The effect of stream flow on the local distribution of mayfly nymphs (Insecta: Ephemeroptera)

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THE EFFECT OF STREAM FLOW ON THE LOCAL DISTRIBUTION OF MAYFLY NYMPHS.

(INSECTA: EPHEMEROPTERA)

by

Joe Linduska

B. A. Degree, Montana State University
Missoula, Montana, 1936

Presented in partial fulfillment of the requirement for the degree of Master of Arts.

Montana State University

1936

Approved:

Chairman of Board of Examiners

Chairman of Committee on Graduate Study
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The author wishes to take this opportunity to express his sincere appreciation to Dr. Gordon B. Castle, of the Department of Zoology, for directing this research. His interest and supervision were a source of much encouragement during the progress of this study. Thanks are also due Dr. L. G. Browman, of the Department of Zoology, for his suggestions and kindly criticisms during the course of the work.
The Effect of Stream Flow on the Local Distribution of Mayfly Nymphs.

(Insecta: Ephemeroptera)

Introduction:

Of the several orders of insects which inhabit mountain streams, the Ephemeroptera usually are most abundant. In the majority of streams in western Montana, the nymphs of this order are the dominant animals present both in numbers of individuals and in numbers of species. The specialization shown by most of the species suggests adaptation to different environmental conditions. They are of major importance as a food for fish, and for this reason, practical application can be made to fish culture work of ecological studies of this group.

The object of this study has been to investigate the importance of the swiftness of the current on the local distribution of mayfly nymphs. The rate of flow of water has been considered the primary physical factor governing the distribution of aquatic organisms by most earlier workers. The importance attached to this factor is evidenced in the following quotations. Sunder Lal Bora (1929, p. 190) says, "Having discussed the chief characters of the various genera in relation to environment, it is now possible to correlate them with the flow of water, the chief factor in the environment." In summary (pp. 174-175) he states, "of the physical conditions that influence the ecological distribution of the torrential fauna the principal one is the rate of flow of the current. The high percentage of oxygen in the water is another important factor, but is dependent on the current to a very great extent. Shallowness and low temperature of the water are also of some importance." The morphological
adaptations of several groups of Ephemeroptera to various conditions of stream flow have been discussed by other workers, notably Dodds and Hiasaw (1924), Hora (1929), Needham and Christenson (1927) and Needham, Traver and Esu (1935). Clemens (1917), in his study of Chironomus albomanicatus, has shown the reaction of that species to various conditions of stream flow and bottom type. During the course of this study it was observed that the type of bottom seemed to have an influence on the distribution of a number of species. These observations are incorporated in Table 3 and further discussed under the discussion on the distribution and habitat of the commoner species taken.

Description of Stream

Rattlesnake creek, the site of this study, originates about 14 miles from the point where it enters the Clark Fork of the Columbia river. It is formed by two main forks and a number of small tributaries, many of which dry up during the late summer months. A portion of the southward extension of the Mission range known locally as the Missoula hills, is drained by one of the forks. The other fork extends about five miles northeast and drains the northern face of Sheep mountain.

The flow of the stream is variable and during the summer, fall and winter months is characterized by wide, moderately flowing stretches or shallow ripples followed by a cascade or an area of rapid descent where the water passes through a narrowed bed. During the spring months a rise of 3-4 feet is usual and at this time the stream is torrential throughout most of its course. The canyon floor over which the creek flows is irregular and more places of torrential flow are to be found
Fig 1
than the average fall of 100 feet to the mile indicates.

The water is clear except for a period of one to two months during the spring run-off. Low temperatures and high oxygenation is maintained, especially in the higher reaches, since the flow originates in cold springs and from the melting of snow which may remain until early summer.

With the exception of a small reservoir about 200 by 500 yards in size, the stream has been preserved in a natural state. The dam, which furnishes water to the city of Missoula, is located about three miles from the outlet of the creek. It is not of sufficient size or height to be an effective barrier to flight of adult mayflies, but preliminary observations have shown that the water is warmed so that a higher average temperature results below this point.

