Aquatic insects in sediment traps
by Francis Wayne Mangels

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Zoology
Montana State University

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Sediment traps were set in three tributaries and in three areas of the upper Gallatin River. The kind, sizes and amount of sedimen- tation was analyzed and related to numbers and orders of aquatic insects found in gravel in the traps. From August, 1972, to October, 1973, samples were taken at monthly intervals in a monthly renewed sample and in a cumulative sample undisturbed since the beginning of the project. These sampling methods show that living space is of prime importance to aquatic insects and sculpins, and that it is a limiting factor for insect communities presently in the upper Gallatin. Measurable current speeds (up to 2.5 fps) did not seem to affect insect numbers. High percentages of organic matter in sediment coincided with high insect numbers, but actual weight had no apparent relationship.

High numbers of insects were present in the spring, but were drastically reduced after runoff. They recovered much more slowly and to lower levels in the cumulative traps, which remained filled with sediment.

The low sedimentation rates through fall and winter resulted in higher insect numbers in cumulative traps, presumably because they were undisturbed. Diptera was the dominant order in all areas.

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ABSTRACT

Sediment traps were set in three tributaries and in three areas of the upper Gallatin River. The kind, sizes and amount of sedimentation was analyzed and related to numbers and orders of aquatic insects found in gravel in the traps. From August, 1972, to October, 1973, samples were taken at monthly intervals in a monthly renewed sample and in a cumulative sample undisturbed since the beginning of the project. These sampling methods show that living space is of prime importance to aquatic insects and sculpins, and that it is a limiting factor for insect communities presently in the upper Gallatin. Measurable current speeds (up to 2.5 fps) did not seem to affect insect numbers. High percentages of organic matter in sediment coincided with high insect numbers, but actual weight had no apparent relationship. High numbers of insects were present in the spring, but were drastically reduced after runoff. They recovered much more slowly and to lower levels in the cumulative traps, which remained filled with sediment. The low sedimentation rates through fall and winter resulted in higher insect numbers in cumulative traps, presumably because they were undisturbed. Diptera was the dominant order in all areas.

INTRODUCTION

Concern has been renewed in recent years as to the effects of sedimentation on aquatic life. "Silt pollution" as it is commonly called, is no doubt detrimental to aquatic life, but silt, or other forms of sediment, is a natural element in all streams. A heavy or increasing amount of it, however, is harmful to many organisms (Cordone and Kelley, 1961; Usinger, 1963). As early as 1936 (Ellis) the problem of increasing siltation was noticed but little attention was given to its effects on insects; most of the attention was directed toward its effects on fisheries. An investigation of china-clay siltation in England is probably the best comprehensive look in recent years at the trout-insect relations under conditions of increased sedimentation (Herbert, et al., 1961). This study, while measuring and stressing turbidity, made only a commentary of observation as to the appearance of the bottoms of the streams studied. This thesis will attempt to clarify further the relation between sedimentation and aquatic insects.

Whilm and Dorris (1968) have attempted to compute a "quality index" to quantify aquatic conditions in which silt plays a major part. They approached the problem from the standpoint of the diversity of species. However, Gaufin & Tarzwell (1956) claimed that association of species are more diagnostic of quality than the number of species. Without belaboring the point, we must agree that aquatic communities are influenced by numerous natural factors, of which sediment is a major one (Oshwald, 1972; Pennak and Gerpen, 1947; Tarzwell, 1937).

