REPRINTED FROM
Vol. 22 • No. 2 • 1971

VIRGINIA JOURNAL OF SCIENCE

OFFICIAL PUBLICATION OF THE
VIRGINIA ACADEMY OF SCIENCE

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Received April 2, 1971

A Feasibility Study Using Conservation Webbing† as an Artificial Substrate in Macrobenthic Studies*

Abstract—A feasibility study was undertaken on a small woodland stream to test a new artificial substrate, Conservation Webbing. The purpose of the study was to evaluate how well the community collected on the substrate material mirrored the natural stream community. Four orders of aquatic insects were consistently found on the substrate material. Two of these orders, the Plecoptera and Diptera, showed a statistically significant increase in numbers with increasing time. The increase in Plecoptera was due to the development of two winter stonefly species, *Allocapnia rickeri* and *Allocapnia virginiana.* Certain species of aquatic insects were collected only from the artificial substrate. Conservation Webbing collected 63% of the fauna known to occur in the stream. It appears that the material would be suited for life history studies of certain species of aquatic insects.

Introduction

The community structure of benthic macroinvertebrates is frequently used to evaluate conditions in streams that receive agricultural, domestic or industrial effluents. Bottom organisms are ideal indicators of stream conditions because they have restricted habitat preference, low mobility, sufficiently long life cycles, and are quickly and directly affected by any deteriorating effluents which enter their environment.

The type of sampling equipment which is selected to collect macrobenthos in a given aquatic habitat depends upon the depth of the water and type of substrate. A Surber sampler is usually used to collect in shallow riffles while in deeper water one of several types of dredges may be used. Another technique of sampling which appears to be gaining wider acceptance is the use of artificial substrates.

Artificial substrates are structures which are placed in an aquatic habitat and left for a suitable period of time in order to allow colonization. Later the substrate is retrieved and the macrobenthic animals are removed and counted. Numerous studies have been made using artificial substrates and several types of material and different techniques have been tried. Concrete structures were among those first proposed (1) and subsequently used (2–4). While these substrates appear to provide a satisfactory surface and are not easily moved in swift water, they are cumbersome, subject to coverage with silt, and breakage. Moon (5) used wire trays covered with stone, sand or weeds from the natural habitat as an artificial substrate to study the migration of the invertebrate fauna in Lake Windermere. Macan (6) found that this technique, however, did not work well in streams. Hester and Dendy (7), and Arthur and Horning (8) designed a multiple plate artificial substrate sampler from masonite. Arthur and Horning (8) found that this type of artificial substrate worked quite well in illustrating the effects of organic pollution from a municipal area on the Mississippi River and a sugar beet refinery on the Minnesota River. The better types of artificial substrates described to date appear to be the "wire basket or box" type which can be filled with a variety of materials. Wene and Wickliff (9) used wire baskets containing coarse rubble. Henson (10) also described a sampler of similar design. Mason, Anderson, and Morrison (11) used cylindrical, welded wire, chromium plated "Bar-B-Q" baskets filled with 9.1 kg of limestone rocks. Hilsenhoff (12) constructed a cylinder (12.7 cm high and 21.7 cm in diameter) with a top and bottom of galvanized wire. The cylinder was then filled with 3.6 kg of limestone rocks and mounted on a patio block (30.5 × 40.7 × 5.7 cm). Hilsenhoff (12) also advanced the "wire basket" concept by designing a sampler-catcher in order that the substrate fauna could not escape as the sampler was being removed from the water.

The purpose of our feasibility study was to use the "wire basket" concept to evaluate the degree to which the macrobenthic species in a small freshwater stream would colonize Conservation Webbing, the artificial substrate. Witham, *et al* (13) tested Conservation Webbing in a marine habitat and

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† Trademark name of material. Available from the 3-M Corporation, New Business Ventures Division, St. Paul, Minnesota.

* This project was supported in part by the United States Department of the Interior, Office of Water Resources Research Grant A-031-Va; Public Health Service Research Grant RR 00016-08 from the National Institute of Health; and, the 3-M Corporation, New Business Ventures Division, St. Paul, Minnesota. The authors wish to acknowledge the assistance of students in Aquatic Ecology at Virginia Commonwealth University who made the summer collections.

