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THE EFFECTS OF AN OIL SPILL ON THE MACROINVERTEBRATES AND FISH IN A SMALL SOUTHWESTERN VIRGINIA CREEK

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ABSTRACT

Plum Creek, a small 4th order tributary of the Clinch River in southwestern Virginia, experienced an oil spill in May, 1973. Approximately 13,000 liters of No. 2 fuel oil entered the creek 4.2 km above the confluence with the Clinch River. Collections of benthos and fishes made at eight stations over a five-month period indicated minimal mortality. Immediate mortality of water snakes and waterfowl appeared relatively high. Fishes did not exhibit significant decreases in numbers of taxa or specimens collected at the site of the spill for the length of the survey.

INTRODUCTION

The effect of oil spills on freshwater organisms is poorly known. Wilber[1] stated that there is such limited information on the effects of oil on wildlife that any indepth discussion would be futile. Swift et al.[2] surveyed the literature on the biological and ecological effects following an oil spill and noted that little quantitative and coherent data were available. Roeth and Wood[3], Ryck and Duchrow[4] and Schultz and Tebo[5] reported contradictory effects of oil spillage on the macroinvertebrates in several midwestern streams. Bury[6] documented the effects and recovery of a diesel oil spill on the fish, reptiles and birds in a small California stream. Wiebe[7] concluded that if 5% crude oil is mixed with water or simply allowed to float on the water surface, the water will be toxic to fish even after the oil is removed. Smith[8] reviewed the effects of petrochemical effluents.

Bioassay studies on the effects of oil on certain aquatic organisms are meager. Turnbull et al.[9] tested the toxicity of No. 2 fuel oil on bluegills and found the 24 hour TLM to be 14,500 mg/l. No bioassay studies were found pertaining to freshwater macroinvertebrates. Blumer et al.[10] reported that assimilated hydrocarbons in fish and shellfish resemble other persistent poisons such as DDT and other synthetic materials.

McKee[11], Bury[6] and others suggest that petroleum products may be detrimental to freshwater aquatic organisms in the following ways:

(1) Free oil and emulsions may act on the epithelial surfaces of fish adhering to the gills and interfering with respiration;

(2) Free oil and emulsions may coat and destroy algae and other plankters;

(3) Settleable oil suspensions may coat the stream bottom destroying benthic organisms and reducing demersal egg viability;

(4) Organic materials may deoxygenate the water sufficiently to kill fish;

(5) Heavy surface coatings of oil may interfere with photosynthesis or prevent reoxygenation of the water in areas already stressed;

(6) Soluble fractions of the petroleum product may have an acute or chronic toxic effect on the aquatic organisms.

This manuscript reports the biological effects of an oil spill on Plum Creek, Virginia, and is a sequel to Hoehn et al.[12]

Study Area

Plum Creek, a small 4th order tributary of Clinch River of the Tennessee River system, is located approximately 26 km west of Tazewill, Virginia. The approximate drainage area of Plum Creek is 23.4 km^2 with a length of about 6.9 km (Anonymous[13]). The majority of the drainage basin is utilized as pasture land. The average gradient for Plum Creek in the region affected by the oil is 2.8 m/km. A secondary sewage treatment plant serving Tazewell, Virginia (population 4,000), discharges into the Clinch River 1.0 km above the mouth of Plum Creek. The average flow of Clinch Piver near the mouth of Plum Creek is 4.8 m^3/sec.

Itinerary of Oil Spill

The tank of a disabled tractor trailer truck overturned and spilled 19 - 23 thousand liters of No. 2 fuel oil, approximately 13

thousand liters of which entered Plum Creek. The remaining oil was contained in a field adjacent to the stream. Approximately 24 hours after the spill, a company experienced in oil retention and cleaning operations, erected a series of floating straw booms at the spill site and at two downstream locations on Plum Creek and Clinch River. In addition, absorbent material was spread on the water surface immediatel behind the upstream dam in an attempt to remove the oil from the surfac Personnel of the Virginia State Water Control Board arrived on the morning of the 8th of May and reported eight dead fish (five suckers and three minnows). On the 9th of May, State Water Control Board personnel observed an additional 25 dead fish (species unknown) and conducted a cursory examination of the macroinvertebrates concluding that populations were not severely harmed by the fuel oil. In addition to these dead organisms, an area resident familiar with game reported 32 dead wild ducks, probably mallards. The authors arrived at Plum Creek on the morning of May 10, some 72 hours after the spill occurred.

