RESEARCH TECHNICAL COMPLETION REPORT
PROJECT A-026-IDA

EFFECTS OF SILTATION AND COARSER SEDIMENTS ON DISTRIBUTION AND ABUNDANCE OF STREAM-INHABITING INSECTS

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PERIOD OF INVESTIGATION - July 1, 1969 to June 30, 1971

The work upon which this report is based was supported by funds provided by the United States Department of Interior, Office of Water Resources Research as authorized under the Water Resources Research Act of 1964.

Water Resources Research Institute
University of Idaho
September 1971

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ABSTRACT

This study was conducted to show the effects of sand and coarser sediments on the distribution and abundance of insects in Emerald Creek and the Middle Fork of the St. Maries River. Stream profile, substrate conditions, water chemistry and benthos were measured at seventeen permanent stations. Substrate simulation studies were conducted in an artificial stream in the laboratory to better define the relationship of substrate to five species of aquatic insects. Coarse and fine gravels with unimbedded cobble were preferred over fine sands and silt with partially or completely imbedded cobble by most insects. Habitats with few cobble and large amounts of sand and silt had low species diversities and biomass. Abnormal sediment production from rockhounding, dredge mining and roadbuilding cause adverse effects on the stream environment and insects.

INTRODUCTION

Increased concern for man's environment has resulted in the initiation of numerous studies in water pollution. It has been shown by several workers that many species of aquatic invertebrates prefer clean, unsilted streams. Coarse and fine gravel substrates with cobble are generally more productive than silted or sandy reaches, manifesting higher species diversity and biomass (Wene and Wickliff, 1940; Pennak and Van Gerpen, 1947; Mackay and Kalff, 1969). For this reason activity which introduces abnormal amounts of sediments into a stream and alters the nature of the streambed has come under increased scrutiny in recent years.

Because insects are represented in at least two trophic levels of stream communities, habitat alterations adversely affecting insects may have far reaching effects on other members of the stream community. For this reason, any activity, i.e., rockhounding, dredge mining, logging or agricultural practices, should be carefully examined before abnormal amounts of silt and sand are introduced. Rockhound and dredge mining operations on Emerald Creek in the past have introduced large amounts of these sediments, resulting in a greatly lowered insect population in major portions of the stream. Since the cessation of rockhound activities three years ago, some areas are flushing and show signs of recovering. Whether or not Emerald Creek, or any stream, can be returned to a near pristine condition once it has been polluted with silt and sand, is difficult to predict. More studies are needed to determine the capabilities of a stream to cleanse itself after the source of the silt is arrested. The objectives of this study were 1) to determine the effects

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REVIEW OF LITERATURE

Relatively few studies have been conducted on insect-substrate relationships; many of these have dealt with individual species rather than collective effects on community structure. Percival and Whitehead (1929) recognized seven substrate types and found certain species were consistently associated with specific substrates. The importance of substrates as a basic factor in determining the distribution of benthic fauna was emphasized by Tarzwell (1937) and Smith and Moyle (1944).

One of the first workers to employ actual sediment analysis in studying organism-substrate relationships correlated the distribution of midge larvae with five substrate particle size ranges (Wene, 1940). Linduska (1942) concluded that substrate types played a major role in determining the distribution of mayflies in Rattlesnake Creek, Montana. The benthic fauna associated with four types of substrates in a Colorado trout stream was described by Pennak and Van Gerpen (1947). Scott (1958) measured three dimensions of stones associated with caddisflies in the River Dean. A "cover fraction factor," which relates the size of stones and the portion of a sample covered with stones, has been suggested as an index of the density of benthic organisms by Scott and Rushforth (1959) and Scott (1960, 1966). The effects of a sand washing plant on stream fauna were studied by Bartsch (1960).

The distribution of bottom fauna in streams in the Tatra Mountains of Poland were correlated with varying substrate sizes by Kamler and Riedel (1960). Thorup (1966) studied organism-substrate relationships in several Danish Streams. Minshall (1968) found that variations in basic community types in Morgan's Creek, Kentucky, resulted from an interplay of substrate, flow, and temperature. Similar conclusions for other streams have been reached by Needham (1930), Ide (1935), Sprules (1947), Berg (1948) and others. Density was found by Mackay and Kalff (1969) to increase in the following substrate series: sand, gravel, stones, leaves and detritus. Biomass increased in the series: gravel, detritus, sand, leaves, and stones. The ecology of mayflies in the St. Maries River in Idaho was studied by Gilpin (1970) who found the distribution of many species to be influenced by substrate conditions.

Shelford (1914), the first to study substrate preferences in the laboratory, found riffle insects preferred stones and hard bottoms over sand. Recently, Cummins (1961, 1964, 1966) and Cummins and Lauff (1969) studied the microdistribution of several species of Plecoptera, Coleoptera and Trichoptera in the laboratory. A combination of laboratory experiments and substrate particle size analysis of field samples was utilized to determine the effect of substrates on two burrowing mayflies by Eriksen (1961, 1963a, 1963b, 1964a, 1964b, 1966). Madsen (1969) found the stonefly nymph, Brachyptera risi (Morton), preferred large substrate particles over small ones in an artificial stream.

Several workers have indirectly studied organism-substrate relationships by providing various substrates for colonization in the natural environment (Moon, 1940; Wene and Wickliff, 1940; Albrecht, 1955; Cianficconi and Riatti, 1957; Dendy, 1963; Brewer and Gleason, 1964; Coleman and Hynes, 1970).

STUDY AREA

This study was conducted on the East Fork and main stem of Emerald Creek and on the Middle Fork of the St. Maries River in northern Idaho (Fig. 1). Emerald Creek is extremely silt polluted due to private and commercial extraction of garnets. The upper Middle Fork of the St. Maries River, similar in physical and chemical characteristics to Emerald Creek with the exception of the silt burden, was selected as the control stream.

Emerald Creek

The East Fork of Emerald Creek arises in the Clearwater Mountains in Latah County and flows northeast through steep terrain until its confluence with the West Fork of Emerald Creek where it enters a broad valley. The main stem of Emerald Creek joins the St. Maries River five miles northwest of Clarkia, Idaho (Fig. 1). The entire stream is characterized by a low elevational gradient, dropping approximately 220 ft. in the ten-mile section involved in this study. The stream supports numerous riffles, runs and intervening pools (Plate 1E-G). The width varies from 11-35 ft; average riffle depth is 4-6 in. with pools 2-4 ft. deep during midsummer. The current velocity ranges from 1.3-2.3 ft./sec. Average summer discharge is 15.6 cu. ft./sec. for the main stem.

The adjacent coniferous forest is basically a *Thuja-Tsuga-Pachistima* association (Daubenmire, 1952). Marginal vegetation consists of alder (*Alnus* sp.) and various grasses, sedges and forbs.

The geology of the East Fork is the Pre-Cambrian belt series. The stream grades into Columbia River basalt below the confluence of the East and West Forks (Ross and Forrester, 1959).

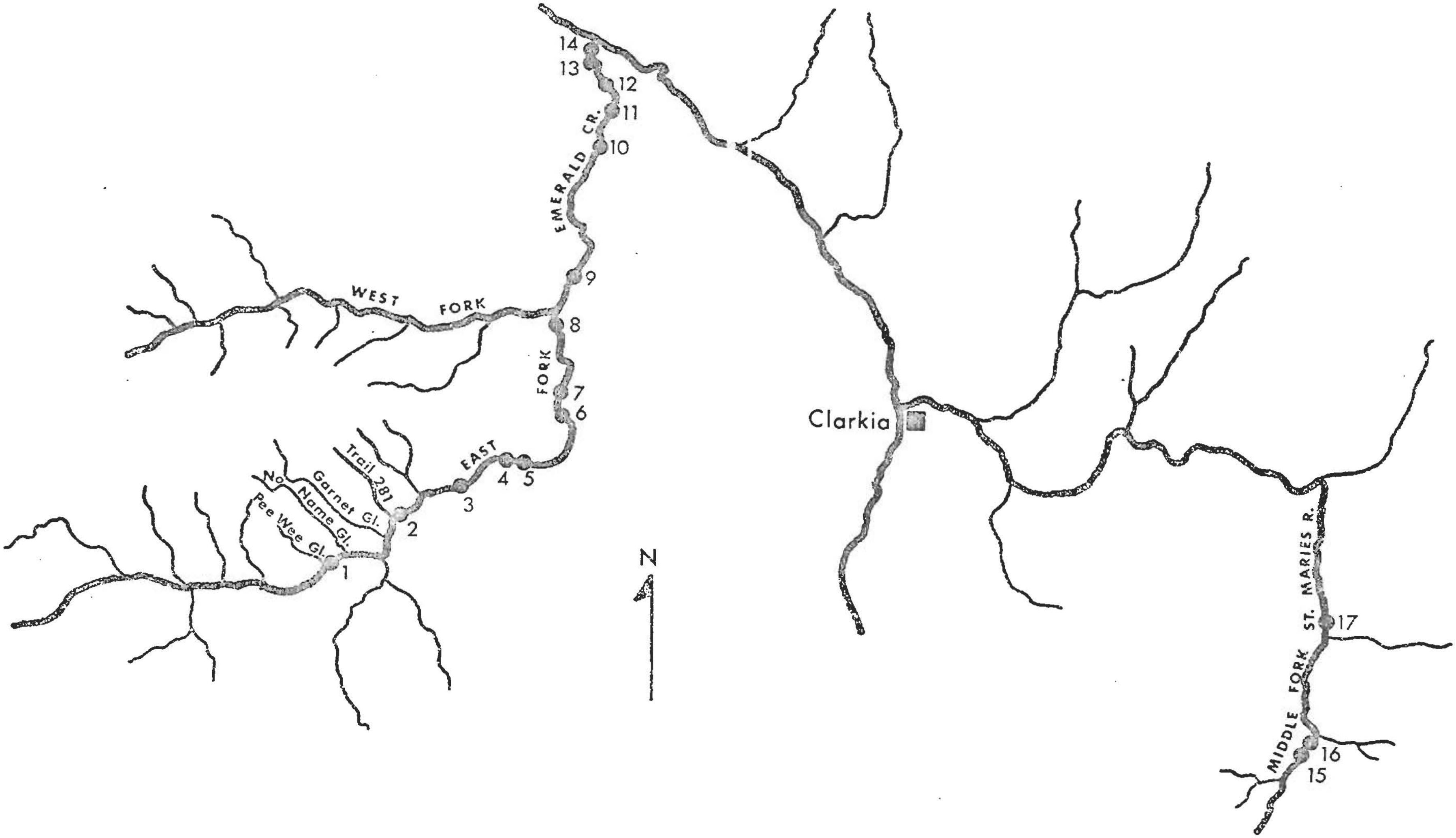

Figure 1. Emerald Creek and the Middle Fork of the St. Maries River in northern Idaho with stations identified by number.

The main stem of Emerald Creek, in contrast to the East Fork, has heavily sedimented runs and pools. A single high-water flow occurs in the spring of each year resulting in massive sediment displacements. As the water flow drops, these sediments are deposited in the flatter portions of the main stem, creating the heavily sedimented runs and pools.

The major uses of the drainage are timber, summer grazing, dredge mining and rockhounding. Sections of both the East and West Forks have been commercially dredged for garnet sand since 1959. Sunshine Mining Company acquired mining rights in 1964 and is currently commercially mining the area for garnet sand (Riegert, personal communication). The dredge site and jig plant are immediately below the confluence of the two forks (Plate 1C,D). Until 1969 the East Fork of Emerald Creek and several of its tributaries were major attractions for rockhounds who came in quest of gem-quality garnets. The Forest Service reported 20,000 visits to Emerald Creek during the summer of 1968. Digging occurred in the stream beds and banks with much of the gravel screened and washed in the streams.

During the winter of 1968-69 the Forest Service acquired 930 acres along the East Fork through a land exchange with the Sunshine Mining Co., Milwaukee Land Co. and Potlatch Forests, Inc. The Forest Service then closed Emerald Creek, Pee Wee Gulch, No Name Gulch, Garnet Gulch and Trail 281 to garnet digging. A commercial lease was let on 40 acres of a small valley floor along the East Fork two miles above the confluence with the West Fork. Digging is prohibited closer than 25 ft. to the creek. A settling pond has been built to retain fine sediments before discharge into the stream.

Middle Fork of the St. Maries River

The upper reach of the Middle Fork of the St. Maries River was used as a control. The stream arises on Hemlock Butte about ten miles southeast of Clarkia (Fig. 1). The headwaters are near pristine condition and relatively similar in size and discharge to the East Fork of Emerald Creek. The stream also flows through steep terrain, has a low to moderate elevational gradient and supports many riffles, runs and pools. The average summer discharge is 11.8 cu. ft./sec. and current velocities range from 1.2-1.6 ft./sec. The principle uses of the drainage have been summer grazing, logging and recreation.

The adjacent forest is primarily a *Thuja-Tsuga-Pachistima* association. Marginal vegetation is composed of alder (*Alnus* sp.), false hellebore (*Veratrum* sp.) and various grasses, sedges and forbs.

The geology of the Middle Fork is the Pre-Cambrian belt series. It lacks the mica-schist underlay which characterizes much of the East Fork of Emerald Creek.