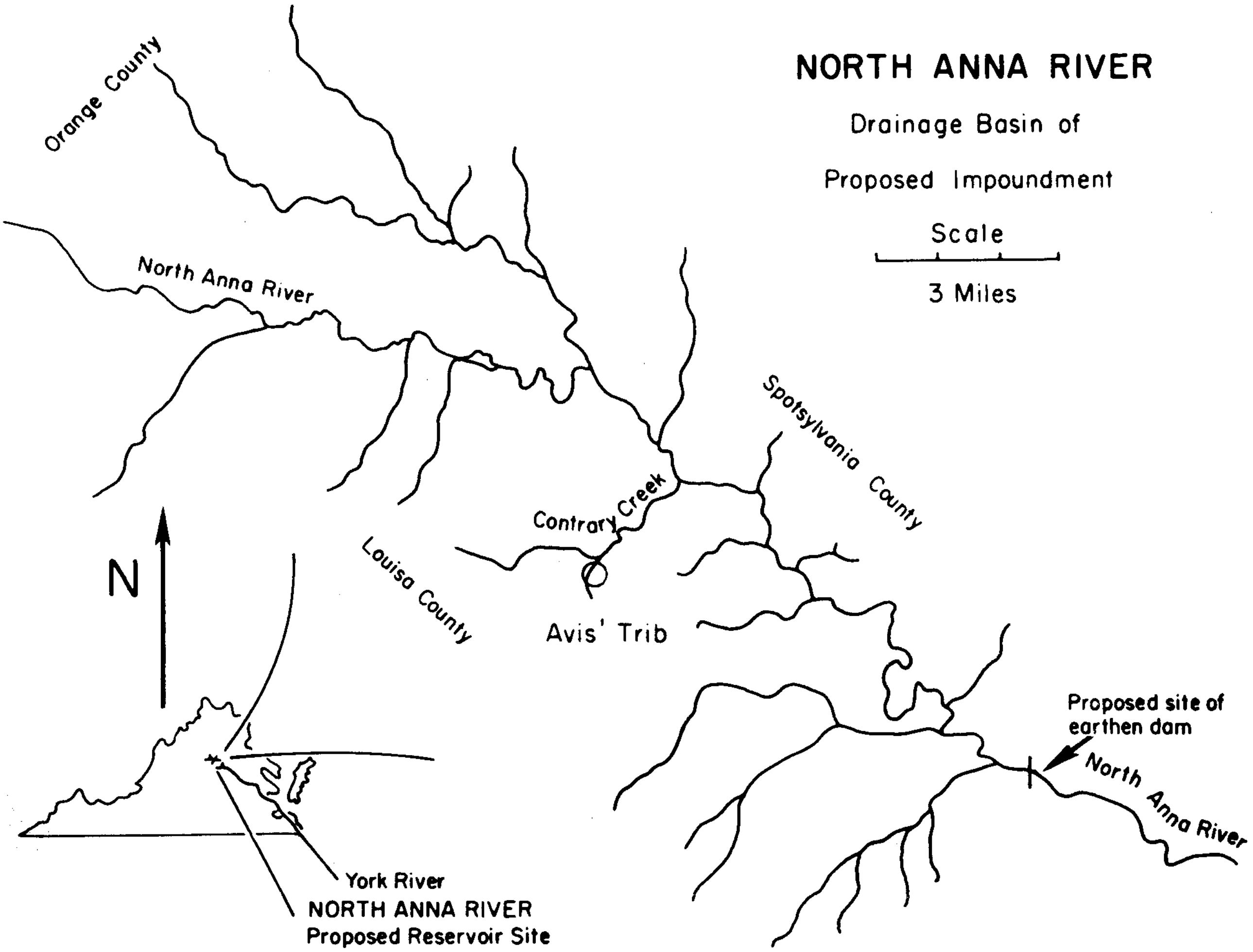

FIG. 1—Location of the study area (Avis' Trib) in the pre-impoundment area on the North Anna River.

found it highly effective in collecting postlarval forms of the spiny lobster, *Panulirus argus*.

Study Area

The study site was a tributary of Contrary Creek in Louisa County, Virginia (Fig. 1). Although Contrary Creek itself has been seriously affected by acid drainage, previous collecting on the tributary had shown that it supported a very diverse macrofaunal community. The small stream was dubbed Avis' Trib (after the junior author) by other students at the university and this name will be used hereafter in the paper for the sake of convenience.