MATERIAL AND METHODS

Eight stations (Hoehn et al.[12]) were sampled for macroinvertebrates and fishes. A short description of each station follows: (Station 1) The confluence of Bundy Branch and Plum Creek, U. S. Route 460 bridge, approximately 45 - 90 m above the spill site. The bottom was characterized by sand, organic detritus, rubble and bedrock (2) Just downstream of the U. S. Route 460 bridge, approximately 45 m upstream from the spill site. The substrate was primarily rubble and bedrock. (3) The spill site, immediately upstream from the first

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straw dam erected to contain the oil. The substrate consisted of sand and organic detritus. (4) Immediately below the straw dam at Station 3. The bottom consisted of bedrock covered with organic detritus. A small riffle composed of rubble was also present. (5) Approximately 0.6 km downstream from the spill site on Mr. John Olmstead's property. The creek in this region was broadly meandering, low gradient and flowing over a bottom of sand and gravel with an occasional rubble riffle. (6) Approximately 3.6 km downstream of the spill, Tazewell county road 632 bridge, and just below second straw dam. The bottom consisted of rubble over bedrock with some organic detritus in the pools. (7) Clinch River at the third straw dam approximately 4.2 km downstream of the spill. The bottom was characterized by extensive rubble riffles grading to a long deep flowing pool. (8) Approximately 2.1 km downstream from the mouth of Plum Creek in the Clinch River. The substrate was extensive shelves of bedrock with some rubble covered in part by large gravels.

Each site was selected to include both riffle and pool habitats. Limited access to the middle section of Plum Creek resulted in only one section for this section. Station 1 was frequently disturbed by cattle and was subject to organic pollution. Decreased flow and stream order upstream of this station prohibited the selection of a more representative site.

Samples of fish and macroinvertebrates were taken at four time intervals: May 10, May 22, June 21 and September 20, 1973. A total of 16 seine hauls, using a 3.6 x 1.2 m, 6.1 mm mesh seine, was made at each station in an attempt to equalize sample effect. A total of 28

fish samples was collected at the first six stations. A total of 90 benthic macroinvertebrate kick samples was taken with a D-frame kick net at all stations. Stations 1 - 7 were sampled at all four time periods while Section 8 was sampled only at periods 2 and 4. Three one-minute kick samples from each station, one from a riffle, one from a run and one from a pool were combined and treated throughout the investigations as one sample.

Both fish and macroinvertebrate data were analyzed using the diversity index proposed by Wilhm and Dorris[14]. In addition, total numbers of organisms and taxa at each station for each period were compared. Benthic samples were further subdivided into four habitat preferences based on life history data of the organisms: surface, water column, bottom and subbottom.

Mud samples were obtained on the 25th of May and 200 g subsamples were dried. Two replicate 30 g soil samples for each station were subjected to 24 hours of extraction by hexanes using soxhlet extractors. The resulting fraction was evaporated and weighed for several days until the loss through evaporation was stabilized. The results of the oil extraction procedure and its subsequent correlation with the macrobenthic invertebrates were reported by Hoehn et al.[12]

RESULTS AND DISCUSSION

Oil was observed at the surface of the water at Stations 2 - 7 for periods 1 and 2, but only after vigorous kicking of the bottom and shoreline vegetation during periods 3 and 4. Oil in the Clinch River appeared restricted to approximately one quarter of the width along the south bank. Dead organisms observed were recorded for the first two sampling periods (Table 1).

TABLE 1. Dead organisms observed during collecting periods one and two.