Should an aquatic insect community be eliminated, a logical question would concern the method of repopulation, including any observable pattern of species and time required for recovery. Gammon (1970) observed the complete elimintation and recovery of a stream insect community due to a heavy discharge of sediment from a gravel-washing plant and the subsequent cleaning after the sedimentation ceased. He speculated on the possibility of downstream aquatic drift as the mode of repopulation of the stream, for the area above the washing operation was unaffected. Waters (1961, 1964, 1966) and Bishop and Hynes (1969) have gathered enough data to indicate this phenomenon is much more common than previously thought. They further indicated that the Ephemeroptera nymphs are common drifters, and Gammon (1970) provides further evidence that under stress, such as high turbidity, insect drifting can be induced. Dimond (1967) has indicated that not only may drift be density-related, but also that if a population is elimintaed by pesticides, drift may repopulate an area. However, if the insects in an entire watershed are eliminated in this manner, repopulation may take years, through the slow process of stream ascension or chance dispersal by flying adults from a nearby unaffected stream as is suggested by Muller (1953). While channelization of a stream for such a purpose as road building has been shown to severely depress a trout population (Elser, 1968; Warner and Porter, 1960), the effect on aquatic insects for that immediate area is unstudied. Waters

(1964) and Gammon (1970) have indicated that recolonization may be only a matter of days, from drifting of insects. However, newly disturbed areas may be unstable, which may hamper the process of repopulation. Percival and Whitehead (1929) comment that since areas of unstable bottoms show comparatively low insect numbers, the lack of a safe resting place from physical damage or entrapment may be responsible.

Attempts to build or cause a population of aquatic insects to increase in uninhabited or sparsely inhabited small areas are rare. Sedimentation factors were not always studied, but come comparisons can be made. Sprules (1947) stacked rocks in a streambed to enhance catches in emergence traps, and was successful. Earlier, Sprules (1941) noted a decline in insect numbers as sediment deposition covered a stream area he was investigating. He suggested the increase or decrease of the amount of habitable substrate as the cause, a theory which has been supported by other studies (Cordone and Kelley, 1961; Hynes, 1970; Percival and Whitehead, 1929; Thorup, 1964; Williams, 1972). Wene and Wickliff (1940) found that rubble in wire baskets placed in stream bottoms yielded much greater insect populations than bottom samples. They do not imply space as a factor but such may be the case. Cummins (1964) found that insects tend to select the coarser bottom materials, and these materials also attract a greater variety of insects particularly stoneflies. Scott (1964) found that species react differently to substrate sizes. Cummins and Lauff (1969) later confirmed and supported a theory that selection does indeed occur for larger sizes, and direction of current (influences due to drifting) is of no particular importance in selection of substrate size.

Plant detritus is an important item in stream ecology. Nelson and Scott (1962) reported that primary consumers in a piedmont stream derive 66% of their energy from plant detritus, most of which is leaf matter. Minshall (1967) reported that leaf material falling into a Kentucky stream was a main source of food for invertebrates. Although most of the animals present were *Gammarus*, his data show that insects, especially Ephemeroptera, had a diet of 50-100% of leaf detritus. Egglishaw's study in Scotland (1964) indicates that aquatic invertebrates are not only present in relatively greater numbers in detritus, but also are attracted to it in proportion to the amount of detritus present, probably for food.

DESCRIPTION OF THE AREA

The research for this paper was conducted in the Gallatin River Drainage, which is the easternmost of the three forks of the Missouri River in southwestern Montana. A nationally famous trout stream, the Gallatin River heads in Yellowstone National Park and flows 140 kilometers to the Missouri River at Three Forks. The upper 100 kilometers flows through a steep, timbered canyon with three sagebrush-willow meadows. The uppermost meadow area is the Snowflake Springs elk range and extends from Yellowstone National Park to Taylor Fork. The middle meadow is in the Porcupine-West Fork area where commercial interests are developing the Big Sky recreational area. The lower meadow is at Spanish Creek and is used for ranching. The upper Gallatin is mostly in the Gallatin National Forest; lodgepole and Douglas-fir are dominant conifers, while aspen often borders the many open areas on the forest. The upper area is historically winter range for the Yellowstone-Gallatin elk herd, (Lovaas, 1970), but like most western forests, its natural history is for the most part, unstudied.

The character of the bed material of the Gallatin River in the entire study area is a great variety of rocks ranging from sedimentary Madison limestone to Yellowstone volcanic types. Included are the rarer jasper and petrified wood to the dominant quartzite and basaltic cobbles and gravels. The soils of the entire river bottom are in the Bigel-

Hobacker Association, which is composed of alluvial gravels and sand as parent materials (Olsen, et al., 1971).