The lower quarter mile of the stream which flows through Greenough park and the city of Missoula has been rip-rapped. With the exception of a few collections made at upper Greenough park this area was not worked over because of the existence of these artificial conditions.

Four general regions, chosen primarily because of accessibility, comprised the total area studied. Since later references will be made to these regions the general location of each is given.

Region 1. Fig. I. 1

The area included in this region extended from the bridge at the north end of Greenough park which is about one-fourth mile from the mouth of the stream to a point about one mile up-stream. The stream in this region is in many ways characteristic of the stream in general but is somewhat less shaded than the higher portions. Points of torrential flow
while present are not as common as in the higher parts of the stream. The creek bed in this region is generally broader, resulting in numerous shallow ripples and a bottom composed of gravel and small stones with occasional large rocks and boulders. More precipitated organic material is found in this region than in any of the other three. Plate 1.

Region 2. Fig. 1, 2

The vicinity designated as Region 2 is an area about two miles long and is up-stream from the first bridge above the north end of Greenough park and is locally known as Orr’s dale. This region lies below Rattlesnake dam as does Region 1. The stream bed is much like that in the first region. The bottom is characteristically rubble and small rock with boulders scattered and occurring mainly in the channel of deep rapids.

Region 3. Fig. 1, 3

This area lies upstream from the first bridge, Sawmill Gulch Bridge, above the Rattlesnake dam in an area known as Lalu park. Some of the swiftest portions of the stream studied were located in this region. It is here that the creek begins to narrow down and cascades and shallow falls become evident. The creek bottom from this point on upstream is generally rough and irregular. Boulders and large rock fragments are predominant in most of the stream bed with gravel and rubble being found along the stream’s edge and around the base of boulders.

Region 4.

This area lies about three-fourths of a mile above station 3 and just below the point where Rattlesnake creek enters the canyon. The creek bed is the same as in Region 3 with sharp rock fragments and large
boulders making up a large portion of the bottom. Flat rock ledges are evident in parts of the stream bed and in places sheer rock walls contrast with the low dirt banks of the lower stream. A relatively small number of collections were made in this region because of the inaccessibility of it during the early part of the year when most of the study was in progress.

Plate 1.

Shallow ripple of Region 1 during low water.

Plate 2.

Rapid of Region 4 during low water.
Equipment and Methods:

A number of collections were made during the spring and summer of 1936. An analysis of these collections in connection with the present study showed the species present at these times of the year to be in about the same order of abundance as they occurred in the present study. The creek is low and frozen over during most of the winter and consequently a study during these months is impracticable. The present field work was carried out during the months of February, March, and April and the creek during this period presented conditions varying from extremely low water during the month of February to moderate flood stages during the second week in April. Collections were made over as varied conditions of depth, bottom type and stream speed as could be found.

The instrument used in measuring the stream speed was Price's acoustic current meter, model 616, manufactured by W. and L. E. Curley, Seattle, Washington. The rubber sounding tube with which the instrument was equipped was replaced with a four and one-half foot length of one-half inch pipe which was marked off in inches and feet. The pipe allowed holding the meter in a given position, eliminated the necessity for ear phones in recording the clicks, and being calibrated, the stream speed and depth were measured in a single operation. The meter is a factory standardized instrument, guaranteed accurate to one-tenth foot per second. The procedure followed in taking the bottom velocity was varied at times to give a better indication of true bottom speed. When large boulders occurred over the proposed collecting site, the measurement was made on the bottom at the sides of the boulders. Clemens (1917) has shown
the influence of the bottom in controlling the rate of flow and has shown the water velocity under and directly behind stones to be considerably less than at the surface of the same stone. Numerous measurements of the stream velocity around and behind stones were made during the course of this work and the results obtained agree with those secured by Clemens. In no instance was the bottom speed found to be in excess of three feet per second.