Species	Station	Period	Number Dead
Fishes			
Campostoma anomalum	6	1	3
	7	2	2
Hybopsis amblops	6	1	1
	7	1	1
Nocomis micropogon	6	1	1
Notropis coccogenis	6	1	1
Rhinichthys atratulus	6	1	1
Hypentelium nigricans	6	1	1
Reptiles			
Natrix sipedon	6	1	1
	7	1	1
	5	2	1
Birds			
Anas platyrhynchos	7	1	1

A total of 3,556 fish representing five families, 21 species, was collected during the survey (Table 2). Based on previous work (Masnik[1] from 4th order streams of the upper Clinch system, this represents about the maximum number of taxa expected. A total of 13,395 macroinvertebrates representing 93 taxa was collected (Table 3). No prior information exists on the benthic fauna of Plum Creek.

Diversity indices calculated for fish from Stations 3 - 7 showed great variability when compared to the control Stations 1 - 2. The range of variation for each station decreased, progressing downstream except for Station 7 which undoubtedly was affected by the sewage

TABLE 2. Presence or absence of fish taken from Plum Creek and Clinch River Stations, all periods.

Species	1	2	3	4	5	6	7
CYPRINIDAE							
Campostoma anomalum	x	x	x	x	x	x	x
Hybopsis amblops	x		x	x	x	x	x
Nocomis micropogon				x	x	x	x
Notropis coccogenis	x			x	x	x	x
Notropis cornutus	x	x	x	x	x	x	x
Notropis leuciodus							x
Notropis lirus					x		x
Notropis rubricroceus	x	x	x	x	x	x	x
Notropis telescopus	x	x		x	x	x	x
Pimephales notatus							x
Rhinichthys atratulus	x	x	x	x	x	x	x
Semotilus atromaculatus	x	x		x	x	x	
CATOSTOMIDAE							
Catostomus commersoni	x			x	x		
Hypentelium nigricans				x	x	x	
COTTIDAE							
Cottus carolinae	x	x	x	x	x	x	x
CENTRARCHIDAE							
Ambloplites rupestris	x		x	x	x	x	x
Micropterus punctulatus	x						
PERCIDAE							
Etheostoma blennioides							x
Etheostoma flabellare	x	x	x	x	x	x	
Etheostoma rufilineatum						x	
Etheostoma simoterum	x	x	x	x	x	x	x

treatment plant located on the Clinch River (Fig. 1). A slight reduction in the number of fishes was observed at all stations, periods 1 - 3 (Fig. 2). The large increase for period 4 was caused by the

TABLE 3. A list of macrobenthic invertebrate taxa collected from Plum Creek and the Clinch River, all periods.

NEMATODA

ANNELIDA
- Lumbriculidae
- Tubificidae

MOLLUSCA
- Gastropoda
  - Anculosa
  - Ferrissia
  - Fossaria
  - Goniobasis
  - Helisoma
  - Lymnaea
  - Physa
- Pelecypoda
  - Pisidium
  - Sphaerium
  - Villosa

CRUSTACEA
- Ispopda
  - Asellus
- Amphipoda
  - Gammarus
- Decapoda
  - Cambarus
  - Orconectes

INSECTA
- Ephemeroptera
  - Ameletus
  - Baetis
  - Caenis
  - Centroptilum
  - Cinygma
  - Cinygmula
  - Ephemera
  - Ephemerella
  - Heptagenia
  - Iron
  - Isonychia
  - Paraleptophlebia
- Ephemeroptera (cont.)
  - Pseudocloeon
  - Tricorythodes
  - Stenonema
- Odonata
  - Agrion
  - Argia
  - Boyeria
  - Enallagma
  - Gomphus
- Plecoptera
  - Allocapnia
  - Alloperla
  - Brachyptera
  - Hastaperla
  - Isoperla
  - Leuctra
  - Nemoura
  - Paragnetina
  - Perlesta
  - Phasganophora
- Hemiptera
  - Gerris
  - Rhagovelia
  - Sigara
- Megaloptera
  - Corydalus
  - Nigronia
  - Sialis
- Trichoptera
  - Cheumatopsyche
  - Chimarra
  - Glossosoma
  - Goera
  - Helicopsyche
  - Hydropsyche
  - Pycnopsyche
  - Rhyacophila
- Lepidoptera
  - Nymphula
- Coleoptera
  - Curculionidae
  - Dineutes
  - Dubiraphia
- Coleoptera (cont.)
  - Dytiscidae
  - Ectopria
  - Gyrinus
  - Helichus
  - Helocharos
  - Macronychus
  - Optioservus
  - Pelonomus
  - Peltodytes
  - Promoresia
  - Psephenus
  - Stenelmis
- Diptera
  - Anopheles
  - Antocha
  - Atherix
  - Chironomidae
  - Chrysops
  - Dixa
  - Hemerodromia
  - Hexatoma
  - Hydrellia
  - Limnephila
  - Ochthera
  - Palpomyia
  - Pilaria
  - Sciomyzidae
  - Simulium
  - Stratiomys
  - Tipula