Station Selection and Distribution

Fourteen stations were established on Emerald Creek and three on the Middle Fork of the St. Maries River (Fig. 1). Eight of the stations on Emerald Creek were above the confluence of the two forks and six below. Most stations were chosen to reflect conditions in riffles and runs which are normally the most productive portions of a stream. Two stations (stations 7 and 12) were established on Emerald Creek to represent silted pool conditions. Stations were distributed to reflect conditions above and below silt sources arising from commercial and private garnet removal. Station 9 was eliminated in late July, 1969 due to the diversion of the stream through the dredge site.

MATERIALS AND METHODS

A. Laboratory Study

Laboratory studies simulating field substrate conditions were conducted in an artificial stream (Plate 1A). The stream was built of 1/4 in. plexiglass in a sub-oval design, 63 in. long, 20 in. wide and 9 in. deep. Three-inch high plexiglass dividers divided the stream into two endzones and four 20 in. x 10 in. test plots (Fig. 2). A splashboard was located at the upper end of each of the two linear channels. Water entered the stream at these splashboards and created a nearly uniform velocity across the stream. The water flowed out of the stream through a circular three-inch outlet located at one end of the stream. It then passed through a charcoal-glass wool filter into a 32 gallon plastic container and was recirculated. A screen was placed over the stream outlet preventing the escape of insects. The continuous channel design of the stream allowed uninhibited movement of the insect population within the stream. Current velocity was regulated by two gate valves on a 1/4 horsepower centrifugal pump with a flow capacity of 30 gal./min. Two rectangular streams (56 in. x 8 in. x 5 in. and 54 in. x 12 in. x 7 in. respectively) were constructed of plexiglass to serve as holding areas for insects to be studied. Screens were used to divide the streams into sections for separation of insect species.

Water used in the artificial streams was collected in the field from the same stream insects were obtained. Temperature was maintained at approximately 5° C with a thermostatically controlled 3/4 horsepower refrigeration unit. Evaporation was minimized by covering the stream with two mil, clear polyethylene sheeting. Water velocity was maintained at 0.5 ft./sec.

except when fine sand was used as the substrate material, at which time velocity was reduced to 0.25 ft./sec.

Fluorescent lights with an automatic timer were used to create a day-night cycle corresponding with natural light conditions.

The species used in the artificial stream were the stonefly, *Pteronarcys californica* Newport, the mayfly, *Ephemerella grandis* Eaton, the caddisflies, *Brachycentrus* sp. and *Arctopsyche grandis* (Banks) and the dipteran *Atherix variegata* Walker. These were chosen because of their abundance, size, hardiness and acclimatization to the artificial stream. Some *P. californica*, *E. grandis* and *A. variegata* were reared to adults, and *Brachycentrus* sp. and *Arctopsyche grandis* were reared to the pupal stage. *Arctopsyche grandis* was the only species difficult to maintain in the stream because of its sensitivity to handling and tendency to collect on the outlet screen.

Specimens were collected in the field with a 26 in. x 36 in., 12-mesh hand screen with wooden handles. Insects were removed from the screen and transported to the laboratory in one-gallon containers immersed in a 32 gallon plastic container filled with stream water. Water temperature remained relatively constant during transit. Insects not used immediately were kept in the holding streams where water, temperature and light conditions similar to the test stream were maintained.

Three types of preference experiments, which allowed the test species to choose between combinations of various substrates and degrees of cobble imbeddedness, were conducted in the artificial stream. Surrounding substrate preference tests were conducted for large gravel (1-1/2 in.), small gravel (1/2-1/4 in.), coarse sand (1/4-1/8 in.) and fine sand (≤ 1/16 in.). In these tests cobble (average size 4 1/2 in.) was present and not imbedded in the substrate. The cobble imbeddedness tests consisted of unimbedded cobble and half-imbedded cobble in association with the four substrate classes previously mentioned. Cobble vs. no-cobble tests allowed insects to choose between the presence and absence of cobble on each of the substrates. In all tests, there were six cobble in each plot. Each test plot had a 1.5 in. layer of #10 commercially graded white sand over which the test substrate was placed. This sand was used as substrate in the endzones. Preliminary tests were conducted to determine if the insects distributed themselves equally among the test plots when all physical parameters were the same.

In the substrate preference tests large gravel was placed in sections A and B at one end of the stream, and a different substrate was placed in sections C and D at the other end (Fig. 2). In the cobble imbeddedness tests and cobble vs. no-cobble tests the substrate was the same in all sections. The cobble in sections A and B was not imbedded; cobble was either imbedded or absent in sections C and D for these tests respectively. This format was used after preliminary tests, in which physical parameters were maintained constant, indicated no preferences for one side of the stream or preferences for a plot immediately below a splashboard due to higher local turbulence.

Insects were distributed equally among the test plots at the beginning of each test. Species were tested together or separately depending upon their availability. The number of insects used in each test depended upon the availability of each species during the year. The introduced population of _P. californica_, _E. grandis_, _Arctopsyche grandis_ and _Atherix variegata_ varied from 35-65 individuals and the _Brachycentrus_ sp. population from 80-100 individuals. Each test lasted 48 hours encompassing two light-dark

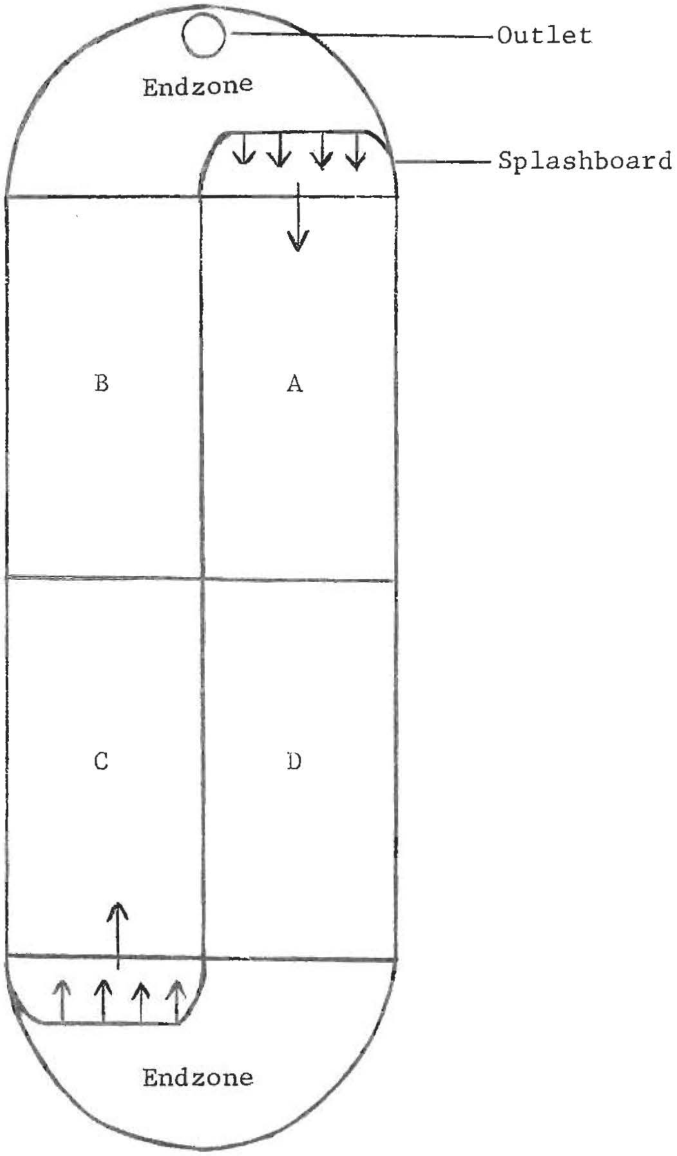

Figure 2. Artificial stream design showing test sections (A, B, C, D) and endzones.

periods. At the end of this time the four plots (A, B, C, D) were screened off and the individuals in each plot counted. Dead specimens and those recovered in the two endzones were not recorded. Each test was replicated three times, and a subjective minimum of 25 recovered specimens was considered necessary to validate each replication. An experiment was repeated if the minimum number was not recovered.

In addition to recording the number of insects in each stream quadrant, the number on cobble was also recorded and expressed as a percentage of the total number of insects in each plot. This was studied to determine if cobble played a more important role as the surrounding substrate decreased in size. All results were analyzed with the Chi-square test and are significant at the 1% level.

B. Field Study

Insect samples and physical evaluation of the streambed were taken once during each of the months of June, July and August of 1969 and 1970. Stations were permanently marked with metal stakes which also served as reference points for line transects.

Field Collecting Techniques

Bottom samples were taken with a modified Hess square-foot bottom sampler (Waters and Knapp, 1961). Samples were taken below a transect line at two to three foot intervals across the stream. The number of samples per station varied from three to eight and was influenced by the width of the stream and heterogeneity of the site. Collected material was preserved in 75% ethyl alcohol until sorted and identified. Taxonomic references by Flint (1960), Jensen (1966), Smith (1968) and Usinger (1968) served as the basis for identifications.

Station Morphometrics

The substrate was analyzed at one-foot intervals along the transect line using three criteria: 1) size of cobble, 2) imbeddedness of cobble, and 3) size of "surrounding substrate." Cobble was considered any rock 2 1/2 in. or larger. Imbeddedness was determined on a five-rank scale where 1 represented unimbedded cobble and 5 represented cobble completely or nearly completely imbedded (Table 1).

Table 1. Five-rank cobble imbeddedness classification.

1 - cobble unimbedded
2 - cobble 1/4 imbedded
3 - cobble 1/2 imbedded
4 - cobble 3/4 imbedded
5 - cobble completely or nearly completely imbedded

The "surrounding substrate" was the predominant material around the cobble or the material occurring in the absence of cobble. It was visually evaluated on a four-rank scale (Table 2).

Table 2. Four-rank "surrounding substrate" classification.

1 - 1 in. or larger
2 - 1/4 in. to 1 in.
3 - 1/16 in. to 1/4 in.
4 - less than 1/16 in.

Evaluation of "surrounding substrate" was based on only surface sediments and was not intended to elucidate deeper sediments.

A stream profile was obtained for each station at monthly intervals during the summer by recording depths at one-foot intervals from a leveled transect line. Height of the water column was also determined to compute stream discharge.

Average current velocity (ft./sec.) was determined with a Midget Current Meter[1] from readings taken at five-foot intervals across the stream at approximately the middle of the water column.

Water Chemistry

Water samples were taken at three stations on Emerald Creek and one on the Middle Fork of the St. Maries River and analyzed for dissolved oxygen, pH, total hardness, turbidity, alkalinity and dissolved iron using a Hach field testing kit[2].

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[1] Leupold and Stevens Instruments, Inc., Portland, Oregon.

[2] Hach Chemical Co., Ames, Iowa.

RESULTS

A. Laboratory Study

Surrounding Substrate Preference Tests

Most species preferred the coarser substrates and took refuge in interstices and under cobble (Table 3). *Brachycentrus* sp. preferred the tops of cobble and large gravel particles while *Atherix variegata* lived beneath the surrounding substrate at the sand-substrate interface. *Pteronarcys californica* and *Arctopsyche grandis* preferred large gravel over small gravel and coarse and fine sands (Fig. 3). *Ephemerella grandis* and *Brachycentrus* sp. preferred large gravel over coarse and fine sands but made no distinction between the large and small gravels. No preferences were shown among small gravel and coarse and fine sands except by *P. californica*, which chose small gravel and fine sand over coarse sand. *Atherix variegata* showed no substrate preference.

Cobble Imbeddedness Tests

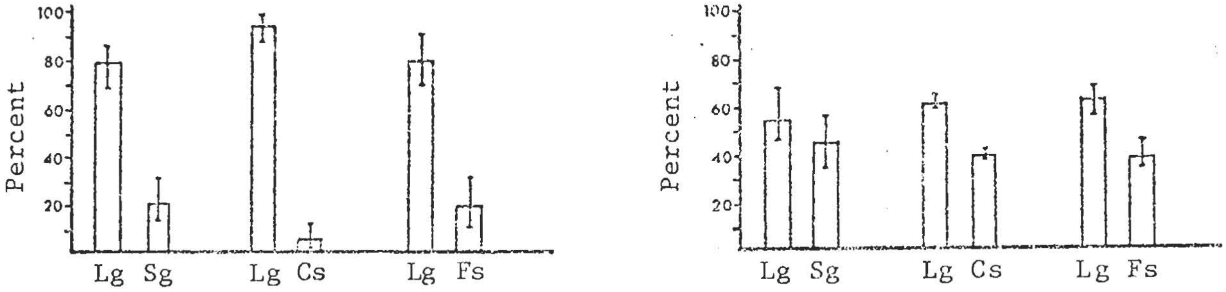
Pteronarcys californica and *Arctopsyche grandis* preferred fully exposed cobble over half-imbedded cobble in association with all four surrounding substrates (Fig. 4). *Ephemerella grandis* prefererred exposed cobble with surrounding substrates of small gravel and coarse and fine sands. *Brachycentrus* sp. and *Atherix variegata* preferred exposed cobble to half-imbedded cobble with a surrounding substrate of fine sand; however, no preferences were indicated for the two imbeddedness values in association with surrounding substrates of large and small gravels and coarse sand.