The net used in taking the insects was of original construction and so designed that it was possible for one person to make collections in swift water. The copper screen used in construction of the net had twenty meshes to the inch.

Plate 3.

Observations on the species, their position on boulders or on the bottom and relative abundance were made and recorded. In addition to observations made in the course of collecting, several trips were made for the sole purpose of observation. A three and one-half by seventeen inch preserving jar which was darkened by pasting strips of black carbon paper over the inner surface for the full length proved quite satisfactory for making underwater observations. At the beginning of
each collecting trip, general weather conditions were recorded and air and water temperature taken. The procedure used in making collections was as follows: the stream flow meter was lowered to the bottom and held in this position until ten clicks, representing 100 revolutions of the propeller, were counted. The interval elapsing during this period was timed with a stop watch. The meter was then raised to a point about one inch below the surface and the stream speed at this point obtained. The collection was then made by placing the net two to three inches directly behind the point measured for velocity and depth; the bottom directly underlying the point where the determinations were made was churned by hand, and the insects dislodged were taken in the net. Any large stones present were examined and picked by hand.

No exact quantitative measures were followed in making the collections, but the bottom area sampled was of a comparable size in all instances, being about sixteen inches wide and two feet long. All the nymphs taken in the collection were counted so that a check on relative abundance might be had. Type of bottom and other pertinent facts were recorded for each collection. All the specimens taken at this time were preserved in seventy per cent alcohol. With a few exceptions all the material collected was determined to species and those about which there was doubt were sent to systematists specializing on this group. Specific determinations were not made by these men and it is possible that this material is undescribed. The relatively small amount of work that has been done on the taxonomy of mayflies in Montana and the west in general proved to be a severe handicap when specific determinations and distribution
records were sought. The number of undetermined species was not great enough, however, to seriously affect the final results.

Results:

During the course of the investigation, 92 collections were made and from this material 18 distinct species were determined. In addition three other forms were taken which may or may not represent different species. These additional specimens were not taken in sufficient numbers to establish their true identity and hence are not included.

List of species collected: Cinygmula sp., Leptophlebia adoptiva HcD., Ephemerella doddii Needham, Ephemerella inermis Eaton, Ephemereella yosemita Traver, Ephemereella sp., Ephtherognos virilis HcD., Ephtherognos doddii HcD., Ephtherognos sp., Ameletus velox Dodds, Iron longimanus Eaton, Ironopsis sp., Ironopsis grandis HcD., Baetis varans HcD., Baetis sp. (rusticana?), Baetis bicaudatus Dodds, Baetis intermedius Dodds, Baetis sp. With the exception of Ameletus velox, which was taken in only two collections, the above species were taken quite consistently.
Table 1  12 commonest species arranged in order of abundance, as they occurred in collections from Regions 1 and 2, and 3 and 4.

<table>
<thead>
<tr>
<th>Region 1 and 2</th>
<th>Region 3 and 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cinymula sp.</td>
<td>A</td>
</tr>
<tr>
<td>2. Ephemerella inermis</td>
<td>A</td>
</tr>
<tr>
<td>3. Ephemerella yosemiti</td>
<td>A</td>
</tr>
<tr>
<td>4. Ephemerella doddsi</td>
<td>C</td>
</tr>
<tr>
<td>5. Rhithrogena doddsi</td>
<td>C</td>
</tr>
<tr>
<td>6. Leptophlebia adoptiva</td>
<td>C</td>
</tr>
<tr>
<td>7. Bactis intermedius</td>
<td>C</td>
</tr>
<tr>
<td>8. Rhithrogena virilis</td>
<td>C</td>
</tr>
<tr>
<td>9. Iron longimanus</td>
<td>F</td>
</tr>
<tr>
<td>10. Ephemerella sp. (near cognata)</td>
<td>P</td>
</tr>
<tr>
<td>11. Bactis vagans</td>
<td>P</td>
</tr>
<tr>
<td>12. Ironopsis sp.</td>
<td>P</td>
</tr>
</tbody>
</table>

A - Abundant. Averaging over 25% of total organisms in each collection.