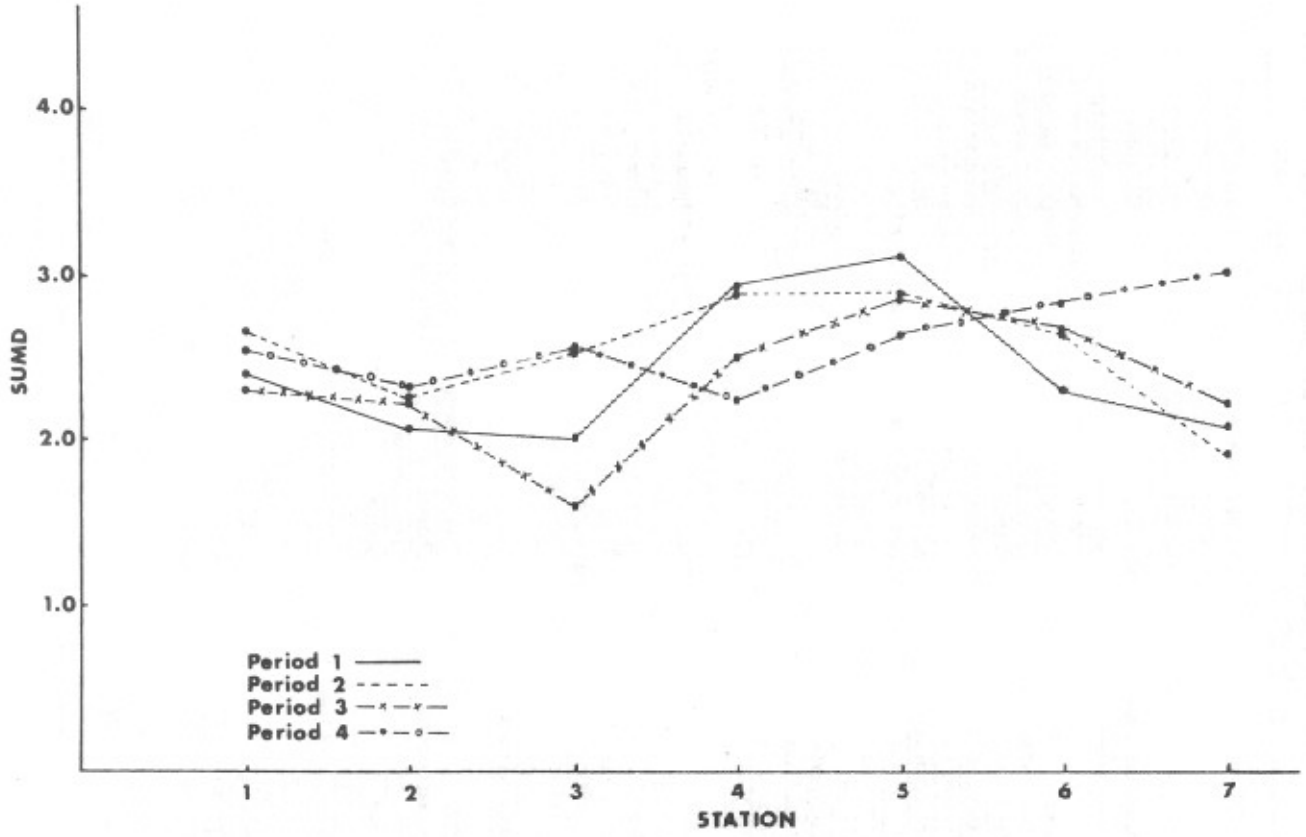

Figure 1

Diversity (SUMD) for fishes by station, calculated for each period.

