ENVIRONMENTAL LETTERS, 7(4), 345-352 (1974)

RELATIONSHIPS BETWEEN SEDIMENT OIL CONCENTRATIONS AND THE MACROINVERTEBRATES PRESENT IN A SMALL STREAM FOLLOWING AN OIL SPILL

Key words: oil spill, community diversity, benthos, sediment oil analysis

R. C. Hoehn
Department of Civil Engineering
and
J. R. Stauffer, Michael T. Masnik, and C. H. Hocutt
Center for Environmental Studies
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061

ABSTRACT

A study was conducted to assess the effects of an oil spill on the macroinvertebrate populations in a small creek in Virginia. Sediments were extracted with hexane, and the residue concentrations were correlated with the numbers and diversities of macroinvertebrates collected downstream of the spill. Based on the available data, it was concluded that the effect of the oil spill was a toxic one rather than one of rendering the sediments unsuitable for colonization.

INTRODUCTION

In May, 1973, an accidental spill of several thousand liters of Number 2 fuel oil into Plum Creek -- a small, third-order stream of the Tennessee-Clinch River System -- provided an excellent opportunity to determine if the impact of such an event could be assessed, at least in part, by relating sediment oil concentrations to the numbers and diversities of macroinvertebrates at several sites downstream of the spill. The spill occurred from the overturned tanker portion of a tank truck. Within a few hours, floating booms constructed of straw were put in the creek to contain the oil, and an absorbant was spread on the surface to remove floating oil. Downstream, a straw dam was constructed to collect any oil not contained or removed upstream.

A few dead fish, crayfish, and caddisflies were observed immediately after the accident, but no extensive damage to the biota was detected. Nevertheless, a detailed follow-up of the area was conducted over a period of several weeks to determine if any subtle changes occurred in the macroinvertebrate populations, and, if so, to determine if any of these changes could be correlated with concentrations of hexane-extractable residues within the sediments. The study is noteworthy because it provided chemical data relative to the sediments that usually are not obtained when damage to benthos by pollutants is being investigated. Too, the method used for analyzing the sediments for oil, while not fully developed at the present time, shows promise of being an acceptable method to quantitate foreign residues in benthic substrates. At present, there is no standard method.

METHODS

Three days after the spill, stations were established on Plum Creek -- two upstream and four downstream of the spill (Figure 1). Biological data were collected during the first visit to the area and again at intervals of approximately 2, 6, and 18 weeks after the spill. At each station, pool and riffle areas were selected as sampling sites for macroinvertebrates, and three one-minute kick-samples were collected from each in a D-frame net. The collection procedure used has been shown to provide excellent qualitative data and adequate semi-quantitive data[1].

Macroinvertebrates collected at each station were preserved in 40% isopropanol and returned to the laboratory for sorting and identification.