Avis' Trib is a small woodland stream approximately 1200 feet long with a 5.4% grade from its origin to its junction with Contrary Creek. The banks are densely populated by birch although there are no trees growing in the stream bottom itself. The stream bed varies in width through the study area (approx. 200 feet) from 1 foot in some of the riffle areas to 6 feet in some of the larger pools. Flow is maintained by the natural drainage of water from the surrounding woodlands and fluctuated considerably during the study due to several rainy periods.

Methods and Materials

Physical and Chemical:

Temperatures were measured with a calibrated long-stem thermometer. The thermometer was placed in the water until equilibration was established. Turbidity values were made on a Bausch and Lomb Spectronic 20 and expressed in Jackson Units. Water samples for routine chemical analyses were collected with a sewage sampler. Oxygen was determined by the Alsterberg-Azide modification of the Winkler technique (14). Alkalinity values were determined by the potentiometric method after the establishment of a differential titration curve (14)

Biological:

Sampling the Natural Community

The natural benthic community was sampled with standard D-frame aquatic dip nets during June 1969 and 1970, and with the Surber sampler in October, 1969, at the initiation of the artificial substrate study. The 1969 dip net samples were taken near the entrance of Avis' Trib into Contrary Creek. In June,

FIG. 2—Placing the baskets containing the artificial substrates.

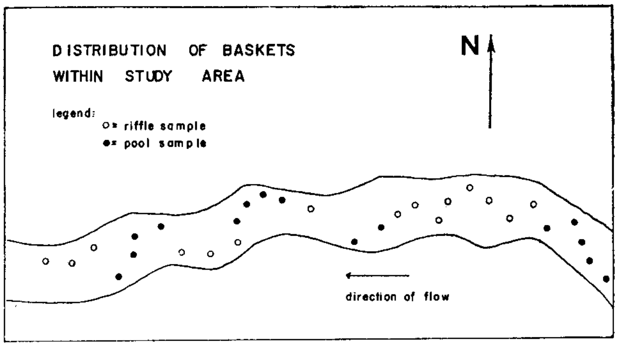

FIG. 3—Distribution of the baskets within the study area.

1970, after completion of the artificial substrate experiment, the samples were collected throughout the area where the artificial substrates had been previously placed. The square foot samples were taken before the upstream area was disturbed by the placement of the Conservation Webbing. All field collections were preserved in formalin, returned to the laboratory, washed onto a No. 30 mesh screen, and sorted under a magnified illuminator.

The Artificial Substrate

Conservation Webbing is a black thermoplastic mesh of nonwoven fibers pressed into sheets 3/8 to 1/2 inch thick. Four layers of the webbing were wired into the bottoms of 30, 9-inch square, aluminum baskets. The baskets were numbered and wired to stakes at intervals of four feet along the stream bed, distributed among riffle and pool areas (Fig. 2 and 3). The depth of water over the substrate material varied, but all were initially covered by an inch or more of water. Every week for ten weeks from October 21, 1969 to December 23, 1969, three numbers were chosen at random and the corresponding baskets were retrieved. The substrate mats and any detritus found in the baskets were put into isopropyl alcohol and taken back to the laboratory. Most of the organisms could be flushed out of the webbing with running water and trapped in a No. 30 mesh sieve. The rest were picked out with forceps using an illuminated magnifier. The organisms were then grouped according to order and counted.

Results and Discussion

Physical and Chemical Properties:

During the ten week period of study the water temperature changed 15 C. The initial temperature was 16 C (October 21) and the final temperature was 4 C (December 23). The lowest temperature recorded was 1 C on December 2 and the greatest changes occurred between October 21-28 with an observed drop of 8 C (16 C–8 C) and November 26–December 2 when a drop of 6 C was observed (7 C–1 C). During the first two weeks of December, ice formation was present along the margins of the stream.

