the light sediment load normally carried by the stream during high run-off situations. The two sides were otherwise similar. Reference section values on day 49 were Figure 3, $\bar{d}$, 2.69 reduced from 3.52, and density 95 organisms/ft^2 reduced from 166 organisms/ft^2 as compared with day 34.

The rank abundance tabulation confirms the effect of the stress, and extends the recovery period beyond the diversity assessment to near day 34 when the Coleopteran, *Cleptelmis sp.* was no longer dominant. During the period of recovery the bottom fauna community in the reference section was dominated by Ephemeroptera. While the experimental section collections contained Ephemeroptera, the community was dominated by the Coleopteran, *Cleptelmis sp.* This may have been due to several factors. The most probable was destruction of food resources for Ephemeroptera and possibly destruction of egg and larval stages of Ephemeroptera by the low pH. Both of these factors could cause a selective reduction in numbers of Ephemeroptera. The Coleopteran, *Cleptelmis sp.* dominated the bottom fauna community in the reference section on day 49 and 64. A suspected high suspended solids concentration placed the reference section under stress at this time. The experimental section on day 49 and 64 had evidently recovered from the initial acid stress and gave no indication of further stress, community dominants were Ephemeroptera.

DRIFT STUDY

A second experimental study was carried out on Mill Creek approximately twelve months after the acute stress study. Studies were made of macroinvertebrate drift and the relationship between drifting organisms, and recolonization and recovery of a damaged area. The literature dealing with drift of stream insects, the major group of macroinvertebrate bottom fauna, is extensive. Environmental factors, both physical and biological, which control drift have been the subject of several investigations. Drift has been related to flow changes (MINSHALL and WINGER, 1968), moonlight (ANDERSON, 1966), light intensity (HOLT and WATERS, 1967), density (DIMOND, 1967) and general invertebrate activity (DEVON, 1968). In general drift in most streams fluctuates according to certain defined patterns. ELLIOT (1965) reported increased drift at night. This has been confirmed by several authors

(PEARSON and FRANKLIN, 1968, WATERS, 1969, REISEN and PRINS, 1972, and KLYUCHEREVA, 1963). Monitoring drift has been proposed as a method to monitor the production rate of bottom fauna communities (WATERS, 1962). In this regard WATERS (1964) studied the recolonization of an area of stream bottom which had been artifically denuded. He concluded that downstream drift of aquatic organisms was a suitable mechanism to restore a disrupted bottom fauna community to normal in a short time.

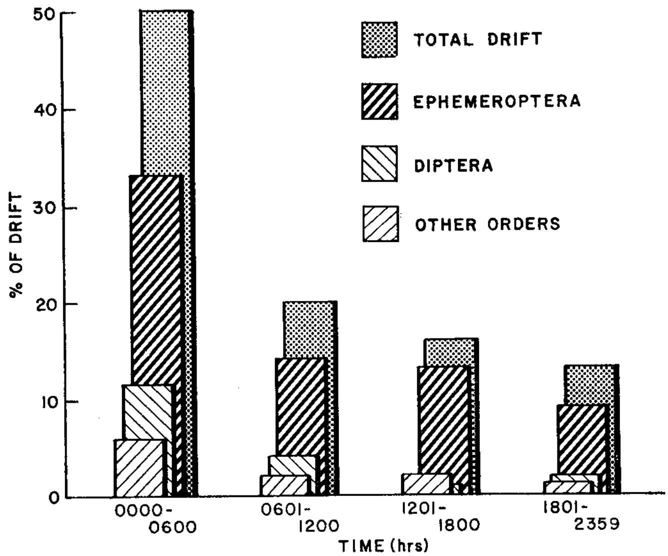

Fig. 3 — Percent of drift collected during 4 6-hour periods.