Cobble vs. No-cobble Tests

Pteronarcys californica, *Ephemerella grandis* and *Arctopsyche grandis* preferred cobble over no-cobble in association with the four surrounding

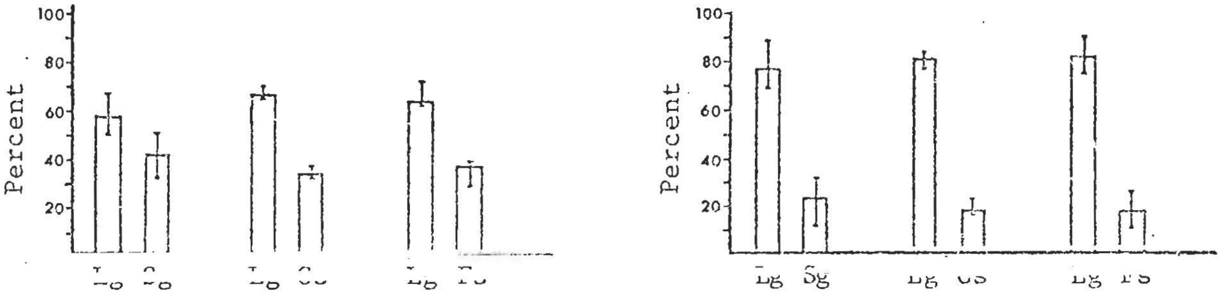
Table 3. Substrate preferences of five species of aquatic insects in an artificial stream.

Species	Substrate Preferences
Ephemeroptera	
Ephemerella grandis	coarser sediments; substrates with unimbedded cobble; found in substrate interstices and on undersides of cobble
Plecoptera	
Pteronarcys californica	large gravel (small gravel by small individuals); substrates with unimbedded cobble; found mostly in interstices under cobble
Trichoptera	
Brachycentrus sp.	large gravel; substrates with unimbedded cobble; attached to upper surfaces of cobble and large gravel
Arctopsyche grandis	large gravel; substrates with unimbedded cobble; found in interstices under cobble
Diptera	
Atherix variegata	no "surrounding substrate" preferences; unimbedded cobble if in fine sand



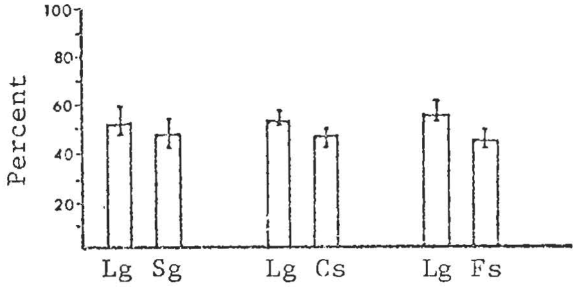
Pteronarcys californica

Brachycentrus sp.



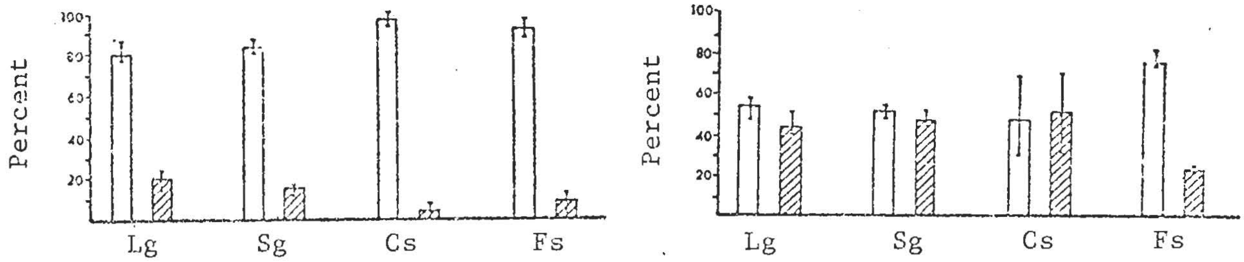
Ephemerella grandis

Arctopsyche grandis



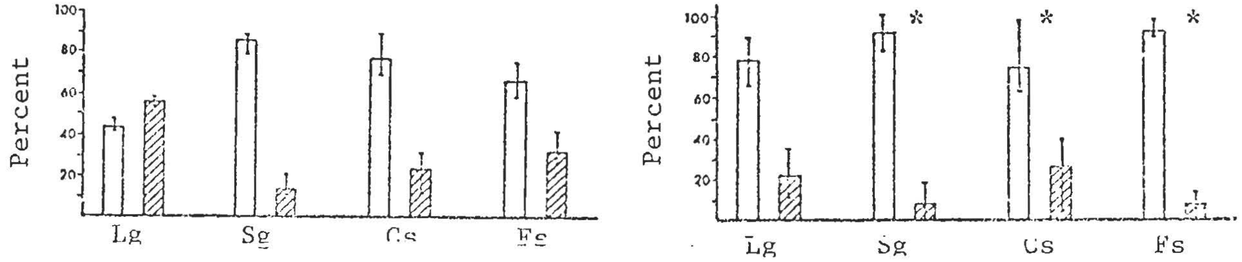
Atherix variegata

Figure 3. Average substrate preferences by five species of aquatic insects for surrounding substrates in an artificial stream.



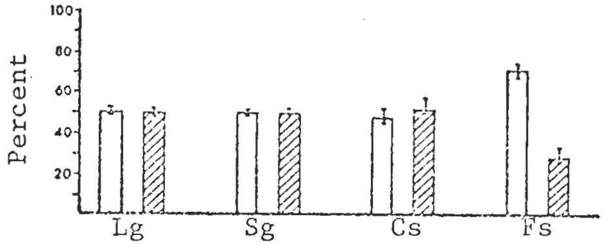
Pteronarcys californica

Brachycentrus sp.



Ephemerella grandis

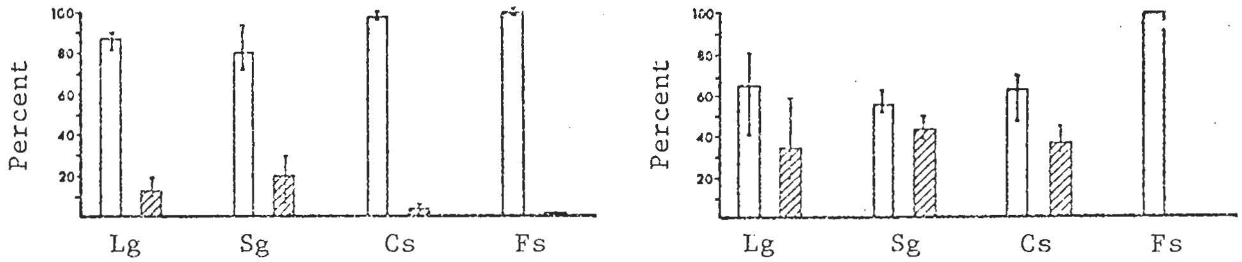
Arctopsyche grandis



Atherix variegata

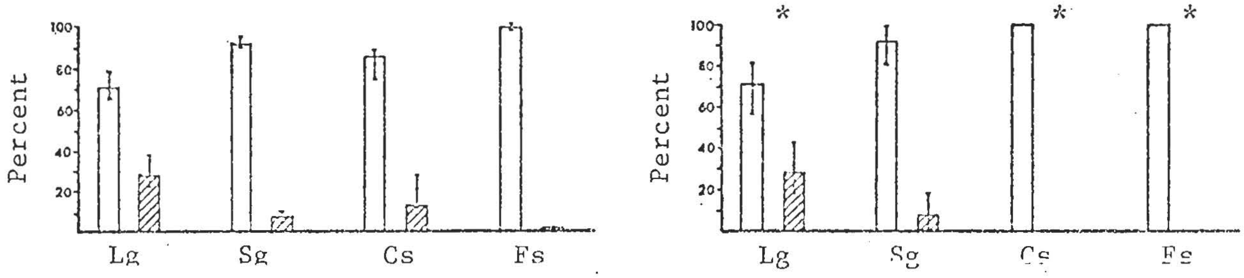
Figure 4. Average substrate preferences by five species of aquatic insects for substrates with unimbedded and half-imbedded cobble. Vertical lines show extremes in the experiments. Lg = large gravel; Sg = small gravel; Cs = coarse sand; Fs = fine sand. □ = unimbedded cobble; ▨ = half-imbedded cobble.

* Experiments with fewer than 25 insects recovered in at least one replication.



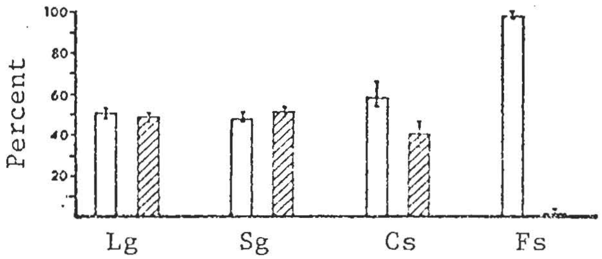
Pteronarcys californica

Brachycentrus sp.



Ephemerella grandis

Arctopsyche grandis



Atherix variegata

Figure 5. Average substrate preferences by five species of aquatic insects for substrates with and without cobble. Vertical lines show extremes in the experiments. Lg = large gravel; Sg = small gravel; Cs = coarse sand; Fs = fine sand. □ = with cobble; ▨ = without cobble.

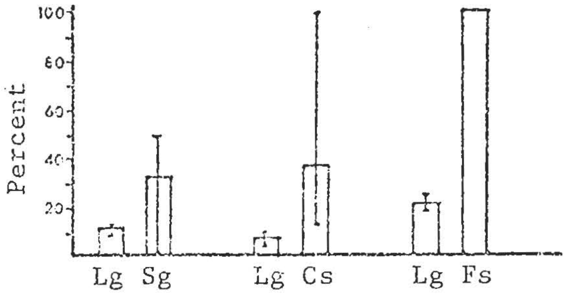
* Experiments with fewer than 25 insects recovered in at least one replication.

substrates (Fig. 5). *Brachycentrus* sp. preferred cobble over no-cobble in association with coarse gravel and fine sand; no preferences were indicated between cobble and no-cobble with intermediate size materials of fine gravel and coarse sand. *Atherix variegata* demonstrated a high preference for exposed cobble in association with a surrounding substrate of fine sand.

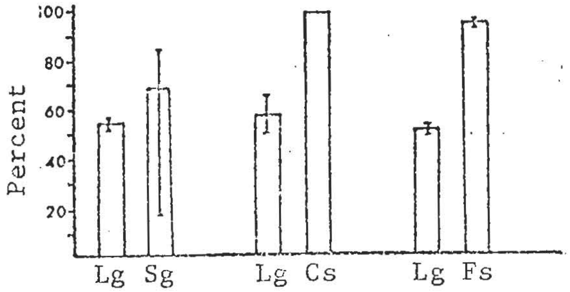
Microdistribution Study

In surrounding substrate preference tests all species except *Brachycentrus* sp. had a larger proportion of their population on cobble in association with fine sand than on cobble with large or small gravels (Fig. 6). No significant difference was found between the numbers of *Brachycentrus* sp. on cobble with a surrounding substrate of small gravel or with one of fine sand. *Atherix variegata* was the only species to show a higher proportion on cobble in association with fine sand than on cobble with a surrounding substrate of coarse sand. *Ephemerella grandis*, *Brachycentrus* sp. and *Arctopsyche grandis* had more insects on cobble with a surrounding substrate of coarse sand than on cobble in association with large gravel.

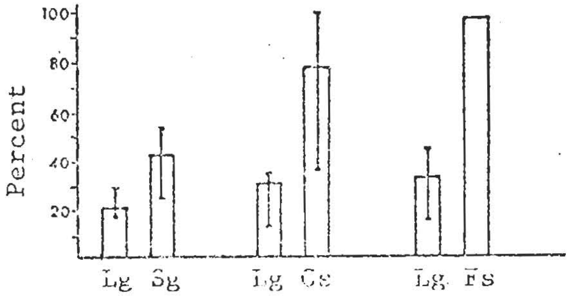
In cobble imbeddedness tests, *Pteronarcys californica*, *Ephemerella grandis* and *Atherix variegata* had a larger number of insects on unimbedded cobble in fine sand than on unimbedded cobble in large or small gravel (Fig. 7). More *Arctopsyche grandis* occurred on unimbedded cobble in fine sand than in large gravel. *Atherix variegata* had more insects on unimbedded cobble in silt than in sand. *P. californica* and *Arctopsyche grandis* had a higher proportion on the unimbedded cobble in coarse sand and small gravel than in large gravel. *P. californica* also had more individuals on unimbedded cobble in coarse sand than small gravel.



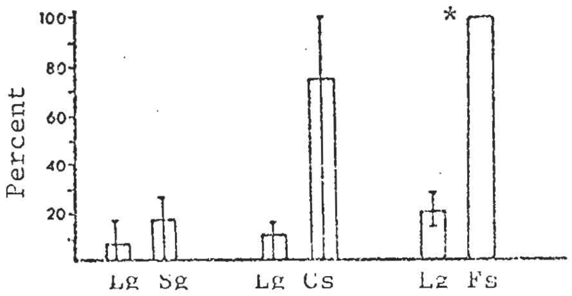
Pteronarcys californica



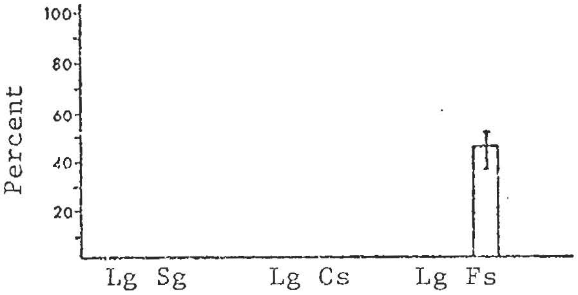
Brachycentrus sp.