The six sampling sites in this study are now described in more detail. The accompanying map (Fig. 1) shows their location. Three tributaries of the West Gallatin River were chosen for sediment trap locations: Taylor Fork (code TF), Porcupine Creek (code PC), and the North-Middle Fork of the West Fork of the West Gallatin River in the Big Sky area (code BS), which is often shortened to Big Sky Creek or West Fork. The Taylor Fork traps were 400 meters above the highway bridge, where theft practically cancelled the data as to usefulness. The Porcupine Creek traps were located fifty feet below the ranger station bridge. The Big Sky traps on the West Fork were located fifty feet above the big culvert one mile below the Meadow Village of the Big Sky project.

In addition, three stations were established on the Gallatin River. It was floated in late June, 1972, to locate suitable areas for setting groups of sediment traps. Riffle areas similar to the preceding three areas were selected in three places: Snowflake (code SF), Milepost 1430 (code M), and the Ruins (code R). Snowflake station was located 100 feet above the Snowflake Springs highway bridge on the inside of a nearly straight meander. The banks and bed were stable, and the bottom sealed with silt in the trap area, but not so in the cobbled mainstream. Milepost 1430 station was located at a cement

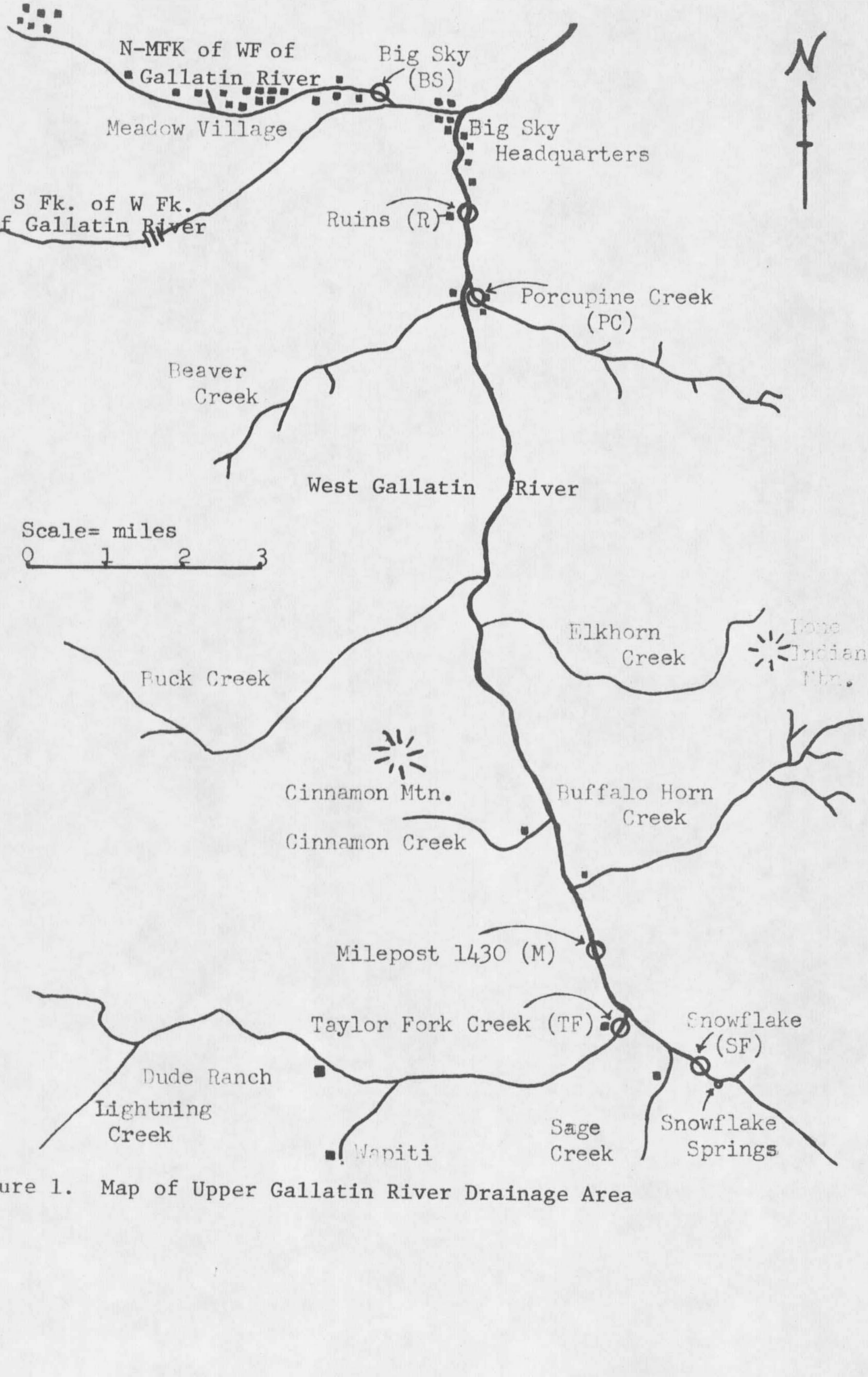

Figure 1. Map of Upper Gallatin River Drainage Area

monument one mile below Taylor Fork. The trap area was well-sealed with silt and on the inside of a slight meander along a gravel bar on the edge of the main current. This main current area was a deep run with a boulder bottom, but the backwaters out of the main current had deposits of the fine gray silt characteristic of Taylor Fork. Taylor Fork and Milepost had silted bottoms and very little algae growth. The Ruins station was at a large old cabin or waystation area one mile below Porcupine Creek, and the cabin wreckage marked the inside of a meander with a gravel bar similar to the other river sampling stations The traps were set along the bar at the edge of the current, as in the other groups of traps.