On day 4 the diversity index was 2.52 and density was 110 organisms/ft^2 in the experimental section, while the diversity was 2.92 and the density was 159 organisms/ft^2 in the reference section. The bottom fauna community in the experimental section was dominated by Coleoptera, *Cleptelmis sp.* while the reference section was co-dominated by *Cleptelmis sp.* and the Ephemeropteran *Baetis sp.* On day 21 diversity in the experimental section was 2.76 and the density was 262 organisms/ft^2 while the diversity was 3.18 and the density was 210 organisms/ft^2 in the reference section. In both the reference and experimental sections on day 21 the bottom fauna community was dominated by Ephemeroptera, *Ephemerella sp.*

Drift samples collected as a reference before acid treatment indicated drift rates were greatest at night, largest drift movement occurring between

0000 and 0600 hours, Figure 3. Ephemeroptera and Diptera were the orders which showed the greatest tendency to drift. Although total drift numbers were at times very high, the majority of those organisms drifting were adult forms, not nymphal or larval forms which would immediately colonize the area. The drift samples collected in conjunction with the experimental acid stress showed similar trends. Total number of recolonizing species collected in one 15 minute drift sample varied between 0 and 50, while total numbers collected were well below 10 organisms/sample even though large numbers of adults were collected. Immediately after acid addition drift out of the experimental site was extremely high. These drift collections included several species of fish such as the Sculpin, *Cottus sp.*, and large numbers of all orders of insect bottom fauna. Drift rate out of the experimental section was still high 2 hours after acid treatment; the samples were dominated by Ephemeroptera, *Isonychia sp.*, *Ephemerella sp.*, and *Baetis sp.* During the same period drift rate out of the reference section was low.

Drift into both experimental and reference sections following the acid stress was similar. Drift rates were low between 0600 and 1800 hours and high between 1800 and 0600 hours. The taxon which showed the highest drift rate was *Baetis sp.* although several other Ephemeroptera, *Isonychia sp.*, *Ephemerella sp.*, and *Stenonema sp.* were recorded in samples. Three taxa of Diptera showed high drift rates, both *Simulium sp.*, and *Antoca sp.* were recorded regularly, while Chironomidae were recorded irregularly. The Trichopteran, *Hydropsyche sp.* was ecorded infrequently in drift samples. Drift rate into the experimental site was greatest immediately following the acid stress. As many as 50 potential recolonizing organisms were collected in one drift sample. These high drift rates into the experimental site coincide with results found by MINSHALL and WINGER (1968), and may explain high diversity and density found in the reference section after acid addition in the first study. Drift rates continued high for approximately 48 hours. At the end of the 66 hour initial sampling period, drift rate was similar to pre-stress drift samples. The sampling which continued on an irregular basis revealed drift rate similar to pre-stress levels, the drift fauna was dominated by Ephemeroptera, *Baetis sp.*

There are a number of factors which may be related to drift initiation. From these studies, the dominant factor related to drift intensity was emergence activity. The density of potential recolonizing organisms in the total drift is small, but it may be a significant source of recolonizing species. During the periods of highest drift intensity as many as 50 potential recolonizing organisms were collected from a 1 foot width of the stream. Average drift was 10 organisms or less per sample but this number multiplied by stream width, and the number of 15 minute periods in a 24 hour period results in a total number of recolonizing organisms in excess of 5000/day. This would be sufficient to bring about rapid recovery if these organisms became established habitat in the damaged area.

CONCLUSION

The results of the experimental acidification of Mill Creek provide information on the response of a stream fauna to an acute stress, and the recovery which follows. Although there was no residual toxicity, the residual effects of the stress, i. e. damage of food resources and elimination of some organisms have an extended effect on the bottom fauna community. During both periods of stress (acid and suspended solids) the community was dominated by the Coleopteran *Cleptelmis sp.*, and the recovery community was dominated by Ephemeroptera. Diversity and density analyses indicated recovery by day 28 while rank-abundance tabulations indicated recovery on day 34.

The drift study confirms the hypothesis that recovery of damaged bottom fauna communities is related to drift. Although drift rates were for the most part low in individual samples, total numbers of drifting organisms would be sufficient to rapidly recolonize a damaged area.

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