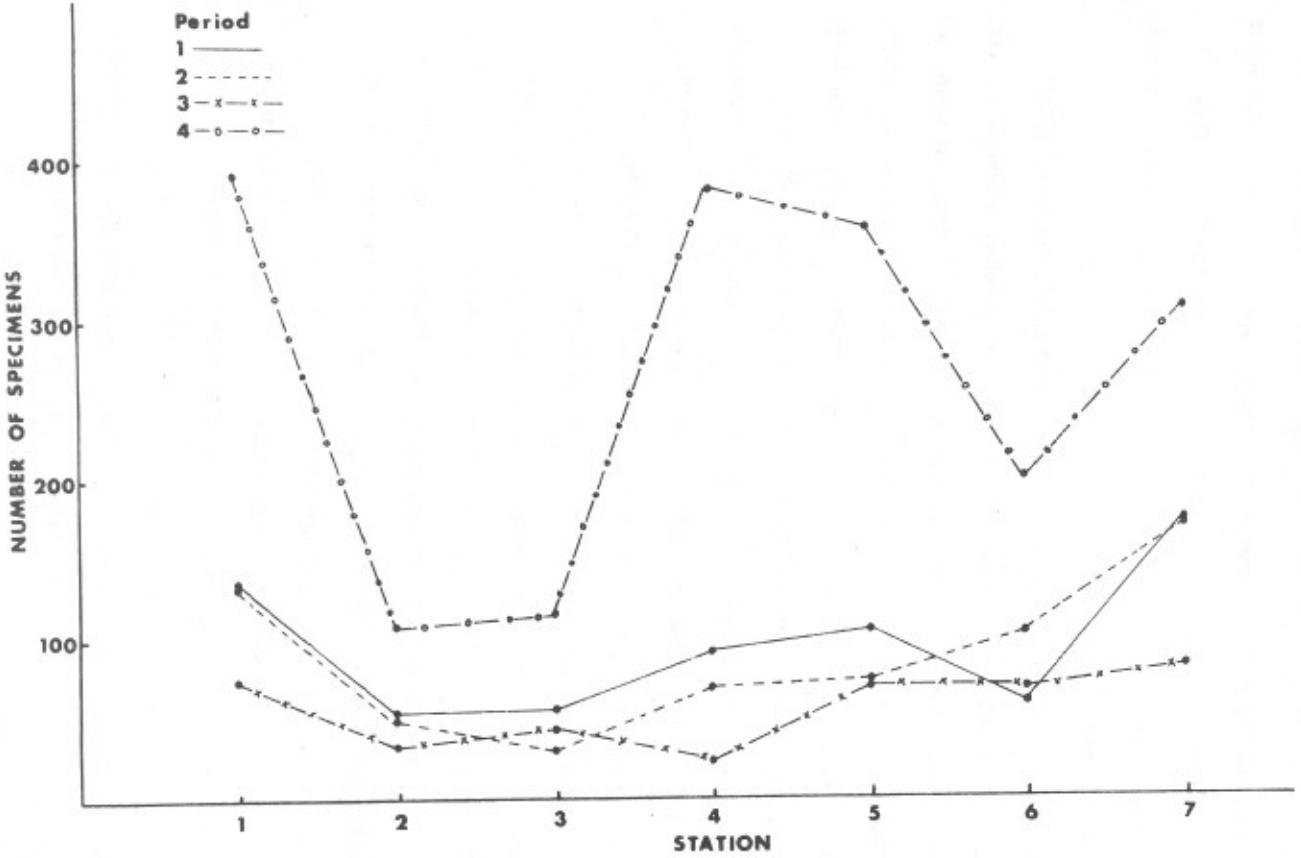

Figure 2
Number of fish collected by station for each period.

capture of a large quantity of juveniles spawned that spring (Fig. 2). The slight reduction in the number of fishes captured immediately after the spill conflicts with a similar study of a tank truck oil spill in a small stream where an estimated 90% immediate mortality was observed (Schultz and Tebo[5]).