Ephemerella grandis



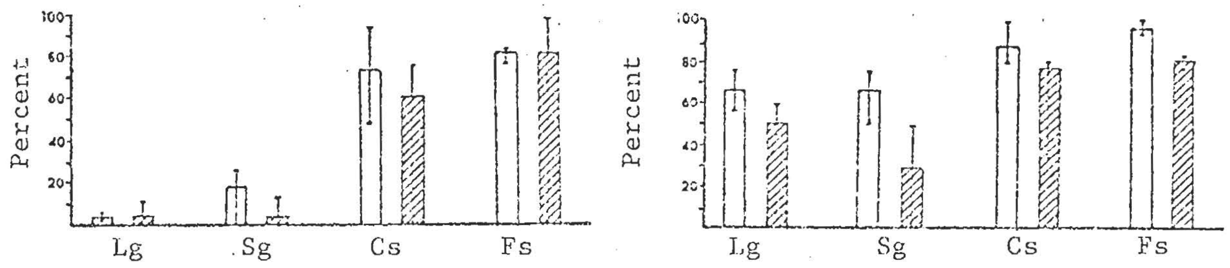
Arctopsyche grandis



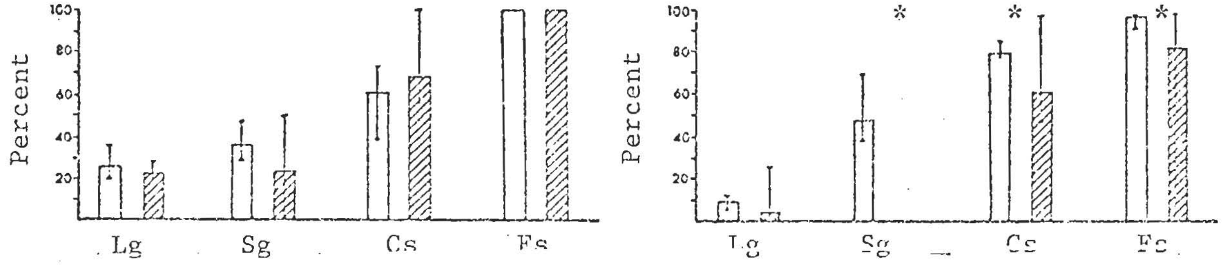
Atherix variegata

Figure 6. Average number of insects on unimbedded cobble during surrounding substrate preference tests expressed as a percentage of the total number found in each cobble-substrate combination. Vertical lines show extremes in the experiments. Lg = large gravel; Sg = small gravel; Cs = coarse sand; Fs = fine sand.

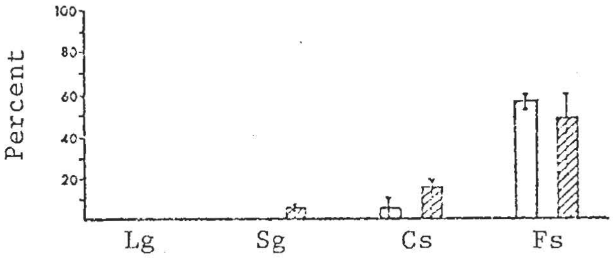
* Experiments with fewer than 25 insects recovered in at least one replication.



Pteronarcys californica   Brachycentrus sp.



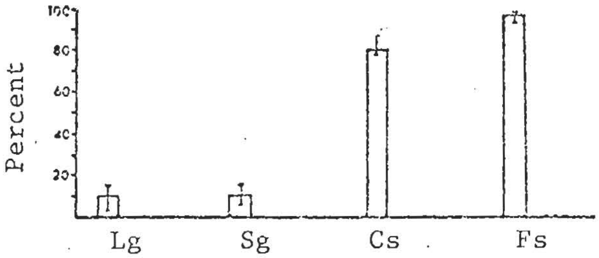
Ephemerella grandis   Arctopsyche grandis



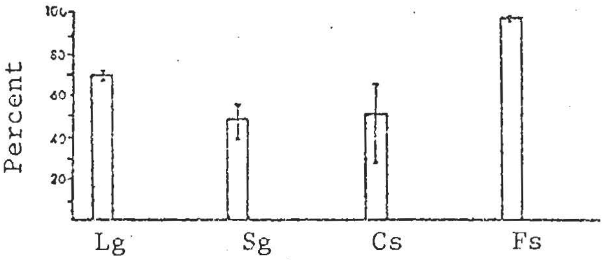
Atherix variegata

Figure 7. Average number of insects on cobble during cobble imbeddedness tests expressed as a percentage of the total number found in each cobble-substrate combination. Vertical lines show extremes in the experiments. Lg = large gravel; Sg = small gravel; Cs = coarse sand; Fs = fine sand. ☐ = unimbedded cobble; ▨ = half-imbedded cobble.

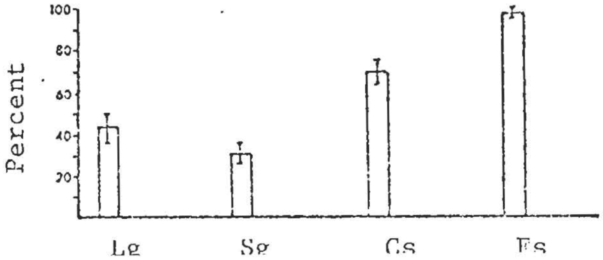
* Experiments with less than 25 insects recovered in at least one replication.



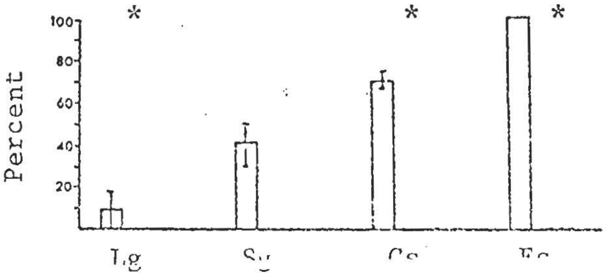
Pteronarcys californica



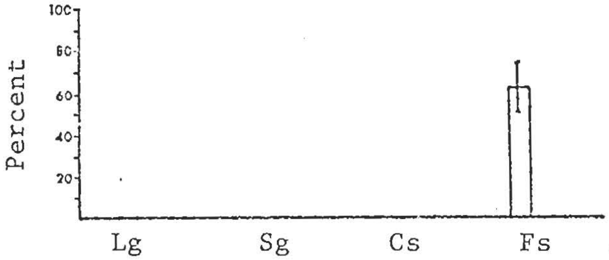
Brachycentrus sp.



Ephemerella grandis



Arctopsyche grandis



Atherix variegata

Figure 8. Average number of insects on unimbedded cobble during cobble vs. no-cobble preference tests. Vertical lines show extremes in the experiments. Lg = large gravel; Sg = small gravel; Cs = coarse sand; Fs = fine sand.

* Experiments with less than 25 insects recovered in at least one replication.

Also in cobble imbeddedness tests, all species except *Brachycentrus* sp. had more insects on imbedded cobble in fine sand than on imbedded cobble in large gravel (Fig. 7). *P. californica*, *Brachycentrus* sp. and *Atherix variegata* occurred more abundantly on imbedded cobble in fine sand than in small gravel; *Atherix variegata* had higher numbers on imbedded cobble in fine sand than on imbedded cobble in coarse sand. *P. californica*, *Arctopsyche grandis* and *Atherix variegata* were more prevalent on imbedded cobble in coarse sand than in large gravel.

In cobble vs. no-cobble tests, all species except *Arctopsyche grandis* had a higher proportion on cobble in fine sand than in small or large gravel (Fig. 8); however, no preference for cobble in fine sand over cobble in small gravel was noted for *A. grandis*. *Brachycentrus* sp. and *Atherix variegata* had more individuals on cobble in fine sand than in coarse sand. *P. californica* and *Arctopsyche grandis* preferred cobble in coarse sand over cobble in large gravel. More individuals of *A. grandis* were recorded on cobble in small gravel than cobble in large gravel.

B. Field Study

Station Morphometrics

Generalized descriptions and identifying characteristics for each station are given in Table 4. Cobble size ranged from 3.3-6.8 in., the larger cobble being found at the lower stations of Emerald Creek and at some upper stations of both Emerald Creek and the Middle Fork of the St. Maries River. All degrees of imbeddedness were found but cobble at most stations was 1/4 or less imbedded. Surrounding substrate size varied but averaged approximately 1/4 in. (Table 5).

Table 4. Station morphometrics of Emerald Creek and the Middle Fork of the St. Maries River in northern Idaho during June-August, 1969-1970.

Station	Size (yds.)	Description[1]	Bottom type	Ave. Depth (in.)	Ave. Current Speed (ft./sec.)
Emerald Creek					
1	4x10	moderate riffle	small plate-like cobble; moderately sanded	4.7	1.4
2	5x7	moderate riffle	small cobble-pebble-sand	5.0	1.6
3	7x15	moderate riffle	small cobble; lightly sanded	4.5	1.6
4	5x6	moderate riffle	bedrock-small cobble; little or no sand	5.3	1.8
5	13x25	slow riffle	small cobble; moderately sanded	3.6	1.2
6	4x10	moderate riffle	small cobble; lightly sanded	8.5	1.3
7	5x10	slow pool	small cobble; heavily sanded	10.0	0.9
8	6x20	moderate riffle	small cobble-pebble; lightly sanded	5.0	1.9
9	6x6	dried up due to stream diversion			
10	11x5	moderate riffle-run	small cobble-pebble; moderately sanded	3.3	1.6
11	8x20	fast riffle	boulder-small cobble; lightly sanded	5.8	2.0
12	7x25	slow pool	large cobble; heavily silted	12.0	0.9
13	8x6	fast riffle	large cobble; lightly sanded	6.0	2.1
14	12x20	slow run	large cobble; heavily sanded	9.0	1.1
Middle Fork St. Maries River					
15	5x10	moderate riffle	small cobble; little or no sand	5.5	1.5
16	4x5	fast riffle	small cobble-pebble-sand	6.3	2.0
17	5x6	fast riffle	small cobble; moderately sanded	5.3	2.0

[1] Slow = 1.2 ft./sec. or less, moderate = 1.3 to 1.9 ft./sec.; fast = 2.0 ft./sec. or more.

Table 5. Stations on Emerald Creek and the Middle Fork of the St. Maries River in northern Idaho ranked by increasing cobble size, imbeddedness and "surrounding substrate" size[1]. Vertical lines indicate groups of stations not differing at the 1% level based on Duncan's multiple range test.

Cobble Size		Cobble Imbeddedness[2]		Substrate Size[2]	
mean	station	mean	station	mean	station
3.33	6	1.28	6	3.38	14
3.46	2	1.30	4	3.28	7
3.50	15	1.38	15	2.78	12
3.58	5	1.40	2	2.58	1
3.71	8	1.43	13	2.48	5
3.85	16	1.50	1	2.46	2
3.96	3	1.53	11	2.43	16
4.05	10	1.53	3	2.41	10
4.13	1	1.55	10	2.41	17
4.40	4	1.56	5	2.36	13
4.61	17	1.81	16	2.08	15
4.71	13	1.86	17	2.06	11
4.77	7	1.91	8	2.01	4
5.57	12	2.27	12	1.98	3
6.10	14	2.40	7	1.93	8
6.88	11	4.86	14	1.91	6

[1] Means computed on data gathered during June-August, 1969-1970.

[2] Cobble imbeddedness and substrate means are represented by values explained in Tables 1 and 2.

Cobble size, imbeddedness and surrounding substrate size were tested for significant differences among stations at the 1% level using Duncan's multiple range test. For each of these characteristics stations fell into several statistically similar groups (Table 5). There were eight such groupings of stations based on cobble size with station 11 significantly different from all other stations. With respect to cobble imbeddedness, station 14 differed significantly from the other stations which fell into five groups. Only four groupings were apparent with respect to substrate size.

Water Chemistries

Water chemistry analysis results for dissolved oxygen, dissolved iron, turbidity, pH, alkalinity and total hardness are given in Table 6. Parts per million of dissolved iron in the lower portion of Emerald Creek showed an increase of up to 100% over the concentration in the upper reaches of this stream. Values for dissolved iron, alkalinity and total hardness in the St. Maries River were only one-half to two-thirds of those for Emerald Creek. Hydrogen ion concentration (pH) dropped 0.6-0.7 units in both streams between 1969 and 1970.

Benthic Fauna

One hundred and seventeen species representing nine orders of insects were found in Emerald Creek and the Middle Fork of the St. Maries River (Table 11 in Appendix). Emerald Creek had 101 species and the Middle Fork of the St. Maries River had 86. Only 70 of these species were common to both streams. The distribution and ranked abundance of these insects, collected during June, July and August of 1969 and 1970, are shown in Tables 7 and 8 respectively. Twelve of the principal species are listed

Table 6. Water chemistry analyses for June-August, 1969-1970 of Emerald Creek and the Middle Fork of the St. Maries River in northern Idaho.

Water Chemistry Tests	Emerald Creek						Middle Fork of St. Maries River	
	Station 1		Station 8		Station 14		Station 15	
	1969	1970	1969	1970	1969	1970	1969	1970
Dissolved oxygen (ppm)	9.7	10.0	8.7	9.7	9.3	10.0	10.0	10.3
Dissolved iron (ppm)	0.3	0.2	0.4	0.4	0.4	0.4	0.3	0.2
Turbidity (JTU)	5.0	0	5.0	0	3.3	6.7	0	1.3
pH	8.3	7.5	8.4	7.8	8.4	7.9	8.1	7.5
Alkalinity (ppm $CaCO_3$)	27.3	28.3	23.3	26.7	25.0	23.3	18.3	18.3
Total Hardness (ppm $CaCO_3$)	15.0	15.0	15.0	13.3	17.5	18.3	8.3	10.0

Table 7. Distribution and abundance[1] of insect species in Emerald Creek and the Middle Fork of the St. Maries River in northern Idaho during June, July and August of 1969.