The Snowflake sampling area is probably affected by sedimentation influenced by the Gallatin elk herd. The willow bottoms and south slope areas of the upper drainage in Yellowstone Park around Lava Butte have a history of severe overgrazing, and the problem persists to a lesser extent today. Subsequent erosion may be the source of most of the sediment. Snowflake springs is another factor, and its water quality effects on aquatic life are unknown; it is the largest tributary in the area and its waters are alkaline.

The Taylor Fork station is most effected by unstable gray volcanic-ash type soils in the drainage. This area, like Snowflake, has a history of severe overgrazing by elk and livestock. The Lightning Creek area is noted for mudslides which occasionally color the creek and then the Gallatin River for days at a time with a very fine, gray silt at all seasons. Taylor Fork is usually at least partly cloudy with this material.

The Milepost station below Taylor Fork is fairly typical of the Gallatin River. It is in a narrow part of the canyon and the river is generally torrential in this area. The banks and the bed are predominantly boulders, and bank vegetation is dominated by conifers. The river deposits of gray silt from Taylor Fork in quiet pockets of water out of the main current.

Porcupine Creek is different from the other drainages in that human impact on the area is presently almost nil. At one time a road did follow the creek, but the bridge above the ranger station washed out about 1965 and was not replaced. The area has unstable soils, and efforts to begin logging the drainage have been blocked. The gravels of Porcupine Creek are basically calcarious argillites and quartzites with some granites from an exposed area 3½ miles above the mouth. The area is winter range for the Gallatin elk herd and has been overgrazed in the past, but like the Snowflake area, attempts are being made to solve the problem. The major source of silt in this drainage is probably streambank erosion and wash from the old road.

The Ruins station area on the river below Porcupine Creek is similar to Snowflake in vegetation type and stream characters, but willows are more abundant and erosion from the Porcupine elk range is probably much less than erosion at the Snowflake area. The dominant gravels are quartzites, with scattering of petrified wood and basaltic and granitic rocks.