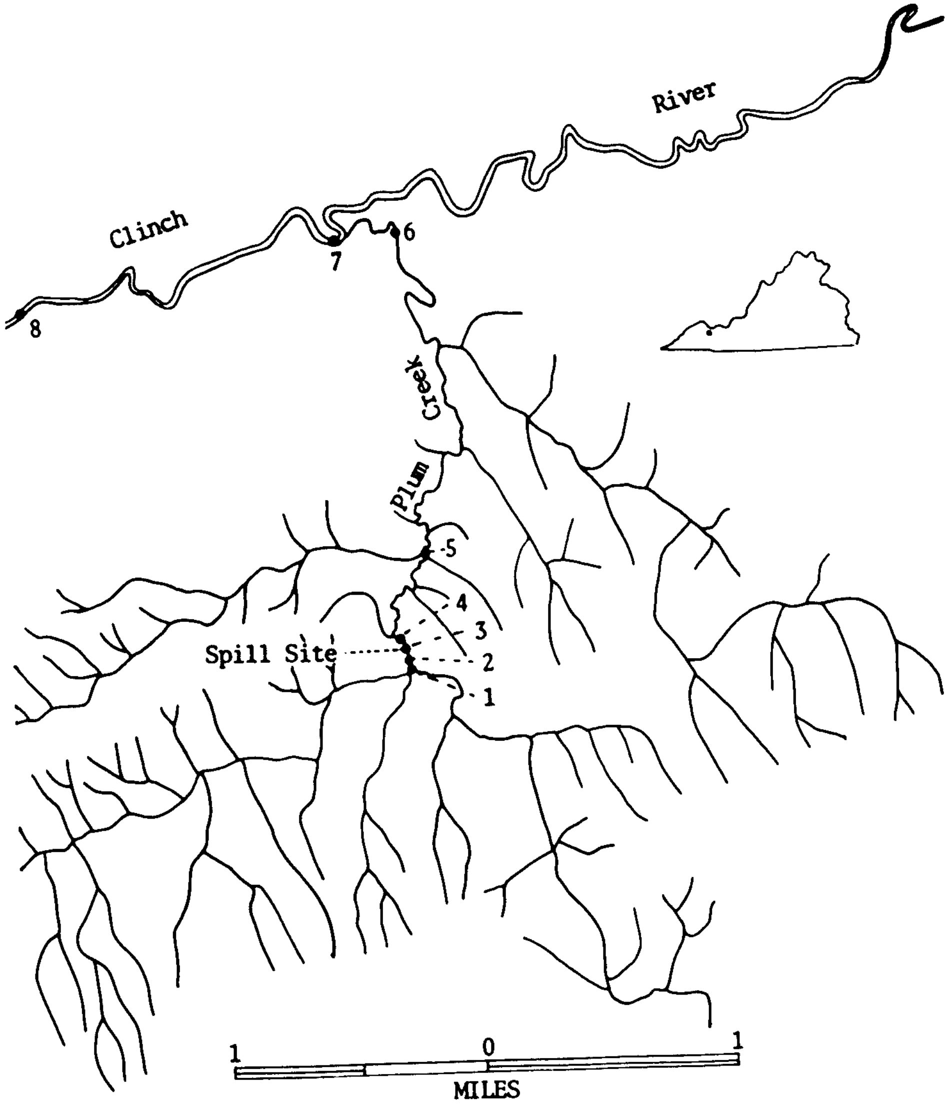

FIG. 1

Map of Plum Creek showing sampling stations

Organisms were enumerated according to their known habitat preferences -- surface, mid-water, bottom, and sub-bottom -- and numbers of both taxa and specimens were recorded for each station[2]. In addition, a diversity index for macroinvertebrates collected at each station was determined according to procedures described by Whilm and Dorris[3].

On the second biological sampling date, approximately two weeks after the spill, sediment samples were collected from the pools and transported on ice to the laboratory where they were spread to dry for several days at room temperature. No scouring rains had occurred in the period between the spill and the date the sediments were collected. All the sediment samples were finely divided and contained a high percentage of clays. Thirty grams of sediment -- which had been cleaned of roots, rocks, and large debris -- were placed in an extraction thimble (5 μ porosity) and extracted with hexane in a Soxhlet extractor for 48 hours at 1-2 cycles per hour. After extraction, the majority of the hexane volume was evaporated at room temperature, and the remainder was transferred, with washings, to a pre-tared crucible and further evaporated. The crucibles were kept in a desiccator until they attained constant weight. After the final weighings, the total, hexane-extractable residues were determined and expressed as weights of residue per gram of sediment that had been extracted. Control tests (five in number) were performed exactly as the experimentals except no sediment was placed in the extraction thimbles. The average weight of the residue recovered during control tests was subtracted from the weight of sediment-extracted residue before dividing by the weight of the sediment that had been extracted.