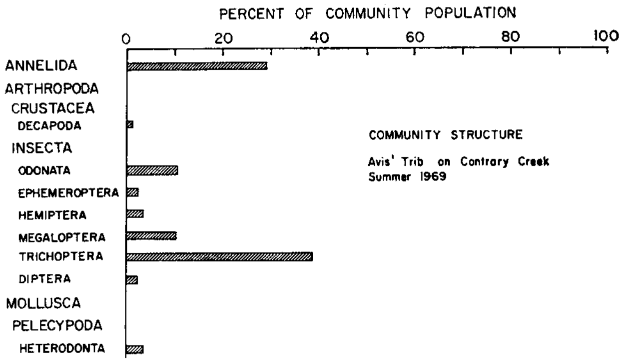

FIG. 4—Histogram of community structure on Avis' Trib, Summer, 1969.

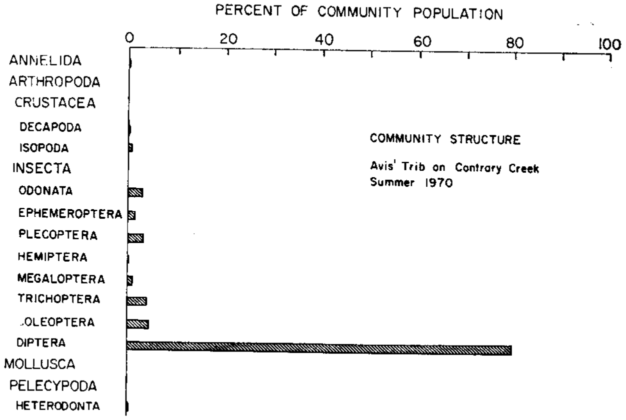

FIG. 5—Histogram of community structure on Avis' Trib, Summer, 1970.

Oxygen values varied between 7.2–11.7 ppm or 75 per cent to 102 per cent saturation. The water had a low alkalinity (11.0 ppm $CaCO_3$) and slightly basic properties (7.5 pH).

The Natural Community:

The community structure of Avis' Trib as evaluated by dip-netting was significantly altered between the two summers as a result of siltation due to basin clearing (Fig. 4 and 5). Clearing operations began in early 1970, and by June, 1970, all riffle and pool areas had completely filled with sand, and the extensive banks of leaf debris had been covered.

Prior to the basin clearing, one of the most abundant and diverse segments of the natural community collected with the dip nets was the Trichoptera. Other than *Hydropsyche* and *Cheumatopsyche,* the more abundant Trichopteran was *Anisocentropus pyraloides. Anisocentropus pyraloides* was particularly abundant along the edges of small riffle areas where a mat of birch leaves had accumulated. Wallace and Sherberger (15), in a life history study of this species, found that early instar larvae appeared to be associated with leaf drifts and late instars with logs and rocks. The representation of this order changed from 38.5% of the total community in 1969 to 4.5% in 1970 after the siltation.

The Plecoptera and Ephemeroptera were less well represented. The only Plecoptera collected was *Acroneuria xanthenes,* and specimens of *Epeorus humeralis, Stenonema ares, Ephemerella catawba,* and *Ephemerella deficiens* represented the Ephemeroptera. The representation of the Ephemeroptera changed little between the two summers. This order represented 3.0% of the community in 1969 and 2.0% in 1970. Strangely enough, the representation of the Plecoptera increased from less than 1.0% in 1969 to 4.0% in 1970.

The Odonata were well represented on Avis' Trib with specimens of *Cordulegaster fasciatus, Lanthus albistylus, Boyeria vinosa, Aeshna verticalis* and *Agrion maculatum* being collected. In 1969, the Odonata represented 10.5% of the organisms collected, but this dropped to 3.0% in 1970.

The Megaloptera also showed a drastic shift representing 10.0% of the community in 1969 but only 1.5% in 1970. *Sialis,* collected in 1969, was not collected in the artificial substrate zone in 1970. *Nigronia serricornis* was very abundant in Avis' Trib. Only one specimen of *Nigronia fasciatus* was collected and this specimen was taken from an artificial substrate. It was surprising to find that the dominant species of *Nirgonia* collected in this habitat was *N. serricornis* rather than *N. fasciatus* since the latter is restricted to cool woodland streams (16). However, *N. serricornis* is less discriminating in its choice of habitat (16) and more widely distributed than *N. fasciatus* (17). One specimen of the aquatic lepidopteran, *Nymphula* was also collected during the summer of 1970.