The West Fork of the Gallatin River drains the basalt and granite of the slopes of Lone Mountain, cretaceous shale of the bottomland and the argillites of the Spanish Peaks. The banks and bed are composed of these materials. Stream vegetation is similar to Porcupine; the creek heads in pine forests and flows through a dry sagebrush, willow, and grass meadow. At present, Meadow Village of the Big Sky project is active in the drainage and disposes of sewage by a lagoon system; some cabins have drain fields. Most of the heavy sediment from construction is caught in an artificial lake at the village; roadbuilding and channelizing have been common. The lake is not entirely adequate as a catchment basin, for the Big Sky streams can be turbid at any time of year due to construction or rains. However, the stream clears rapidly after a few days. Taylor Fork, in contrast, remains very cloudy for weeks after rain. The West Fork is chemically similar to Porcupine Creek, but has a higher alkalinity (80 vs 109 ppm), and much higher phosphate (.005 vs .013 ppm) and nitrogen (.001 vs .030 ppm).

Snow surveys by the Soil Conservation Service reported the Gallatin drainage 6% above average, with the nearby Madison drainage 3% above average over 15 year periods. Snow pack was nearly normal for 1973, the year of the study.

METHODS

Care was taken to choose stations for sampling in areas that were similar in gradient and bottom material, so that these sampling stations should be hydrologically similar. Although Hughes (1966) concludes that illumination of stream bottoms has a minimal effect on aquatic populations, all sampling stations were in exposed areas in the stream or only partially shaded.

The sediment traps were standard size 16" diameter by 4" deep galvanized steel oil drain pans placed in the stream bed. All pans had a slight film of oil on them, and they were wiped clean with a rag dampened with ethyl alcohol. This procedure avoided contaminants which could adversely affect insect populations. Rocks having an axis of over eighty centimeters were selected from the stream bed, scrubbed clean of all mud and algae, and packed into the cans. A vegetable brush was used to clean rocks because iron or brass brushes would have left a metallic sheen on the rocks. Approximately the same sizes and composition of rocks were used in all pans. These precautions were taken to maintain as nearly a natural situation as possible and standardize results.

The pans were set into holes in the stream bed so that the open top of a pan was level with the natural stream bottom. The holes were dug with a fork spade and with the feet. A sealing top lid was placed over the prepared can of cleaned rocks; and the unit was set in the hole, leveled, and the material from the hole filled in around the outside of the can. The unit remained sealed for at least ten minutes and then was rechecked so material would not wash in from the disturbance of removing the lid. The lid was then removed and the set was complete.

A total of 13 cans was placed at each station, 12 for accumulative and one for a monthly sample. The cans were set in water four to eight inches deep beginning with the most upstream one first, then working downstream in a convenient pattern. No pan was nearer than four feet to another. All pans were set in an area where the streamflow was similar to that of the others in the same group and also the groups at other stations. A map was drawn to facilitate finding cans when snow or high water obscured them.

One accumulative and one monthly can was collected at each station about the first of every month. After the average water velocity over the top of the can at two inches was measured by a Gurley pygmy current meter, the sealing lid was clamped onto the can as it set in the stream bed, and the entire unit was lifted out. The farthest one downstream was taken first, then the next can upstream in the same manner. Each can's rocks were washed with the water in their can and the remaining gravel, mud, and insects were poured into an appropriately labeled plastic container. These contents were immediately preserved with 20-50 ml of formaline, with the greater amounts being used if much

The rocks from the upstream cumulative sample pan were placed in the hole left by its removal to retain the level riffle characteristic of the sampling station area. The rocks of the farthest downstream pan were repacked into the same can and reset according to the original method into the same hole to be repeatedly used as a monthly sample. The cumulative cans upstream revealed the accumulation of sediment and insects through the year and were not reset. Samples were processed within one week at the laboratory in Bozeman. In some cases cans could not be collected in winter due to several feet of ice cover. The monthly samples were reset in midstream in winter with the original methods so a sample could be obtained in mid-winter. In some areas, severe freezing made this impossible.