Diversity indices calculated for the macroinvertebrates showed similar high levels of variability at stations located below the spill site (Fig. 3). The bottom was primarily composed of sand and muds, oft disturbed by cattle, with little riffle habitat present. It is interesting to note that Stations 4 and 6, both immediately downstream from the persistent straw dams which were erected to contain the oil, exhibited the highest levels of variability. Hoehn et al.[12] found the highest levels of hexane extractables at these stations. Apparently, the straw which was used to trap oil was never entirely removed and eventually settled to the bottom of the stream to act as a reservoir. The straw dam erected just above Station 7 was quickly washed away by the Clinch River. Little evidence of the dam was present during the first visit to the site by the authors. Analyses of the numbers of specimens and taxa collected were highly variable and provided no information on the effect of the oil on the benthic community.

The number of specimens of subbottom dwelling macroinvertebrates expressed by station for each time period (Fig. 4) showed a gradual reduction for the stations below the spill site. Oil contaminated soils as well as straw could have possibly been covered by sediments traveling as bed load from upper uncontaminated regions and subsquentl uncovered during periods of heavy rainfall to affect subbottom macroinvertebrates downstream.

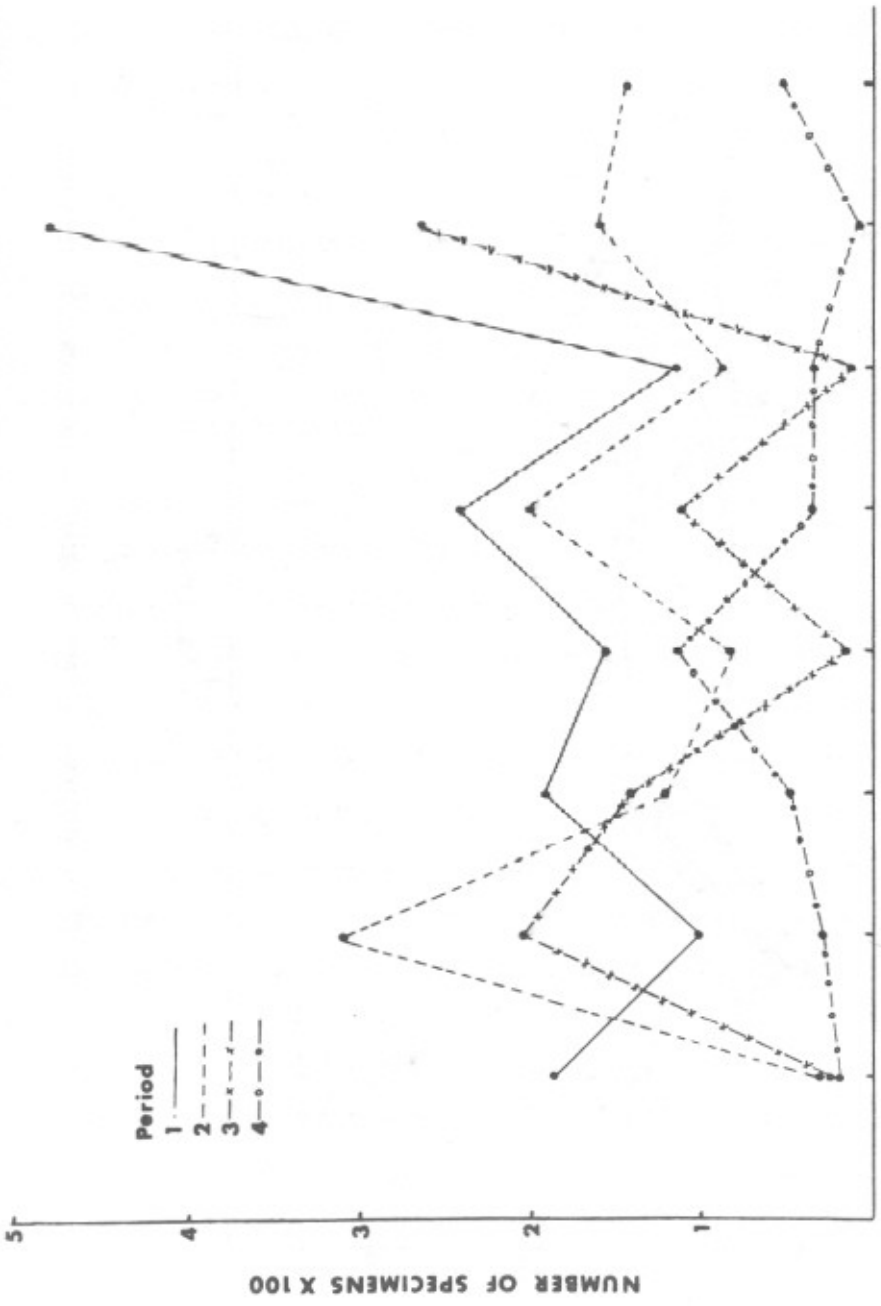

Figure 4 Number of subbottom community macroinvertebrates collected by station for each period.

The effects of fuel oil spills on the ecology of freshwater streams is poorly known. The Plum Creek oil spill resulted in immediate mortality of some taxa; however, significant mortality of macroinvertebrates and fishes was not observed. Slight reductions in population levels were found, however, it was concluded that the biological effect of the oil spill on Plum Creek and Clinch River was minimal.