The greatest contrast seen in community structure between the two summers was in the representation of the Diptera. The representation of this order increased from 2.5% in 1969 to 80.0% in 1970. Several genera which were not collected during the 1969 summer were very common during the 1970 summer. The Chironomidae in the latter collection represented the major portion of the community in 1970. The more abundant specimens consisted of *Pentaneura, Polypedilum, Procladius,* and *Brillia flavifrons.* In addition to the Chironomidae, five different genera of Tipulidae were collected, but were represented mainly by *Tipula abdominalis.* Several specimens of *Simulium* were also collected. An increase in the Dipteran portion of the aquatic community was also noted by Aggus and Warren (18) who found that the Dipteran element "appeared to increase" after basin clearing in the Beaver Lake Basin in Arkansas.

The Coleoptera, like the Diptera and Plecoptera, increased slightly between the two sampling periods. Occupying less than 1% in 1969 the representation of the order increased to 4.5% in 1970. The Heterodonta, represented by *Sphaerium striatum,* decreased from 6.5% in 1969 to less than 1% in 1970.

Collections in October, 1969, with the Surber sampler in a riffle only, prior to initiating the artificial substrate experiment and before siltation from the basin clearing, showed that the standing crop of the bottom fauna community approached 14,920 animals/m^2. Larvae of Coleoptera (particularly Elmidae and Psephenidae) were the most abundant representing 35.5% of the total number of animals collected. The Diptera were represented mainly by members of the Tipulidae, principally *Hexatoma,* and represented 31.1% of the benthic community. The Trichoptera were the next most abundant and consisted mainly of *Cheumatopsyche* and *Hydropsyche.* The Trichoptera represented 20.0% of the population. The remaining components of the benthic community were represented less abundantly by the Ephemeroptera (*Stenonema ares*—6.6%), Odonata (*Cordulegaster fasciatus* and *Lanthus albistylus*—4.4%), Plecoptera (*Acroneuria xanthenes*—5.2%), Megaloptera (*Nigronia serricornis*—3.0%), Hemiptera (*Merragata*—0.8%), Mollusca (*Sphaerium striatum*—3.0%), and Oligochaeta

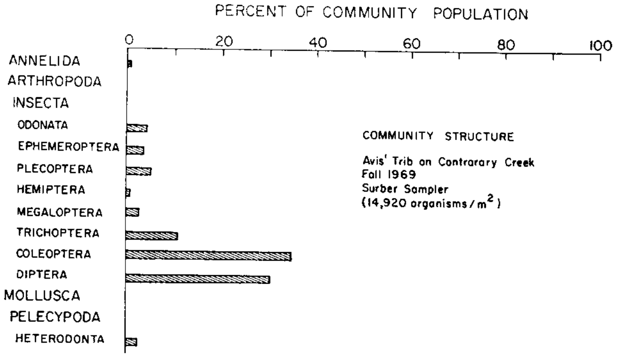

FIG. 6—Histogram of community structure on Avis' Trib, Fall, 1969.

(0.8%). Genera common to the pool areas were not represented in the square foot samples. A histogram of community structure is presented in Fig. 6.

The Community of the Artificial Substrate:

Table I summarizes the extent of colonization of the substrate by the macrobenthic community. Fig. 7 graphically represents the tabulated data. As Fig. 7 illustrates, only four orders of aquatic insects were consistently found on the artificial substrates during the ten week period of study. The degree to which the artificial substrate material collected representatives of the natural macrobenthic community can be summarized as follows: Group 1, organisms which showed a statistically significant increase in numbers with increasing time; Group 2, organisms present on the substrates throughout the study, but no increase in numbers in relationship to time; Group 3, organisms occasionally present on the substrate material; Group 4, organisms present in the natural stream community, but never collected on the substrate.

As Fig. 7 illustrates, the Plecoptera and Diptera were the only two orders of the macrobenthic community which showed a statistically significant increase in numbers with time. Additional time would be required to determine the population density at which these orders would have become stable. Other investigators (9, 11) have found that approximately 4-6 weeks are necessary for maximum colonization to be achieved. The Trichoptera and Ephemeroptera illustrated the second condition. Certain species of these orders were collected within a week and persisted at a very low density throughout the experiment. The Amphipoda, Megaloptera, and Coleoptera illustrated the third condition and probably entered occasionally to feed but not to establish residence. Members of the Annelida, Mollusca, Isopoda, Decapoda, and Odonata were never found in the baskets and exhibited the fourth condition. The Annelida, Mollusca, and Isopoda are not very abundant in this stream, but the Decapoda and Odonata are abundant.