Species	Stations															
	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17
EPHEMEROPTERA																
Ameletus sp.	r	c	c	r	r	r		r	r	r		r	r	r	r	c
Baetis bicaudatus	r	r	r		r	r			r	r		r	r		r	c
Baetis tricaudatus	c	a	a	a	a	a	r	a	a	a	r	a	r	c	c	a
Centroptilum sp.	r	r	r	r	r	r	r	r	r		r		r			
Cinygmula sp.	r	r	r	r	r				r	r				c	c	r
Epeorus albertae		r	c	c	r	c		c	c	c		r				
Epeorus longimanus			r		r	r		r	r	c		r		r	r	c
Ephemerella coloradensis														c	c	r
Ephemerella doddsi														r	c	r
Ephemerella edmundsi		r												r	c	r
Ephemerella flavilinea		r	c	r	c	r		r	c	c		r		r	r	r
Ephemerella grandis	r	r	r	c	c	r		r	c	r		r		r	c	c
Ephemerella hecuba	r	c	c	c	c	r		r	a	r	r		r			r
Ephemerella hystrix															r	r
Ephemerella inermis	r	r		r						r				r	r	r
Ephemerella margarita	r	c	a	a	a	a		c	c	r		r			r	
Ephemerella spinifera	r													r		
Ephemerella teresa	c	a	c	r	c	c		r	c	a		c	r	c	r	c
Ephemerella tibialis	c	r	r	r	r	r		r	r					a	a	a
Heptagenia criddlei		r	a	c	a	a		a	a	c	r	r				r
Paraleptophlebia bicornuta		r	c	r	r	c		r	r		r					
Paraleptophlebia debilis	r	r	r	r		r	r			r						r
Paraleptophlebia heteronea	r	r	r		r	c		r		r		r		r		
Pseudocloeon sp.			r													
Rhithrogena robusta										r		r	r	r	r	
Tricorythodes minutus				r	r	c	r	r	a	r	r	r	r			
ODONOTA																
Agrion aequabile							r									
Argia sp.						r										
Ophiogomphus severus						r			r	r						
PLECOPTERA																
Acroneuria californica			r	r	r	r		c	r			r		r	c	r
Alloperla sp.	c	c	c	r	c	r		r	r	r	r	c	r	r	c	r
Arcynopteryx sp. A		r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
Arcynopteryx sp. B		r	r	r	r	r		r	r	c	r	c	r			
Isogenus sp.	r	r	c	r	r	r		r	r	r			r	c	c	c
Isoperla sp.				r		r		r								
Leuctra sp.	r	r	r											r		
Nemoura sp.	r	r	r					r						r	r	r

[1] r = rare (1-25 insects); c = common (26-100 insects); a = abundant (> 100 insects).

Table 7. Continued.

Species	Stations															
	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17
Paraperla sp.														r	r	r
Peltoperla sp.																r
Pteronarcella sp.									c	r		r		r		
Pteronarcys californica		r	r			r		r	r	r		r				
HEMIPTERA																
Corixidae							r						r			
NEUROPTERA																
Sialis sp.							r									
COLEOPTERA																
Brychius sp.	r	r	r	r												
Cleptelmis ornata	c	a	r	r	r	r		r	r	r	r			r	r	r
Dubiraphia sp.							r									
Helophorus sp.		r														
Heterlimnius corpulentus	c	r		r	r	r		r	r	r		r		a	a	a
Lara sp.	r							r								r
Microcylloepus sp.												r				
Narpus concolor	r	r			r									r	r	r
Optioservus seriatus	r	a	a	a	a	a	c	a	a	a	r	a	r	r	c	a
Oreodytes sp.	r	r	r	r	r	r	r	r		r	r	r	r	r		
Zaitzevia parvula	r	c	r	c	c	c	r	c	c	r	r	r	r	r		
TRICHOPTERA																
Agraylea sp.	r	r	r	r	r	r		r				r	r			r
Amiocentrus sp.																r
Apatania sp.		r	r	r	r	r										r
Arctopsyche grandis	r	r														r
Brachycentrus sp.		r	r						c	a		a	r			r
Cheumatopsyche sp.					r	r	r	a	r	r		c				
Dicosmoecus sp.	r													r	r	r
Glossosoma sp.			r	r	r	r		r	r	r		r	r	r	r	r
Goera sp.								r								
Hydropsyche sp.		r	r	r	r	r		r		a		a	r			r
Hydroptila sp.	r															
Lepidostoma sp.	r	r	r	r	r	r	r									
Micrasema sp.	a	a	r	r	r		r		r	c		r		c	r	c
Neophylax sp.	r	r		r										r		
Neothremma sp.																r
Oxyethira sp.			r													
Parapsyche sp.															r	r
Rhyacophila acropedes								r						r	r	
Rhyacophila angelita								r						r	r	r
Rhyacophila rotunda																r
Rhyacophila tucula															r	r
Rhyacophila vaccua																r

Table 7. Continued.

Species	Stations															
	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17
Rhyacophila vagrita				r											r	r
Rhyacophila verrula	r														r	r
Wormaldia sp.	r		r	r	r	r		c	r	c		r		r		
LEPIDOPTERA																
Paragyractis sp.										r						
DIPTERA																
Ablabesmyia sp.	r	r	r	r	r	r	r	r			r			r	r	r
Antocha monticola		r	r	r	r	r		r	r	r		r	r	r	r	r
Atherix variegata	r	c	r	r	r	r	r	r	r	r		r				
Cardiocladius sp.	c	c	c	c	r	r	r	r		r	r	r	a	a	a	c
Cricotopus sp. A	c	a	r	r	c	r		r	r	r		r				r
Cricotopus sp. B	r	r	r	r	r	r		r				r		r	r	r
Dicranota sp.		r	r					r						r	r	
Empididae, sp. A	c													c	c	c
Empididae, sp. B		r	r		r									r	r	r
Empididae, sp. C				r	r				r			r				
Forcipomyia sp.								r						r		
Limnophila sp. A	r	c	r	r	c	r	r	r	r	r	c	c	c	r	r	r
Limnophila sp. B		r	r		r		r					r	r	r	r	
Micropsectra sp.	r	c	c	r	r	r	r	r	r		r	c	r	c	r	r
Nemotelus sp.				r												
Palpomyia sp.	r						r								r	r
Prosimulium sp.	r	r	r						r	r		r		r	r	r
Simulium sp.	c	c	r		r			r	r	r		r		r	r	r
Tabanus sp.					r		r	r			r					
Tipulidae, sp. B														r		r
Tipulidae, sp. C				r	r	r		r								
Tipulidae, sp. D	r	r														
Tribelos sp.	r	r		r	r	c	c				r			r		
Zavrelia sp.	r	c		r	r	r		r	r				r			r

Table 8. Distribution and abundance[1] of insect species in Emerald Creek and the Middle Fork of the St. Maries River in northern Idaho during June, July and August of 1970.

Species	Stations															
	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17
EPHEMEROPTERA																
Ameletus sp.	r	r	r	r	r	r	r		r	r			r	r	r	r
Baetis bicaudatus				r					r	r	r	c		c	r	c
Baetis tricaudatus	c	c	c	c	c	c	r	c	a	c	r	c	c	c	c	c
Centroptilum sp.			r		r	r	r				r		r	r		
Cinygmula sp.	r	c	r	r	c	c	r	r	c	r	r	r		c	a	r
Epeorus albertae		r	c	c	c	c	r	a	a	c	r	c	r	r	r	r
Epeorus grandis														r		
Epeorus longimanus		r	r		r		r	c	c	c		c		c	c	c
Ephemerella coloradensis														c	c	r
Ephemerella doddsi														r	r	r
Ephemerella edmundsi	r	r												r	r	r
Ephemerella flavilinea		c	c	c	a	r	r	r	c	c	r	r		r	r	r
Ephemerella grandis	r	r	r	r	c	r	r	r	c	r				r	r	r
Ephemerella hecuba		r	r	r	r	r	r		c	r	r					
Ephemerella hystrix																r
Ephemerella inermis	r	c	r	r	r		r		r				r	r	r	r
Ephemerella margarita		r	c	c	a	c	r	r	c	r	r	r				
Ephemerella teresa	r	c	r	r	r		r	r	c	a	r	a				
Ephemerella tibialis	c	c	r	r	r	r	r	c	c	r		r		a	a	a
Heptagenia criddlei		r	c	r	c	a	r	c	a	c	c	r				
Heptagenia simpliciodes	r															
Paraleptophlebia bicornuta		r	c	r	r	a	c		r	r	r					
Paraleptophlebia debilis			r		r	r				r	r					
Paraleptophlebia heteronea	r	c	c	r	r	c	c	r				r		r	r	
Rhithrogena robusta	r													r	r	c
Tricorythodes minutus			r	r	r	r	a	r	r	r	r	r	r			
ODONATA																
Ophiogomphus severus							r									
PLECOPTERA																
Acroneuria californica	r	r	c	r	r	r		c	r			r		r	r	r
Alloperla sp.	c	r	c	r	c	r	r	r	r	r	r	r		c	r	c
Arcynopteryx sp. A	r			r	r		r	r	c	r	r	r		r	r	r
Arcynopteryx sp. B	r	r	r	r	r	r	r	r	c	c	r	r	r		r	r
Isogenus sp.	r	r	r	r	r	r	r	r	r	r				r	r	r
Isoperla sp.	r				r	r		r								
Leuctra sp.	r	r	r	r												r
Nemoura sp.		r	r						r	r		r	r	r	r	r
Paraperla sp.														r		r
Peltoperla sp.																r

[1] r = rare (1-25 insects); c = common (26-100 insects); a = abundant (> 100 insects).

Table 8. Continued.

Species	Stations															
	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17
Pteronarcys californica		r	r		r	r		r	r	r		r				
HEMIPTERA																
Corixidae							r									
NEUROPTERA																
Sialis sp.			r			r	r									
COLEOPTERA																
Brychius sp.	r		r	r		r					r					
Cleptelmis ornata	r	a	r	r	r		r	r	r	r		r			r	r
Dubiraphia sp.							r						r			
Heterlimnius corpulentus	r	r			r	r		r	r	r		r	r	a	a	a
Lara sp.			r													
Narpus concolor	r	r		r				r						r	r	r
Optioservus seriatus	r	a	a	a	a	a	a	a	a	a	r	a	c	r	r	a
Oreodytes sp.	r	c	r		r		r				r					
Zaitzevia parvula	r	c	r	c	c	r	r	c	r	r		r		r		
TRICHOPTERA																
Agraylea sp.		c	r		r	r					r	r				
Amiocentrus sp.												r				
Apatania sp.		r	r		r			r						r		
Arctopsyche grandis	r	r												r	r	
Athripsodes sp.											r					
Brachycentrus sp.					r				r	a	r	a	r			
Cheumatopsyche sp.			r	r	r	r	r	a	r	r	r	r				
Dicosmoecus sp.						r								r	r	r
Glossosoma sp.			r	r	r	r	r	c	r	c	r	c		r	r	r
Hydropsyche sp.	r	r	r	r	r	r		c	r	c	c	a				
Lepidostoma sp.		r	r	r	r	r	r		r	r						
Limnephilinae													r			
Micrasema sp.	c	a	r	r	c	r				c				r	r	r
Neophylax sp.		r	r		r				r			r		r	r	
Onocosmoecus sp.		r														
Polycentropus sp.											r					
Psychomyia sp.							r	r			r	r				
Rhyacophila acropedes															r	r
Rhyacophila angelita								r		r		r		r	r	r
Rhyacophila coloradensis												r				
Rhyacophila vepulsa	r													r	r	r
Rhyacophila verrula														r		r
Stactobiella sp.											c	r				
Wormaldia sp.	r	r	r	r	r			c	r	r		r		r		r

Table 8. Continued.

Species	Stations															
	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17
DIPTERA																
Ablabesmyia sp.	r	r	r	r	r	r	r	r			r			r	r	
Antocha monticola	r	r	r	r	r	r	r	r	r	r	r	c		r	r	
Atherix variegata	r	r	r	r	c	r	r			r	r	r				
Blephariceridae													r			
Cardiocladius sp.	r	c	c	r	c	r	r	r	r	r	r	r	r	c	c	c
Cricotopus sp. A	r	c	r	r	r	r	r	r	r	r		r				r
Cricotopus sp. B	r	r	r	r	r			r		r		r		r	r	
Dicranota sp.	r				r				r					r	r	
Empididae, sp. A	r				r							r		c	r	c
Empididae, sp. B		r	r											r		
Empididae, sp. C					r	r				r	r					r
Gonomyia sp.													r			
Limnophila sp. A	r	r	r	r	c	r	r	r	c	r	r	c	c	r	r	r
Limnophila sp. B		r	r	r	r	r	r	r			r			r		r
Micropsectra sp.		r	r	r	c	r	r	r	r	r	r	r		c	r	r
Palpomyia sp.			r	r	r		r							r		
Prosimulium sp.	r	r	r	r	r			r	r	r		r		r	r	r
Simulium sp.	r	r	r		r		r	r	r	c		c		r	c	r
Tabanus sp.				r	r		r				r		r			
Tipulidae, sp. A															r	
Tribelos sp.	r	r	c		r		a		r	r	r				r	r
Zavrelia sp.							r									

separately giving their distribution and percent composition for each station during 1969 and 1970 (Table 9).