The steel cans used for sediment traps had a capacity of twelve liters, while sediment mixture was consistently four liters. Thus, the volume of prepared rocks in the cans was about eight liters. The uniformity of cobble sizes used in packing the cans explains this consistency (Granton and Fraser, 1935). The plastic containers used had a wide mouth, sealing lid, and a capacity of five liters. They were inexpensive and adequate for storing the mixture. However, small rocks which had come in with the bedload during spring runoff had to be kept separate or the container would overflow.

In the laboratory, the sediment mixtures in the plastic containers were separated into size classes of materials by wet sieving through standard screens of sizes 10, 20, and 40. The field material was passed through, hand agitated, and rinsed if necessary. Even though this was difficult in the finer screens, field material was never ground through because of the insects in it. Precautions were taken to catch overflow and reduce sediment loss, and by observation practically none of the silt fraction was lost in sieving. This loss of sediment occurred only when over one thousand grams of material was processed and its loss was not considered significant. Material finer than the 40 sieve was obtained by settling for one hour and decanting. Standard Methods (APHA, 1970) defines unsettleable matter as that which remains suspended after one hour; this material was discarded.

Aquatic insects were picked by hand from the 10 to 20 sieves. Each load was washed into a white enameled pan to render the insects more visible. The insects were removed and labeled for later classification, and the remaining matter was set aside for oven drying. Standard Methods (APHA, 1970) states that 30 mesh is considered the minimum for screening aquatic insects. In spite of the gentle agitation of the sieving process and frequent insect picking sessions amounting to several per single sediment can, much breaking up of insects was common. No insects were found in the 30 mesh which was used May through August, some in the 20, and over half were in the 10 mesh screen. When insects were broken, half an insect was considered a whole one. The only fish encountered, sculpins, were recorded separately.

The material remaining after insects and fish were removed was kept in its respective size classes and dried in a hot air oven at 65° C for at least 48 hours. All material had to be dry by sight, smell, and touch. All larger fragments of organic matter were broken to assure the inside was dry also. The clay-silt fraction (finer than 40 mesh) was ground with a mortar and pestle when dry to sight and touch and then dried an additional day. Frequent weighing for constant weight showed this was an accurate method for assuring samples were completely dry. Jackson (1956) recommended material be air dried at 55° C for 48 hours.

Samples were weighed to the nearest .01 gram except for sample sizes over 500 grams, where the measurement was to the nearest .1 gram. Care was used to pour the sample into the weighing containers slowly and carefully so that grains were not lost nor excessive fly dust created. The containers were rapped five times to shake clinging dust free.

The weighed oven-dry samples were then transferred to pyrex breakers and burned in a muffle furnace at 350-400° C for 8-10 hours. This is the accepted temperature for removal of carbon without volatilizing nitrogenous and other inorganic compounds (Jackson, 1956). As an experiment, one sample was recorded after burning and then burned again over a weekend; the difference was less than .1 gram in a 100 gram sample, so burning time was apparently adequate. Ash was considered negligible and the difference in weight after burning was regarded as the weight of organic matter.

RESULTS AT SNOWFLAKE STATION (SF)

An examination of the sizes of particles at Snowflake Station (Table 1) indicated that a greater weight of smaller particles was common in the traps sampled on a monthly basis, except during runoff when only heavier particles could settle. The cumulative traps more commonly held a greater proportion of pebbles than the monthly traps. Except for during the runoff period, silt always was the heaviest portion of the total sediment in all traps.

In monthly traps, the amount of sediment accumulated in the Snowflake area decreased slowly from summer to midwinter and rose slowly again until the spring runoff in May (Fig. 2). It then increased rapidly in May and peaked in July. The cumulative traps showed a slight increase over winter and a slight decrease in total weight of sediment as current speed increased slightly before the rain spring runoff period, when the highest weight of sediment occurred. During this May-June period, all sediment traps were filled completely due to the relatively heavy sediment load associated with the high water. During July and August following, the traps accumulated the same per month as before in August 1972.

The actual weight of organic matter (Fig. 3) essentially parallels the total sediment weight (Fig. 2). The percentage is high (16-5%) in the fall of both years (Table 1), and low (3-1%) during the runoff.

A similar pattern of percentage of organic matter is seen in the