We cannot offer any explanation at this time for the sudden drop in density on the seventh week. The only environmental factor which showed a significant change at this time was temperature. Within a week (November 26–December 2), water temperature dropped 6 C. There was no marked change in volume flow or physical disturbances within the study zone.

Conclusions about the colonization of the substrate are clouded by the fact that the baskets trapped leaves and other debris from upstream and caused enough damming to reduce the current and turn riffle areas into virtual pools (Fig. 8). If the water flow had not been affected, some of the taxa not collected may have eventually moved onto the substrate. Nearly all of the animals collected on the substrate were herbivorus. The substrate evidently offered a haven for the small, weakly swimming organisms and enough detritus was present on or within the substrate to satisfy food requirements. The relative lack of large predators in the baskets, even though the baskets were so constructed to allow even the larger crayfish to enter, and the implied extra protection offered by the substrate baskets, probably led to the marked abundance of some Plecoptera and Diptera.

We are also uncertain as to the preferential acceptance or rejection of the substrate material by the macrobenthos. Organisms would come into contact with the Conservation Webbing either through migration or drift. Whether or not there is a tactic response to remain on the substrate will require further investigation.

Fauna of the Substrate:

As Fig. 7 illustrates, the Diptera showed the greatest increase in numbers during the study period. The maximum number of animals (mean value for 3 substrates) collected during the ten week study was 89.33 animals on the ninth week. This represents approximately 1722.2 animals/m². The average density for the ten week period approximated 832.4 animals/m². The order consisted mainly of

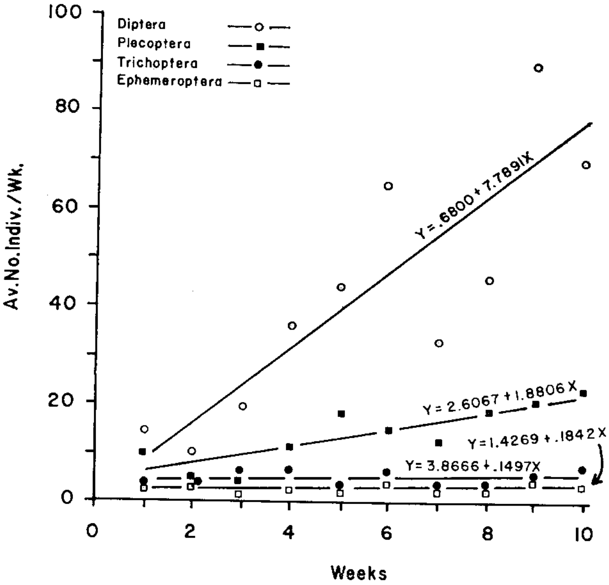

FIG. 7—The relationship between density and time of certain insect orders found on the artificial substrate.

TABLE I

Macrobenthic Species From Natural Habitat and Artificial Substrate; "X" Indicates Presence of the Species.