The orders Odonata, Hemiptera and Neuroptera were collectively represented by only five species. They were most abundant at station 7, a sandy pool with emergent reeds along the bank. Lepidoptera, represented by the pyralid *Paragyractis* sp. were found only in August, 1969 on the large lava boulders of station 11.

Ephemeroptera were well represented in both streams. Twenty-eight species were found, 24 in Emerald Creek and 26 in the St. Maries River. Most showed a wide distribution; however, a few were restricted to one stream or a portion of one stream. Heavily silted areas (stations 7, 12 and 14) had fewer species and numbers of individuals (Tables 7-9). Most species were found in both lightly and moderately sanded riffles, though lower populations generally prevailed in moderately sanded riffles.

Stoneflies were uncommon in the study areas; a total of twelve species were represented in the two streams. *Acroneuria californica*, *Alloperla* sp., *Arcynopteryx* sp. and *Isogenus* sp. were widely distributed in both streams. *Isoperla* sp., *Leuctra* sp., *Paraperla* sp. and *Peltoperla* sp. were restricted to the upper reaches of Emerald Creek and to the Middle Fork of the St. Maries River (Table 8). Sandy-silted habitats with few or no rocks (stations 7 and 14) had few stoneflies and reflected poor habitat conditions for this group.

The order Coleoptera was represented by the families Haliplidae, Dytiscidae and Elmidae. Of the eleven species collected, only five were widely distributed (Tables 7 and 8). These showed a preference for riffles over pools but showed no preferences between lightly or moderately sanded riffles.

Table 9. Distribution, abundance and percent composition of selected insect species in Emerald Creek and the Middle Fork of the St. Maries River in northern Idaho during June-August, 1969-1970.

Species		Stations																													
		1		2		3		4		5		6		7		8		10		11		12		13		14		15		16		17	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Baetis tricaudatus	1969	86	8.7	172	7.7	224	17.1	169	17.5	314	16.9	192	11.4	6	3.	122	8.4	482	18.1	188	8.0	2	1.3	106	6.3	15	5.5	51	4.2	53	4.1	122	7.3
	1970	53	1.2	67	4.5	66	8.7	39	6.2	84	4.4	46	4.3	6	0.	58	4.9	354	20.5	60	4.9	24	6.9	77	4.2	27	13.3	76	7.7	57	19.6	37	8.2
Ephemerella tibialis	1969	38	3.8	21	0.9	19	1.4	4	0.4	21	1.1	9	0.5			6	0.4	19	0.7									250	20.6	174	13.7	321	19.2
	1970	32	7.3	53	3.5	12	1.2	6	0.9	14	0.7	1	--	2	0.	56	4.8	34	1.9	4	0.3			3	0.1			134	13.6	138	15.9	103	9.8
Heptagenia criddlei	1969			10	0.4	117	8.9	59	6.1	123	6.6	310	18.4			200	13.8	159	5.9	26	1.1	10	6.5	4	0.3							3	0.1
	1970			3	0.2	31	3.1	16	2.5	28	1.4	324	30.6	22	2.	56	4.8	269	15.6	26	2.1	27	7.8	4	0.2								
Acroneuria californica	1969					4	0.3	5	0.5	2	0.1	1	--			28	1.9	3	--					8	0.6			19	1.5	26	2.0	8	0.4
	1970	2	0.4	12	0.8	28	2.8	13	2.0	2	0.1	11	1.0			36	3.0	7	0.4					2	0.1			24	2.4	19	2.2	6	0.5
Alloperla sp.	1969	65	6.6	27	1.2	28	2.1	14	1.4	30	1.6	22	1.3			4	0.2	25	0.9	15	0.6	1	0.6	96	7.5	3	1.1	24	1.9	50	3.9	25	1.5
	1970	28	6.4	17	1.1	33	3.3	25	3.9	50	2.6	11	1.0	3	0.	7	0.6	10	0.5	10	0.8	5	1.4	25	1.3			28	2.8	20	2.3	35	3.3
Heterlimnius corpulentus	1969	64	6.5	12	0.5			1	0.1	1	--	1	--			6	0.4	1	--	3	0.1			2	0.1			135	11.1	198	15.6	192	11.5
	1970	14	3.2	15	1.0					5	0.2	1	--			3	0.2	1	--	1	--			4	0.2	1	0.4	154	15.6	149	17.2	276	16.7
Optioservus seriatus	1969	16	1.6	218	9.8	136	10.4	179	18.6	401	21.6	522	31.0	29	15.	505	34.9	1088	40.8	304	13.0	23	15.0	240	15.8	17	6.2	22	1.8	65	5.1	346	20.7
	1970	23	5.3	273	18.5	111	11.2	152	24.2	572	30.3	136	12.8	125	15.	254	21.7	299	17.3	107	8.7	20	5.7	239	13.2	40	19.7	20	2.0	18	2.0	175	16.6
Hydropsyche sp.	1969			4	0.1	8	0.6	5	0.5	5	0.2	4	0.2			15	1.0			189	8.1			223	17.5	1	0.3					4	0.2
	1970	1	0.2	17	1.1	18	1.8	18	2.8	16	0.8	1	--			26	2.2	2	0.1	87	7.1	30	8.6	329	18.1								
Micrasema sp.	1969	217	22.1	210	9.5	3	0.2	5	0.5	1	--			6	3.			1	--	69	2.9			1	--			56	4.6	11	0.8	52	3.1
	1970	39	9.0	187	12.6	8	0.8	2	0.3	77	4.0	1	--							44	3.5							15	1.5	4	0.4	12	1.1
Wormaldia sp.	1969	3	0.3			18	1.3	13	1.3	25	1.3	2	0.1			98	6.7	3	0.1	27	1.1			18	1.4			1	--				
	1970	3	0.6	21	1.4	11	1.1	10	1.5	21	1.1					43	3.6	2	0.1	11	0.9			7	0.3			3	0.3			4	0.3
Atherix variegata	1969	9	0.9	63	2.8	4	0.3	15	1.5	24	1.2	8	0.4	1	0.	3	0.2	6	0.2	2	--			2	0.1								
	1970	6	1.3	22	1.4	19	1.9	8	1.2	78	4.1	6	0.5	4	0.					2	0.1	1	0.2	10	0.5								
Simulium sp.	1969	30	3.0	69	3.1	5	0.3			17	0.9					5	0.3	4	0.1	8	0.3			21	1.6			7	0.5	2	0.1	21	1.2
	1970	5	1.1	5	0.3	1	0.1			4	0.2			1	0 1	10	0.8	8	0.4	28	2.2			93	5.1			25	2.5	31	3.5	4	0.3

Of the 33 trichoptera species most were represented by only a few specimens at a few stations (Tables 7 and 8). Rhyacophila spp. were found mostly in the faster, unsilted riffles of the Middle Fork of the St. Maries River; a few were found in similar habitats (stations 8, 11 and 13) on Emerald Creek. Most trichoptera larvae preferred riffles over pools and runs.

Diptera were widely distributed in both streams, although rare in numbers. Tipulidae, Chironomidae and Simuliidae were most widely distributed and had the largest numbers. Some species of Chironomidae showed a preference for riffles while others were equally distributed in riffles and pools. Tipulids were found in higher numbers in sandy or silted riffles and pools, while simuliids were reduced or absent in these habitats.

Qualitative and quantitative differences were found among stations and between the two years. These differences were reflected in average species diversity and biomass for each station (Table 10). Species diversity was calculated using the Shannon Information Theory formula, $H = \frac{c}{N} (\log_{10} N! - \log_{10} n_i!)$, where c = 3.321 is a conversion factor from base 10 to base 2, N = the total number of individuals, and n = the number of individuals in each species (Lloyd, 1968). Diversity was highest at the headwater stations and lowest in pool habitats (Table 10). Biomass, expressed as a volumetric measurement, ranged from 0.05-0.64 ml./sq. ft. (Table 10). It tended to be higher in the lower half of Emerald Creek and in the St. Maries River. As with species diversity, biomass was lowest at pool stations.

To determine significant differences among stations with respect to species diversity and biomass, a Duncan's multiple range test was conducted

Table 10. Stations on Emerald Creek and the Middle Fork of the St. Maries River in northern Idaho ranked by increasing species diversity and biomass[1]. Vertical lines indicate groups of stations not differing at the 1% level according to Duncan's multiple range test.

Species Diversity		Biomass (ml/sq. ft.)	
mean	station	mean	station
2.024	14	.05	12
2.961	10	.06	14
3.034	6	.12	1
3.129	7	.16	7
3.144	8	.25	4
3.149	11	.25	3
3.184	12	.31	5
3.221	13	.34	8
3.316	17	.34	16
3.369	4	.34	6
3.475	16	.38	17
3.486	5	.39	10
3.637	15	.40	15
3.676	1	.42	11
3.795	3	.43	2
3.856	2	.64	13

[1] Means computed from data collected during June-August, 1969-1970.

at the 1% level for each of these characteristics (Table 10). Most stations grouped into statistically similar entities, the members of which did not differ from each other. Six such groups of stations existed with respect to species diversity with station 14 having a diversity value significantly lower than all other stations. Station 13 had a biomass significantly higher than all other stations which fell into four statistically similar groups with respect to this characteristic.

Dendrograms of Similarities

To show similarities among stations based on cobble size and imbeddedness, surrounding substrate size and average water depth and velocity, a weighted pair-group cluster analysis as described by Sokal and Sneath (1963) and Estabrook (1967) was used in an attempt to generate a dendrogram. With this method only two stations or groups of stations were permitted to cluster together. In 1969 ten stations had a similarity value of one, meaning they were identical. Three stations in 1970 also had similarity values of one. Most other stations had similarity values above 0.66 both years. These relatively similar values did not reflect meaningful differences among stations, therefore a dendrogram was not generated for these data.

Dendrograms showing station similarities based on the distribution and abundance of insect species for 1969 and 1970 were projected using the weighted pair-group method (Figure 9). The upper and lower confidence limits at the 98% level are indicated by dashed lines. Stations clustering between these limits were neither statistically similar nor dissimilar. Stations 7 and 12 were not included in the 1969 dendrogram because data for these stations were collected for only one month that year. Station 9 was omitted because it was sampled only twice in 1969 before it dried up. Four

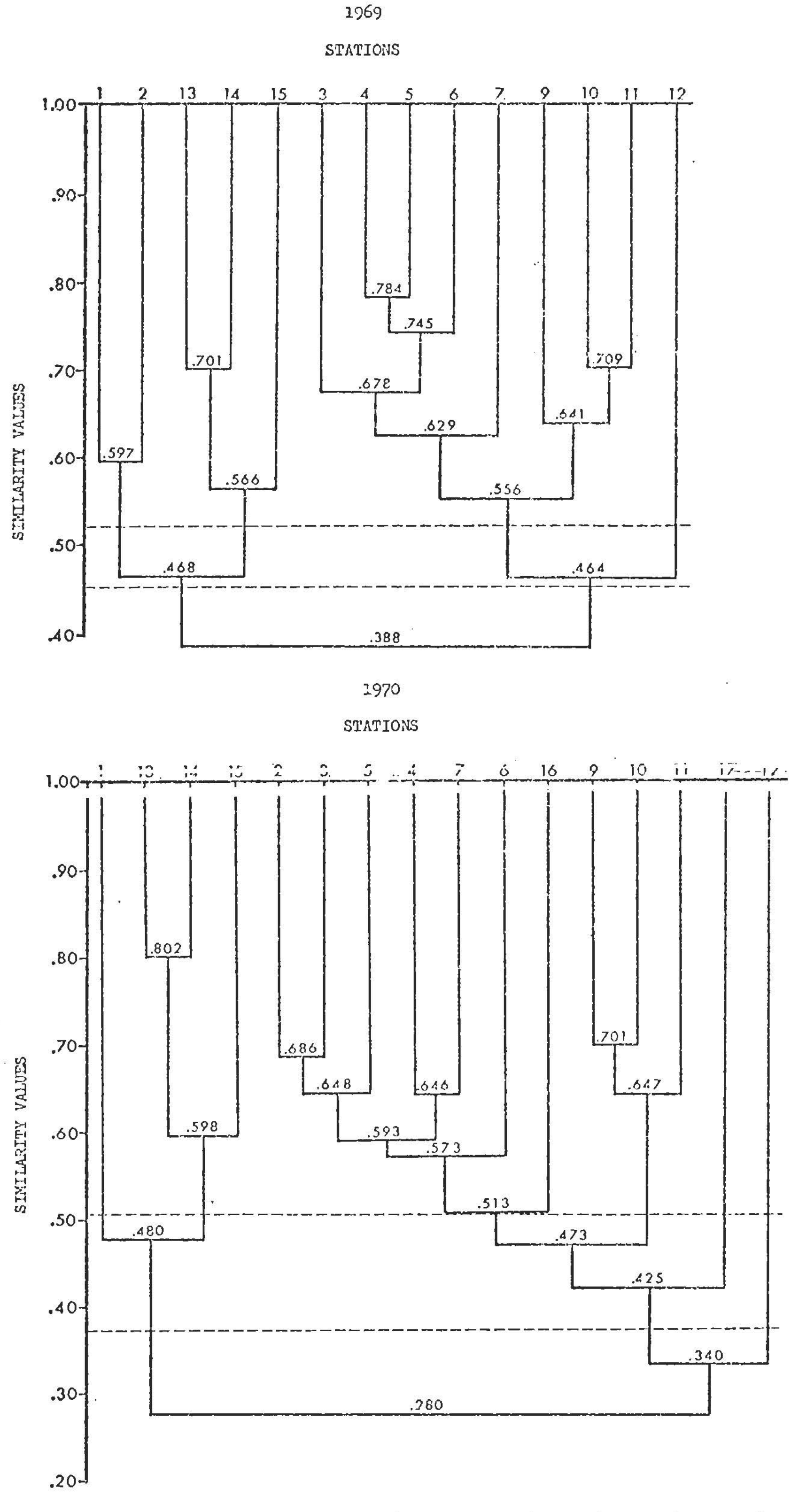


Figure 9. Dendrograms of station similarities based on distribution of insect species in Emerald Creek and the Middle Fork of the St. Maries River in northern Idaho June-August, 1969-1970. Dashed lines indicate the upper and lower confidence limits at the 98% level.

clusters are apparent, especially in the dendrogram for 1969. Two clusters are composed of the headwater stations of Emerald Creek and the Middle Fork of the St. Maries River respectively. The third cluster is composed of the other stations on the East Fork of Emerald Creek. The last cluster is composed of the riffle stations found on the main stem of Emerald Creek.