RESULTS AND DISCUSSION

Data collected on the second sampling date are shown in Figure 2. The apparent effect of the oil was to reduce the numbers of invertebrates

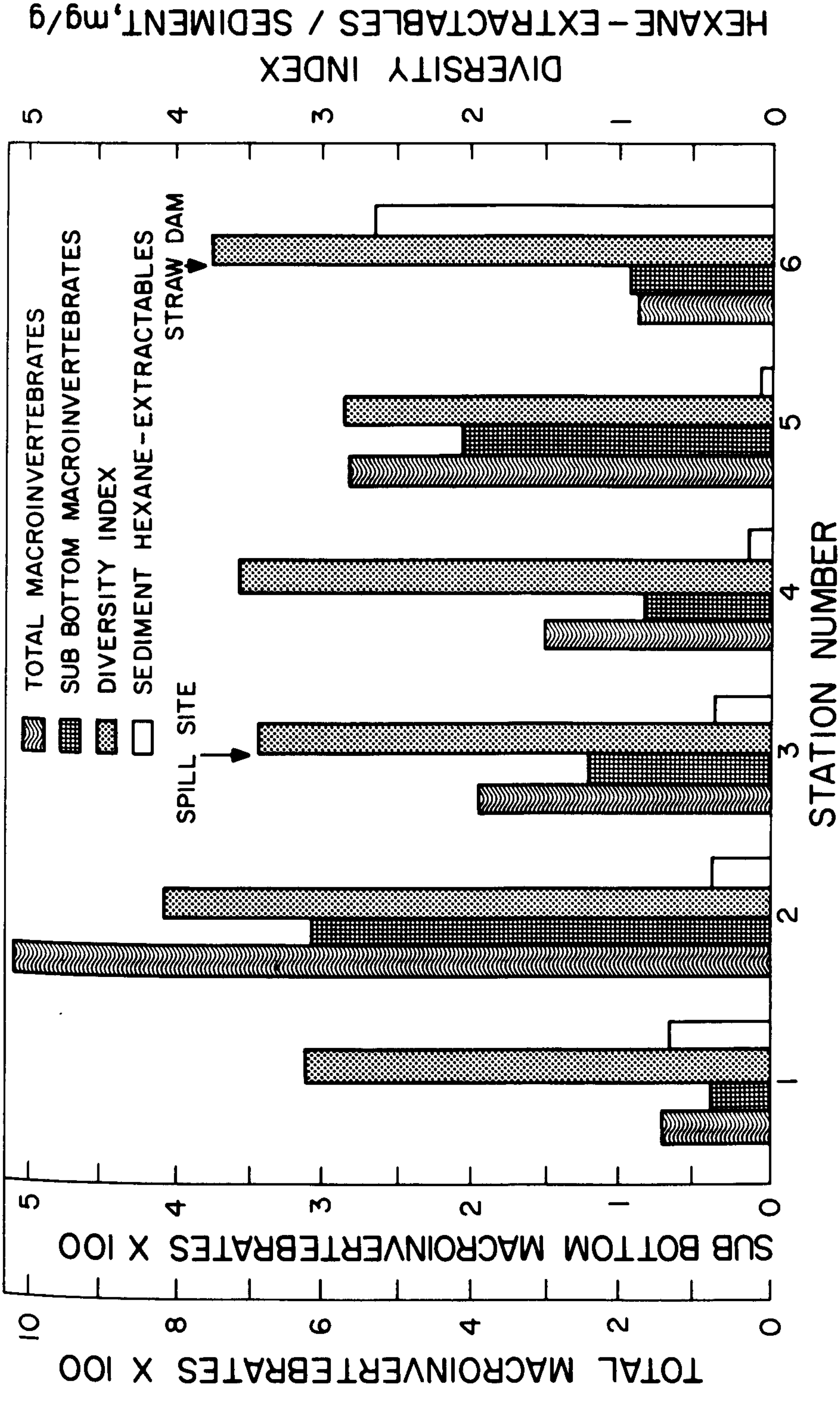

FIG. 2

Macroinvertebrate diversity and abundance compared to hexane-extractable residues in sediments at stations along Plum Creek at Stations 3 and 4 without seriously affecting the diversity. The fact that the diversity did not change, even though the total numbers of organisms decreased, indicates that each taxa within the communities was affected equally rather than selectively. Higher populations were evident at Station 5, which indicates that recovery was occurring, but at Station 6 -- the site below the straw dam -- the populations again decreased dramatically. Also at Station 6, the greatest quantity of hexane-extractable residue was recovered, reflecting the fact that the straw that comprised the dam was never removed from the creek. Apparently, the oil trapped on the straw eventually settled to the bottom of the stream behind the dam, contained either on water-soaked straw or on other suspended material flowing over the oil-saturated dam. Biological data collected on the first and third sampling dates were similar to that shown in Figure 2. By the fourth sampling date, approximately 18 weeks after the spill, the downstream sites on Plum Creek were as populous as the control stations. Observations by the authors indicated that there was no evidence of damage to the Clinch River.

It appears from an analysis of the data that the reduction of macroinvertebrates at Stations 3 and 4 was a result of the toxicity of the water-soluble components of the oil. Similar effects on other biota in Plum Creek were reported by Masnik _et al._[4] Increased numbers at Station 5 indicate that the toxic effects were diminishing. If the effect of the oil had been to render the sediment unsuitable for colonization, one would expect the sediment oil concentrations to increase as the sub-bottom population decreased. Too, the sediment oil concentration should have increased progressively downstream as more and more oil-bearing suspended matter became incorporated into the sediments. Figure 2 shows that neither of these two conditions existed. At Station 6, either or both of the possible oil effects could have caused the observed reduction in macroinvertebrates.