	Organisms	D-Frame Aquatic Dip Nets		Surber Sampler	Conservation Webbing
		1969	1970	1969	
PHYLUM:	Annelida				
CLASS:	Oligochaeta	X	X	X	X
PHYLUM:	Mollusca				
CLASS:	Pelecypoda				
	Sphaerium striatum	X	X	X	
PHYLUM:	Arthropoda				
CLASS:	Crustacea				
ORDER:	Decapoda				
	Cambarus	X	X		
ORDER:	Isopoda				
	Asellus	X			
ORDER:	Amphipoda				
	Gammarus				X
CLASS:	Insecta				
ORDER:	Odonata				
	Cordulgaster fasciatus	X		X	
	Lanthus albistylus	X	X	X	
	Aeshna verticalis		X	X	
	Boyeria vinosa	X			
ORDER:	*Agrion maculatum*	X	X		
ORDER:	Ephemeroptera				
	Epeorus humeralis	X			
	Stenonema ares	X	X	X	X
	Ephemerella deficiens	X		X	
	Ephemerella catawba	X			
	Paraleptophlebia mollis				X
	Ephemerella aestiva				X
ORDER:	Plecoptera				
	Acroneuria xanthenes	X	X	X	X
	Hastaperla brevis				X
	Allocapnia rickeri				X
	Allocapnia virginiana				X
ORDER:	Hemiptera				
	Corixidae	X			
	Gerris	X			
	Merragata			X	
ORDER:	Magaloptera				
	Nigronia fasciata				X
	Nirgonia serricornis	X	X	X	X
	Sialis	X			
ORDER:	Lepidoptera				
	Nymphula (-Paraponyx)		X		
ORDER:	Trichoptera				
	Cheumatopsyche	X	X	X	X
	Hydropsyche	X	X	X	X
	Dolophilodes	X	X		X
	Rhyacophila vibox	X	X		X
	Drusinus	X	X		
	Lepidostoma	X	X		
	Anisocentropus pyraloides	X	X	X	
	Heteroplectron americanum	X	X		
	Phylocentropus				X
	Psilotreta				X
ORDER:	Coleoptera				
	Psephenus herricki		X	X	
	Dryops		X	X	X
	Anchytarsus		X	X	X
	Agabinus			X	
ORDER:	Diptera				
	Tipula abdominalis		X	X	X
	Dicranota	X	X		X
	Limnophila		X		
	Hexatoma			X	
	Pseudolimnophila		X		
	Simulium	X		X	X
	Brillia flavifrons		X		X
	Corynoneura taris		X		X
	Procladius		X		X
	Polypedilum		X		X
	Pentaneura		X		X

FIG. 8—An illustration showing how the presence of the baskets changed the physical habitat.

representatives of the Tipulidae and Chironomidae with the latter being the more abundant. Several genera which were collected on the substrate in large numbers were completely absent from the collections made with the Surber sampler or dip nets. An analysis of the substrates showed no relationship between the composition of genera present and location of the substrate and/or time. *Corynoneura taris* and *Brillia flavifrons* were the most abundant genera present on the substrate material. The two most abundant Chironomid predators on the substrate were *Procladius* and *Polypedilum*.

The predominant species of stoneflies collected on the substrate were *Allocapnia virginiana* and *Allocapnia rickeri,* although a few specimens of *Hastoperla brevis* were also collected. These nymphs are herbivorous and are characteristically found where leaf detritus and/or diatoms occur (19, 20). The dominance of the winter stonefly group during the substrate study and absence during other sampling periods is to be expected since their period of activity is November through March (21). The mean standing crop of these species over the ten week period was 13 nymphs/substrate or $344.4/m^2$.

In addition to the species of caddisfly larvae collected in routine sampling, *Psilotreta* was the major form of caddisfly collected on the substrate and this genus was never taken by the other methods. *Psilotreta* has proven to be very abundant in other streams studied in the area, and it is presently unclear why its absence would be so conspicuous in routine collecting. Like *Psilotreta, Phylocentropus* was collected only on the artificial substrate, but occurred less frequently than *Psilotreta. Heteroplectron americanum, Drusinus* and *Lepidostoma* were the only genera collected by the other techniques which were never taken on the substrate material.

The three species of Ephemeroptera which were collected on the substrate were *Stenonema ares, Paraleptophlebia mollis,* and *Ephemerella aestiva.* The mean standing crop for these three species on the substrate was 471.6 individuals/m^2 for the ten week study period. The latter two species were another example of being collected *only* on the artificial substrate.

Summary

A feasibility study was undertaken to use a new artificial substrate material, Conservation Webbing, in an effort to determine how well the substrate community would represent the natural stream community. Approximately 43 species of macroinvertebrates were collected with D-frame aquatic dip nets and the Surber sampler in Avis' Trib on Contrary Creek. Since the artificial substrate collected approximately 27 species or 63% of the species living in the stream, it is obvious that one cannot interpret the data obtained from the substrate (diversity, community composition, or productivity) as being representative of the natural community. However, the substrate is ideally suited for life history studies of certain segments of the bottom fauna community since the substrate collects certain species of the macrobenthic community which were either not as abundant in ordinary routine sampling or missed completely. Clifford (22) pointed out that the life history approach of studying streams has not been applied extensively in North America. This substrate would facilitate this type of investigation. Another area of promising investigation is the fact that the Chironomidae are readily collected by the substrate material. Therefore, studies dealing with these organisms would be aided because they can be collected in large quantities with this material. It seems that Conservation Webbing would work well in lake studies.

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