DISCUSSION

A. Laboratory Study

Nymphs of the stonefly Pteronarcys californica exhibited a negative phototaxic behavior which was an important factor in their distribution in the laboratory. Because of their size, larger individuals (20-50 mm.) were forced to take refuge under cobble while smaller specimens (11-20 mm.) were able to hide in the interstices of large and small gravel. As the surrounding substrate decreased in size, intersticial spaces also decreased, eliminating potentially occupiable habitats and causing their preference for large gravel (Fig. 3). With the higher number of nymphs under cobble in the smaller-sized substrates and the fewer occupiable interstices, many of the nymphs were forced onto the under side of the cobble (Figs. 6-8). This was also caused by the less stable nature of the smaller substrates, especially the sands. Imbedding cobble in coarse and fine sands prevented the nymphs from hiding under it and removing the cobble eliminated the principal refuge for the larger individuals. This explains their preference for substrates with unimbedded cobble (Figs. 4 and 5).

Like P. californica, the mayfly Ephemerella grandis demonstrated preferences for larger sediments (Fig. 3) and unimbedded cobble (Figs. 4 and 5) and for the same reasons. Because of its smaller size (8-15 mm.), it was able to penetrate substrate interstices to a greater depth. This is believed to account for their non-preference between unimbedded and half-imbedded cobble in association with large gravel (Figs. 4 and 7). This also explains why half-imbedding cobble did not affect the number of individuals on the cobble (Fig. 7) as much as decreasing the size of the surrounding substrate (Figs. 6-8).

The case-bearing caddisfly Brachycentrus sp. attaches its case to the upper surfaces of cobble and larger, more stable substrate particles. For this reason it showed no preference between large and small gravels with exposed cobble, but did prefer large gravel over coarse and fine sands which were too small and unstable for attachment (Fig. 3). Because of their habit of attaching to the upper surfaces of cobble, their macro-distribution was not affected by half-imbedding cobble except when the cobble was surrounded by fine sand (Fig. 4). Half-imbedding cobble in this sediment brought the insects in closer proximity with moving sand grains, the abrasive effects of which may have been instrumental in their avoidance of this cobble-surrounding substrate combination. Finer substrates with completely imbedded cobble, simulated by removing the cobble, lacked habitable surfaces provided by exposed cobble; thus, fine sand without cobble was an unhabitable substratum due to its lack of any point of attachment (Fig. 5).

Original intentions were not to record tests in which less than 25 specimens were recovered. Due to the difficulty of recovering this minimum of Arctopsyche grandis, results were analyzed even though 25 insects were not recovered in several tests. This caddisfly differs from Brachycentrus sp. in that it is a net spinner and lives almost exclusively in the interstitial spaces of the surrounding substrate along the sides of and beneath cobble. Thus, like P. californica and Ephemerella grandis, it preferred large gravel (Fig. 3) and substrates with unimbedded cobble (Figs. 4 and 5). Decreasing the surrounding substrate size reduced the interstices and forced this species to spin nets on the bottom of cobble (Figures 6-8). Half-imbedding cobble eliminated much of the area beneath the cobble suitable for habitation, thereby reducing the number of insects on cobble (Fig. 7).

The larvae of the snipe fly Atherix variegata lives just beneath the surface of sand and silt found in the interstices of coarser substrates. They have eight pairs of prolegs which they use for attachment and crawling, maintaining contact with cobble and substrate particles large enough to support their movements through the adjacent sand and silt. For this reason this species showed no preferences among the four substrate sizes used in the laboratory (Fig. 3). Half-imbedding cobble or removing it in fine sand reduced or eliminated respectively the only surfaces capable of supporting the insects' movements, thus limiting their distribution. The gravels and coarse sand provided particles stable enough for this species' movements; therefore, imbedding or removing cobble did not affect their distribution (Figs. 4 and 5). Their habit of living at the sand-surrounding substrate interface is reflected by their absence on unimbedded cobble except when fine sand was the surrounding substrate (Fig. 6-8). When cobble was imbedded, it provided support for their movements, especially in the finer sediments (Fig. 7).

B. Field Study

Physical Analysis of Stations

The statistical analysis of stations with respect to substrate characteristics, i.e., cobble size and imbeddedness and surrounding substrate size (Table 5), did not yield much significant data. This was due to the similarity of many stations with respect to each of these characteristics. Most stations were included in several groups with respect to cobble size. Differences among average cobble sizes in most of these groups was less than 1/2 in. It is believed insects cannot discriminate between these small differences. It is believed a more realistic division would create two groups, those with cobble less than 5 in. and those with cobble larger than 5 in. Only three stations had cobble more than 1/4 imbedded, and of these, two were less than 1/2 imbedded. It is believed these three groups would be more realistic and should replace the six statistical groups in Table 5. For the same reasons, stations should be regrouped with respect to surrounding substrate size. Again, all but three stations should be grouped together with average substrate sizes of 1/4-5/8 in. Surrounding substrate at most of station 12 was sand and silt. The west bank of this station is a basalt ledge from which large rocks have fallen. Disregarding the section of the stream with large rocks would give this station an average substrate size close to 1/16 in. Thus, stations 7, 12 and 14 with average substrates of 1/8 in. or smaller would be grouped together.

Because of the interactions of these factors and others, i.e., current velocity, temperature, detritus, etc., these groupings are not reflected in the dendrograms based on insect distribution and abundance (Fig. 9). Any two of these substrate characteristics may cancel the effects of the third. Thus, large cobble, a productive habitat (Tarzwell, 1937; Mackay and Kalff, 1969) can be made uninhabitable by imbedding it in finer sediment. Imbedding the same cobble in larger sediment or similar sized cobble may actually increase the favorability of that substrate. This fact was demonstrated by results from stations 12 and 14 which had large cobble. Station 14 was nearly completely inundated by a 6-18 in. burden of coarse sand and had the lowest species diversity (Table 10). Station 12 had a large amount of sand and silt but also had an accumulation of large cobble along one bank which resulted in a higher species diversity.

Water Chemistries

Because of the similar values among stations for dissolved oxygen, turbidity and pH, it is not believed that these factors appreciably affected the distribution and abundance of insects (Table 6). Since alkalinity, total hardness and dissolved iron values were relatively low, differences between Emerald Creek and the Middle Fork of the St. Maries River stations were considered negligible.

Population Dynamics and Community Structure

The lower reach of Emerald Creek, compared to its headwaters, tended to have a lower diversity which corresponded to the shallower, more heavily silted conditions of that portion of the stream. The low diversity at the mouth of Emerald Creek (Station 14) is believed due to the limited number of species and small populations at this station, caused by the heavy accumulation of sand which eliminated favorable habitats for most species. Station 7, a sandy run, and station 12, a silted pool, had sparse, partially exposed cobble and smaller rocks, thus providing a wider variety of microhabitats. This is believed to have resulted in diversities higher than that at station 14, though superficially the three stations appeared quite similar. In contrast to station 14, stations 6 and 10 had large insect communities. The diversities at these stations were low because individuals of only three or four species comprised the majority of the total community. Highest diversities were found in light to moderately sanded riffles with *Fontinalis* sp. due to the variety of microhabitats provided under these conditions.

In contrast to species diversity, biomass tended to be lower in the upper reaches of Emerald Creek (Table 10). This was probably due to the lesser allochtonous material and other nutrients in the upper reaches of the stream. The high biomass at station 2 was probably due to the presence of *Fontinalis* sp. and dead stems which provided a favorable habitat for a large number of insects (Percival and Whitehead, 1929; Tarzwell, 1937). Stations on the headwaters of the Middle Fork of the St. Maries River were similar to upper Emerald Creek stations in terms of biomass which was probably influenced by similar substrates, water chemistry and current velocities. Station 11 had a biomass significantly higher than other stations due, it is believed, to the relatively silt-free, cobble-boulder substrate and presence of extensive *Fontinalis* sp. Heavily sanded and silted stations had the lowest biomass because of the limited number of species that find these substrates habitable and the small size of most of these species.

Substrate similarities and differences were also reflected in dendrograms based on the distribution and abundance of insects (Fig. 9), although it is recognized that many other factors, i.e., current, temperature, exposure, etc., also enter into this kind of analysis. It is believed the high similarity between stations 15 and 16 on the Middle Fork of the St. Maries River was caused by their proximity to each other (75 yds.) rather than by substrate and current characteristics which were different (Tables 4 and 5). Station 17, although superficially similar to station 15, was sandier and located one mile downstream. This is believed to account for its lower similarity value with stations 15 and 16. The Middle Fork of the St. Maries River was significantly dissimilar to most stations on Emerald Creek. Since substrate and current values were similar, this is believed due to the geographic separation of the two streams and the location of stations 15-17 in the headwaters of the Middle Fork of the St. Maries River. These assumptions are strengthened by the fact that the two uppermost stations on Emerald Creek were the only ones not significantly different from these stations in 1969.

Stations 1 and 2 on Emerald Creek were biologically similar in 1969 but very dissimilar in 1970. This reflected the difference in the type of cobble and increased amounts of sand at station 1 due to road construction.

Riffles on the East Fork of Emerald Creek (stations 3-6 and 8) were similar to each other as were riffles on the main stem of Emerald Creek (Stations 10, 11 and 13). This again reflected the similarity of cobble, surrounding substrate, current and other characteristics among these stations. That differences existed between riffles above and below the confluence of the East and West Forks of Emerald Creek was shown by the formation of two clusters (Fig. 9). Clustering of these two groups at a significant value in 1969 indicated a characteristic, riffles, common to all. The inclusion of station 7 in the 1970 dendrogram and its clustering with other stations on the East Fork lowered the average similarity value at which stations 10, 11 and 13 could join, making these clusters neither similar nor dissimilar for that year.

Stations 7 and 14, both heavily sanded runs, did not cluster together because station 7 had sparse cobble and some smaller rocks, therefore supporting a more varied population (Tables 7 and 8). Station 14 had no cobble or substrate larger than 1/8 in., resulting in an insect community peculiar to that station. This is reflected by station 14 not grouping with any station in 1969 and being significantly dissimilar to all stations in 1970.

C. Aquatic Insect-Substrate Relationships

Ephemeroptera

The majority of mayfly species were widely distributed in both streams, although there were several exceptions (Tables 6 and 7).

Ephemerella coloradensis and *E. doddsi* were found only in the Middle Fork of the St. Maries River. Because of their restriction to these upper stations and the similarity of these stations to others with respect to substrate, it is believed substrate was not a limiting factor. Instead, temperature or some other characteristic of headwater stations not analyzed in this study and geographic separation of the two streams was probably responsible for their distribution. Most species were absent from heavily silted and sanded stations in 1969 because of the smothering and elimination of microhabitats. In 1970 stations 7 and 12 had more species represented than in 1969, but in rare numbers (Table 7). This change is commensurate with an improvement in the sand and silt substrates as a result of cessation of rockhound activities in the upper reach. Station 14 remained relatively unchanged during the study and had a very sparse mayfly population both years. Many of the specimens collected from this station are believed to have drifted from an upstream riffle. *Ephemerella grandis* was found at most stations but was rare (Table 6). Its absence from stations 7, 12 and 14 reflects negative affinities for finer sediments in absence of unimbedded cobble as shown in the laboratory (Figs. 3-5). However, some tolerance for fine sand was shown in the laboratory by individuals found on half-imbedded cobble at the sand-rock interface. It cannot be said that these individuals preferred the sand as it appeared they only moved down to it to avoid being exposed on the tops of the cobble. *Caenis latipennis* Banks has been reported showing affinities for a thin skim of silt in coarser sediments in the laboratory (Cummins and Lauff, 1969). Harrison and Elsworth (1958), however, found another mayfly species, *Pseudocloeon vinosum* Banks, requiring an extremely silt-free environment.