The fact that low numbers of organisms were recovered at the first control station (Station 1) is attributed to the fact that there was contamination of that site by drainage from a cow pasture. Also at that site, the hexane-extractable residue was greater than that for most of the other stations, indicating that organic substances other than oil were removed from the sediments by the solvent. However, it is not difficult for the analyst to differentiate between oil residues and those of other organic compounds. Qualitative characteristics such as color, consistency, and odor aid in the identification. Usually, organics commonly found in humus will smell somewhat rancid and may solidify when all the hexane is evaporated. These and other difficulties need to be explored further to determine if hexane is the best solvent to use for the extractions.

It should be stressed that an analysis of the biological data such as that just presented has not been possible in the few reported studie of oil spills in freshwater environments (e. g. Bury[5]) because no attempts were made in those studies to assess the concentration of oil either in the sediments or in the stream water. The method of sediment analysis reported in this paper, though still not perfected, provides a means whereby conditions in stream sediments contaminated by oil can be analyzed immediately to help interpret biological data or can be monitored over a long period of time in order to determine when the detrimental effects of the oil contamination can be expected to subside sufficiently to permit recolonization by benthos.

SUMMARY AND CONCLUSIONS

This investigation involved an assessment of the effects of an oil spill on the macroinvertebrates in a small creek located in southwestern Virginia. The effect was believed to be mainly one of toxicity caused by the water-soluble fractions of the oil. The bases for this conclusion were, first, that the numbers of invertebrates were reduced without a concomitant decrease in diversity and, second, that decreased populations of organisms were observed at sites where there were low concentrations of hexane-extractable residues in the sediments.

The sediment analysis detailed in this paper provides a means for obtaining data that can be correlated with biological data in assessing both the immediate and the long-term impact of oil spills on streams. At the present time, there is no standard method for quantitating the oil residues contained within sediments.

REFERENCES

1. Frost, S. A., Can. J. Zool. 49, 167 (1971).
2. Usinger, R. L., "Aquatic Insects of California with Keys to North American Genera and California Species," University of California Press, Berkeley, California (1971).
3. Wilhm, J. L. and Dorris, T. C., Bioscience 18, 477 (1968).
4. Masnik, M. T., Stauffer, J. R., Hocutt, C. H., and Wilson, J. H., Proc. 35th Ann. Meeting Southeastern Biologists 21, No. 2 (1974).
5. Bury, R. B., Calif. Fish and Game 58, 291 (1972).

Received August 15, 1974
Accepted August 30, 1974