C - Common. Averaging 10 - 24% of total organisms in each collection.

P - Present. Averaging less than 10% of total organisms in each collection.

* - Not taken in regions 3 and 4.

** - Relative abundance determined by making an equal number of collections over all velocity ranges (0-8 ft. per sec.) in regions 1, 2 and 3, 4.

Table 1 shows the twelve commonest species found, listed in order of abundance as they occurred in the four regions studied. Since no significant differences in distribution were found between regions 1 and 2 and between regions 3 and 4, it is convenient to group the two lower stations and the two higher ones and present the data for the four regions under two headings.

The most significant difference in the population of the two areas is shown by the relative numbers of Ephemerella yosemiti taken in the two areas. This species ranked third in abundance in regions 1 and 2, but it
was not taken at all in regions 3 and 4. The absence of this nymph in regions 3 and 4 can hardly be attributed to differences in stream velocity since an equal number of collections were made over all velocity ranges (0-8 feet per second) in regions 1, 2 and 3, 4. *Ironopsis* sp., taken only sparingly in regions 1 and 2 and occupying twelfth place on the list of the twelve commonest species for this area, is the dominant species in the higher regions 3 and 4.

The difference in relative abundance of *Cinygma* sp. between the two areas is greater than Table 2 might indicate. In regions 1 and 2 it proved to be about two times as plentiful as all the other species combined, yet in regions 3 and 4 it is but seventh in order of abundance and a few collections made some distance above region 4 indicated it might be entirely absent in this higher area. The gradual elimination of this species as well as *Ironopsis* sp. and *E. yosemite* cannot be attributed to stream speed since identical conditions of stream velocity occur through all of these regions.
Table 2  10 commonest species, in order of abundance, as they occurred under various stream velocities

<table>
<thead>
<tr>
<th></th>
<th>0-1.9 ft. per sec.</th>
<th>2-3.9 ft. per sec.</th>
<th>4-5.9 ft. per sec.</th>
<th>6-8 ft. per sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Cinygmula sp.</td>
<td>A Cinygmula sp.</td>
<td>A Rhithrogena doddsi</td>
<td>C Ironopsis sp.</td>
<td>A</td>
</tr>
<tr>
<td>2. Ephemera yosemita</td>
<td>C Ephemera inermis</td>
<td>C Ephemera inermis</td>
<td>C Ephemera doddsi</td>
<td>A</td>
</tr>
<tr>
<td>3. Ephemera inermis</td>
<td>C Leptophlebia adoptiva</td>
<td>C Ephemera doddsi</td>
<td>C Rhithrogena doddsi</td>
<td>C</td>
</tr>
<tr>
<td>4. Leptophlebia adoptiva</td>
<td>C Ephemera doddsi</td>
<td>C Cinygmula sp.</td>
<td>C Cinygmula sp.</td>
<td>C</td>
</tr>
<tr>
<td>5. Rhithrogena doddsi</td>
<td>C Rhithrogena doddsi</td>
<td>C Ironopsis sp.</td>
<td>C Rhithrogena virilis</td>
<td>C</td>
</tr>
<tr>
<td>6. Ephemera doddsi</td>
<td>C Ephemera yosemita</td>
<td>C Rhithrogena virilis</td>
<td>C Ephemera inermis</td>
<td>C</td>
</tr>
<tr>
<td>7. Rhithrogena virilis</td>
<td>C Bactis intermedius</td>
<td>P Ephemera yosemita</td>
<td>Leptophlebia adoptiva</td>
<td>P</td>
</tr>
<tr>
<td>8. Bactis intermedius</td>
<td>P Ephemera sp. (near cognata)</td>
<td>P Leptophlebia adoptiva</td>
<td>Iron longimanus</td>
<td>P</td>
</tr>
<tr>
<td>10. Ironopsis sp.</td>
<td>P Ironopsis sp.</td>
<td>P Bactis intermedius</td>
<td>P Bactis intermedius</td>
<td>P</td>
</tr>
</tbody>
</table>

A - Abundant. Averaging over 25% of total organisms in each collection.