The widespread practice of using straw booms to prevent the spread of the oil on the surface should be reevaluated. The leaching of oil fractions from the straw over long periods of time may exert a chronic detrimental effect on the environment. Rapid and complete removal of the straw dam following the elimination of the surface born oil fractions is recommended.

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REFERENCES

1. Wilber, C. G., "The Biological Aspects of Water Pollution," Charles C. Thomas, Springfield, Illinois (1969).
2. Swift, W. H., Touhill, C. J., Templeton, W. L., Roseman, D. P., J. Wat. Poll. Cont. Fed. 41 (1969).

3. Roeth, K. L. and Wood, T. S., Proc. 22nd Ann. Meet. Midwest Benthological Soc. (1974).

4. Rych, F., Jr. and Duchrow, R. M., Proc. 22nd Ann. Meet. Midwest Benthological Soc. (1974).

5. Schultz, D. A. and Tebo, L. B., Jr., Proc. 22nd Ann. Meet. Midwest Benthological Soc. (1974).

6. Bury, R. B., Calif. Fish and Game 58 (1972).

7. Wiebe, A. H., Trans. Amer. Fish. Soc. 65 (1935).

8. Smith, A. L., Can. Fish. Mar. Serv. Tech. Rept. 472 (1974).

9. Turnbull, J., DeMann, J. G. and Weston, R. F., Toxicity of various refinery materials to fresh water fish. Symp. Waste Disp. Petro. Ind., Ind. Eng. Chem. 46 (1954).

10. Blumer, M., Sanders, H. L., Grassle, J. F. and Hampson, G. R., Environment 13 (1971).

11. McKee, J. E., Calif. Wat. Poll. Cont. Bd., Publ. No. 16 (1956).

12. Hoehn, R. C., Stauffer, J. R., Masnik, M. T. and Hocutt, C. H., Environ. Letters 7 (1974).

13. Anonymous, "Tennessee and Big Sandy River Basins," Va. Dep. of Conserv. and Econ. Devel., Div. of Wat. Res. (1972).

14. Wilhm, M. T. and Dorris, T. C., BioScience 18 (1968).

15. Masnik, M. T., "Composition, longitudinal distribution and zoogeography of the fish fauna of the upper Clinch River in Tennessee and Virginia," Unpublished Doctoral Dissertation, Va. Poly. Inst. & St. Univ., Blacksburg, Va. (1974).

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