Baetis tricaudatus and Heptagenia criddlei, two of the principal mayfly species in the study area, demonstrated varying degrees of sensitivity to the altered environment. Populations were noticeably lower in the lower reaches of Emerald Creek. This is believed due to the shallower, slower and more heavily sanded and silted conditions. It should be pointed out, however, that H. criddlei was able to tolerate sandy or silted conditions when in the presence of cobble. This was demonstrated by their presence at station 12 both years and its appearance at station 7 in 1970. The absence of H. criddlei and lower numbers of B. tricaudatus at station 1 were probably due to the nature of the cobble which was in the form of thin plate-like rocks. Lower numbers of H. criddlei at stations 2 and 4 are believed due to the lack of cobble and the presence of sand and bedrock at the two stations respectively. This agrees with results of Pennak and Van Gerpen (1947), Minshall (1968), and Mackay and Kalff (1969) who found cobble sized rocks to be a more productive substrate than sand or bedrock.

Plecoptera

Five species of stoneflies were recorded in the field, most in rare numbers. Leuctra sp., Paraperla sp. and Peltoperla sp. were found only in the Middle Fork of the St. Maries River and the upper stations on Emerald Creek (Tables 6 and 7). This is similar to the distribution of the beforementioned mayflies, Ephemerella coloradensis and E. doddsi, and is also believed to be caused by some limiting factor in the headwaters of streams other than substrate.

Acroneuria californica was one of the most common stoneflies. Only two individuals were found at station 1, however (Table 9). Its limited occurrence there is believed due to the plate-like cobble and sandy substrate. The absence of this species at station 11 was probably because of sampling inequities as it was found at station 13, a station physically similar. Its absence at station 14, which lacked any particles larger than 1/8 in., and at stations 7 and 12 which were heavily sanded and silted was caused by its preference for cobble and coarser sediments. Preference for cobble and coarser substrates, because of their stability and interstitial spaces, was shown in the laboratory by another stonefly, *Pteronarcys californica* (Figs. 3-8). Similar findings have been reported for *Perlista placida* (Hagen) by Cummins and Lauff (1969) and *Brachyptera risi* by Madsen (1969). In contrast to *A. californica*, *Alloperla* sp. showed more tolerance to sand and silt. The large population at station 1 was probably the result of the presence of *Fontinalis* sp. and algae. The five specimens collected from stations 7, 12 and 14, heavily silted and sanded substrates, were probably present due to drift.

Coleoptera

Beetles, represented principally by the family Elmidae (Tables 7 and 8), showed a wide range of tolerance to various substrates. They were found consistently at riffles but not in the runs and pools. This may have been due to the sand and silt substrate or to the slower current found at those stations. *Heterlimnius corpulentus*, although found at 13 stations, apparently preferred the headwaters, again indicating some influential factor or factors not studied. Their negative affinity for silt and sand bottoms is shown by their absence and low numbers at stations 7, 12 and 14. This agrees with Leech and Chandler (1956) who stated that elmids may be rare in streams with heavy sediment loads or with mud or sand bottoms.

Unlike H. corpulentus, Optioservus seriatus tended to have smaller populations at headwater stations. The same factor, characteristic of headwaters, which favored H. corpulentus may have been limiting this species. Its largest population was found at a moderately sanded riffle where it comprised up to 40% of the total insect community (Table 9). This is believed due to the large amount of allochtonous leaf material present. The higher numbers collected from the heavily sedimented pool and run stations, as compared to other species, indicate more tolerance for sand and silt bottoms. This may have been a result of their small size which allowed them to utilize smaller interstices and substrate particles.

Trichoptera

Thirty-three species of caddisflies were collected in the field. Only seven were found at eight or more stations and these usually in rare numbers (Tables 7 and 8). Nearly all species showed an avoidance for sandy, uncobbled habitats, e.g. stations 7 and 14. Their absence from these stations is believed due to the lack of cobble since several species were found at station 12 which was heavily silted, but had many cobble-sized rocks. Eight species of Rhyacophila were recovered, occuring principally in the Middle Fork of the St. Maries River. Only a few well-cobbled, moderate to fast riffles supported Rhyacophila spp. in Emerald Creek due to the silt and sand present at most stations. This agrees with results found by Smith (1968) who reported this genus in clean, fast riffles. The distribution of Hydropsyche sp. was also affected by faster currents and large cobble as shown by their abundance at stations 11 and 13. Their absence at station 1 is probably due to the plate-like cobble and sandy condition at this station. Their absence at station 10 is probably due to the near absence of cobble over most of the riffle, the substrate being nearly uniform one-inch pebble. This agrees with results obtained from the cobble present or absent preference tests conducted in the laboratory with the similar species, Arctopsyche grandis (Fig. 5). The presence of large cobble at station 12 is believed to account for the population of Hydropsyche sp. there even though the surrounding substrate was sand and silt.

Large populations of Micrasema sp. at stations 1, 2, 11, 15 and 17 (Table 8) were probably due to the presence of the moss, Fontinalis sp., with which the larvae were closely associated. Numerous cobble-sized rocks and a slower current (1.2 ft./sec.) at station 5 also provided a favorable environment for this species although Fontinalis sp. was absent. The collective effects of current velocity and substrate are believed to be important factors influencing the distribution of this small, case-bearing trichopteran. In contrast, Brachycentrus sp. preferred faster currents with gravel-cobble substrates for attachment. The importance of substrate as a factor influencing this species' distribution was amply demonstrated in the field and laboratory (Tables 6 and 7; Figs. 3-5).

The absence of the net spinning caddisfly, Wormaldia sp. from heavily sanded or silted runs and pools is believed caused by the slower currents at these stations and the smothering effect of the sand and silt. It also was restricted in headwaters by a factor other than substrate as it was found at lower stations with similar substrates.

Diptera

Diptera larvae generally demonstrated similar responses to substrates as other orders. The largest numbers were collected from lightly to moderately sanded riffles; the least numbers were found in heavily sanded and silted runs and pools. These latter stations were mainly populated by tipulids and chironomids able to survive there because of their burrowing habits. Tipulids were responsible for most of the biomass at heavily sedimented pools and runs because of their larger size.

The only species to show any positive affinities for fine sediments was Tabanus sp. This was probably due to its burrowing habits and the presence of many tipulids and chironomids on which it may have preyed. The snipe fly, Atherix variegata, lives in a similar microenvironment as Tabanus sp. However, A. variegata has prolegs and uses these in crawling. Thus it was found at most stations on Emerald Creek. Its absence at station 14 indicates its need for substrate particles large enough to support its movements in the surrounding substrate. This was also found in the laboratory (Figs. 3-5). The presence of a few individuals at stations 11 and 17 indicates their tolerance of sand and silt in the presence of cobble or other stable particles. No reason can be given for their absence at stations in the Middle Fork of the St. Maries River.

In contrast to most of the dipteran species collected, the black fly Simulium sp. requires a silt-free environment. This species is a filter feeder, anchoring itself to the upper portions of cobble and other support in the faster currents. Because of its mode of life it is very susceptible to the abrasive effects of drifting silt and sand. Wu (1931) reported that they move to portions of rocks and twigs which remain silt free. Their presence at stations 11 and 13 reflect the faster currents (2.0 ft./sec.) and large cobble providing anchoring surfaces above the influence of moving sediments near the stream bottom. Slow currents (0.9-1.1 ft./sec.) and the lack of suitable surfaces for attachment limited their distribution at the silted and sanded pools and runs (stations 7, 12, and 14).

SUMMARY

This study was initiated to determine the effects of sand and coarser sediments on the distribution and abundance of aquatic insects. Emerald Creek was chosen as the study area because of rockhound and dredge mining activities which have introduced large amounts of sediment into the stream. The Middle Fork of the St. Maries River served as a control because of relatively unaltered conditions. Fourteen stations were established on Emerald Creek and three on the upper reaches of the Middle Fork of the St. Maries River.

Five species, *Pteronarcys californica*, *Ephemerella grandis*, *Brachycentrus* sp., *Arctopsyche grandis* and *Atherix variegata* were tested for substrate preferences in an artificial stream in the laboratory. Four sizes of surrounding substrates were tested in association with cobble imbeddedness. Most species preferred unimbedded cobble with a coarse surrounding substrate.

Field stations were analyzed physically and biotically. Cobble size, imbeddedness and surrounding substrate size were statistically similar at most stations. Heavily sanded or silted pools and runs proved to be physically and biologically dissimilar. Species diversity was higher in the upper reaches of Emerald Creek and the Middle Fork of the St. Maries River, while biomass tended to be slightly higher in the lower reach of Emerald Creek.

Ephemeroptera were widely distributed in both streams and showed varying degrees of adaptability to moderately sanded riffles. Pools and heavily sanded runs showed marked reduction in mayfly populations. A few species were limited to the headwaters of the two streams. Stoneflies

were uncommon in both streams. Several of the species showed a wide distribution while others were limited. All showed affinities for riffles and coarser sediments. Four species of the family Elmidae accounted for the majority of the beetles collected. These species were widely distributed and showed varying degrees of adaptability to heavily sanded or silted conditions. Most trichoptera species were represented by only a few individuals. They preferred clean, fast riffles with coarse substrates. Diptera, especially chironomids, were common and abundant throughout the streams. Some species were found in riffles and pools while others were restricted to heavily sanded pools and runs.

High sediment production from man-caused activities caused deterioration of stream habitat, resulting in reduced species diversity, density and biomass in Emerald Creek.

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APPENDIX

Table 11. Checklist of insect species in Emerald Creek and the Middle Fork of the St. Maries River.

EPHEMEROPTERA

Ameletus sp.
Baetis bicaudatus Dodds
Baetis tricaudatus Dodds
Centroptilum sp.
Cinygmula sp.
Epeorus (*Iron*) *albertae* (McDunnough)
Epeorus (*Ironopsis*) *grandis* (McDunnough)
Epeorus (*Iron*) *longimanus* (Eaton)
Ephemerella (*Drunella*) *coloradensis* Dodds
Ephemerella (*Drunella*) *doddsi* Needham
Ephemerella (*Caudatella*) *edmundsi* Allen
Ephemerella (*Drunella*) *flavilinea* McDunnough
Ephemerella (*Drunella*) *grandis* Eaton
Ephemerella (*Timpanoga*) *hecuba* Eaton
Ephemerella (*Caudatella*) *hystrix* Traver
Ephemerella (*Ephemerella*) *inermis* Eaton
Ephemerella (*Attenuatella*) *margarita* Needham
Ephemerella (*Drunella*) *spinifera* Needham
Ephemerella (*Serratella*) *teresa* Traver
Ephemerella (*Serratella*) *tibialis* McDunnough
Heptagenia criddlei McDunnough
Heptagenia simpliciodes McDunnough
Paraleptophlebia bicornuta (McDunnough)
Paraleptophlebia debilis (Walker)
Paraleptophlebia heteronea (McDunnough)
Pseudocloeon sp.
Rhithrogena robusta Dodds
Tricorythodes minutus Traver

ODONOTA

Agrion aequabile Kennedy
Argia sp.
Ophiogomphus severus Hagen

PLECOPTERA

Acroneuria californica (Banks)
Alloperla sp.
Arcynopteryx sp. A
Arcynopteryx sp. B
Isogenus sp.
Isoperla sp.
Leuctra sp.
Nemoura sp.
Paraperla sp.
Peltoperla sp.
Pteronarcella sp.
Pteronarcys californica Newport

Table 11. Continued.

HEMIPTERA

- Corixidae

NEUROPTERA

- *Sialis* sp.

COLEOPTERA

- *Brychius* sp.
- *Cleptelmis ornata* (Schaeffer)
- *Dubiraphia* sp.
- *Helophorus* sp.
- *Heterlimnius corpulentus* (LeConte)
- *Lara* sp.
- *Microcylloepus* sp.
- *Narpus concolor* LeConte
- *Optioservus seriatus* (LeConte)
- *Oreodytes* sp.
- *Zaitzevia parvula* Horn

TRICHOPTERA

- *Agraylea* sp.
- *Amiocentrus* sp.
- *Apatania* sp.
- *Arctopsyche grandis* (Banks)
- *Athripsodes* sp.
- *Brachycentrus* sp.
- *Cheumatopsyche* sp.
- *Dicosmoecus* sp.
- *Glossosoma* sp.
- *Goera* sp.
- *Hydropsyche* sp.
- *Hydroptila* sp.
- *Lepidostoma* sp.
- Limnephilinae (Unidentified sp.)
- *Micrasema* sp.
- *Neophylax* sp.
- *Neothremma* sp.
- *Onocosmoecus* sp.
- *Oxyethira* sp.
- *Parapsyche* sp.
- *Polycentropus* sp.
- *Psychomyia* sp.
- *Rhyacophila acropedes* Banks
- *Rhyacophila angelita* Banks
- *Rhyacophila coloradensis* Banks
- *Rhyacophila rotunda* Banks
- *Rhyacophila tucula* Ross
- *Rhyacophila vaccua* Milne

Table 11. Continued.

Rhyacophila vagrita Milne
Rhyacophila vepulsa Milne
Rhyacophila verrula Milne
Stactobiella sp.
Wormaldia sp.

LEPIDOPTERA

Paragyractis sp.

DIPTERA

Ablabesmyia sp.
Antocha monticola Alexander
Atherix variegata Walker
Blephariceridae
Cardiocladius sp.
Cricotopus sp. A
Cricotopus sp. B
Dicranota sp.
Empididae, sp. A
Empididae, sp. B
Empididae, sp. C
Forcipomyia sp.
Gonomyia sp.
Limnophila sp.
Micropsectra sp.
Nemotelus sp.
Palpomyia sp.
Prosimulium sp.
Simulium sp.
Tabanus sp.
Tipulidae, sp. A
Tipulidae, sp. B
Tipulidae, sp. C
Tipulidae, sp. D
Tribelos sp.
Zavrelia sp.