C - Common. Averaging 10 - 24% of total organisms in each collection.

P - Present. Averaging less than 10% of total organisms in each collection.

* Velocities given are maximum surface velocities.

Data taken from all collections made in Regions 1-4.
Table 2 shows the distribution of the organisms in various stream speeds. The ten commonest species found in each stream speed are listed in order of abundance. It is interesting to note that of the eighteen species taken, the ten found to be most abundant for surface speeds of 0-1.9 feet per second are also the ten most abundant where the surface velocity reaches six to eight feet per second. Furthermore, the ten dominant species in the 0-1.9 feet per second speed are, with a single exception, the ten most abundant in all the speeds measured. In fact, for speeds from 0-5 feet per second there is no significant change in order of abundance. It will be noticed from the table, however, that there appears to be several significant changes in relative abundance in the collections made at six to eight feet per second velocities over those made at 0-4 feet per second speeds. *Ironopsis* sp., for instance, is the dominant nymph in six to eight feet per second speeds whereas it is tenth in abundance at 0-1.9 speeds. Unfortunately more of the collections in five to eight feet per second velocities were made in Regions three and four where *Ironopsis* was the dominant species of the stream, since these velocities were somewhat commoner in the higher reaches. Furthermore, most of the 0-4 feet per second collections were made at the lower regions which further accentuates this difference which appears to be caused by velocity differences.
Table 3. General observations on the commoner species and where they were found in greatest numbers.

<table>
<thead>
<tr>
<th>Species</th>
<th>Preferred habitat (Bottom type)</th>
<th>Position in habitat</th>
<th>Approx. velocity range in habitat (ft. per second.)</th>
<th>Surface velocity over habitat (ft. per second.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cinyrella sp.</td>
<td>Rock-rubble bottom. Avoided gravel and boulder bottoms.</td>
<td>Under stones.</td>
<td>0-3</td>
<td>0-3</td>
</tr>
<tr>
<td>Ironopsis sp.</td>
<td>Small rock-boulder bottom.</td>
<td>Mostly on underside of rocks. Moved freely over boulder surface.</td>
<td>0-3</td>
<td>0-3</td>
</tr>
<tr>
<td>Ephererella yosemiti Traver</td>
<td>Rubble bottom in shallow ripple with organic debris.</td>
<td>On and under organic material.</td>
<td>0-3</td>
<td>0-5</td>
</tr>
<tr>
<td>Ephererella doddai Needham</td>
<td>Deep rapid, clean bottom. Smooth rocks and boulders.</td>
<td>Common on under side of rocks. Observed on sides and top of boulders.</td>
<td>0-4</td>
<td>0-8</td>
</tr>
<tr>
<td>Ephererella inornis Eaton</td>
<td>Gravel-large rock bottom when trash present.</td>
<td>In gravel and trash around base of boulders. Not on boulders.</td>
<td>0-2</td>
<td>0-8</td>
</tr>
<tr>
<td>Ephererella sp.</td>
<td>Gravel-large rock bottom when trash present.</td>
<td>In gravel and trash. Occasionally between rocks.</td>
<td>0-3</td>
<td>0-3</td>
</tr>
<tr>
<td>Phithrogosa virilis McD.</td>
<td>Rubble beds around base of boulders. Clean bottom.</td>
<td>Moved about quite freely.</td>
<td>0-4</td>
<td>0-8.25</td>
</tr>
<tr>
<td>Phithrogosa doddsi McD.</td>
<td>Rock-boulder bottom.</td>
<td>On and under stones.</td>
<td>C-4</td>
<td>0-8</td>
</tr>
<tr>
<td>Leptoplebia adoptivis McD.</td>
<td>Large rock bottom.</td>
<td>Behind and under stones.</td>
<td>0-2</td>
<td>0-8</td>
</tr>
<tr>
<td>Iron longirostris Eaton</td>
<td>Stream's edge. Silt covered rocks.</td>
<td>On and under stones.</td>
<td>0-3</td>
<td>0-8</td>
</tr>
<tr>
<td>Raedii intercali Dods</td>
<td>Stream's edge. Silt covered rocks. Also in swifter regions.</td>
<td>On and under stones. Occasionally on boulder surface.</td>
<td>0-3</td>
<td>0-8</td>
</tr>
<tr>
<td>Raedii vagans McD.</td>
<td>Large rock bottom.</td>
<td>Free ranging. Occasionally on boulders.</td>
<td>0-2</td>
<td>0-8</td>
</tr>
</tbody>
</table>

The term rubble as used here refers to size rather than shape and character. The size being an intermediate of gravel and rock, about fist size.

The words rock and stone are used interchangeably and signify rock pieces 3-12 inches in width.
Local distribution and habitat of the commoner species collected.

*Cinygmula* sp.

This nymph though resembling *Cinygmula* *ramaleyi* Dodds differs mainly in size and coloration. Subsequent collection and examination of adult material may show it to be *C. ramaleyi* but the study of a considerable number of nymphs seems to warrant a distinct ranking.

This nymph showed quite a general distribution and was taken from beneath stones on the bottom in a variety of environments and stream velocities. It was by far the most abundant species in most of the stream and was taken in nearly all collections and over a range of surface velocities of 0-8 feet per second. This was by far the predominant species in stations one and two. It was observed that it diminished in numbers in collections made upstream until at station four it was but rarely taken. Since the insect is taken only on the bottom beneath stones where stream current is negligible, its great decrease in numbers and apparent absence from collections made above region four must be attributed to some factor other than the action of stream flow.

No extensive study of the temperature differences in the stream was made during the course of this study. The temperatures taken were generally for but one station at each collection date and consequently any differences in temperature between stations cannot be evidenced from these records. However, preliminary records on temperatures taken in the summer showed the stations (1 and 2) below the dam to be from 1.5 to 4 degrees centigrade warmer than the stations above (3 and 4).

Ide (1935) has demonstrated the importance of temperature on mayfly distribution and the above observations made on *Cinygmula* sp. seems to
indicate a temperature reaction. The differences in relative abundance and in maturity seem to indicate that this species is nearing its threshold of development in the upper portions of the stream due probably to the lower average temperature existing in these regions. Whether this be true or not, it is obvious that stream flow in this instance is not important in governing the distribution of this species since conditions of stream flow allowing its presence are present throughout the course of the stream.

Ironopsis sp.

This nymph, taken so commonly in regions three and four, is very near Ironopsis grandis Mcl. The very noticeable difference in size, however, separates it from Ironopsis grandis, which is much the larger. Subsequent collection and study of adults may show it to be a small form of I. grandis but it is advisable, in the present discussion to give it a separate standing.

This nymph was taken in all water speeds from 0-8 feet per second. It was one of the few species taken which could be consistently seen on the top and sides of boulders where the stream flow was of appreciable velocity. In regions three and four, where it was by far the most abundant nymph, it could be observed pressed against the surface of boulders and maintaining itself in water flowing up to eight feet per second.

The number of insects observed along the tops of boulders where the water speed is high was small, however, compared to the much greater numbers found along the bottom in the same speed. In several instances, where this species was observed on boulders where the stream flow was
eight feet per second, a gradation in numbers from the top to the bottom of the rock was noticed. On boulders eighteen to twenty inches in height the greatest concentration of individuals on the rock was found as a rule to be about midway on the rock and invariably on the sides only. The current at this point was found to be from 2-4.5 feet per second. This nymph was also found abundantly in shallow water where a ripple existed and in this environment was found directly on the bottom. Small rocks lifted from the bottom in these shallow ripples showed the nymphs clinging to the under side.

The current-resisting power of this species of _Ironopsis_ lies in the modification of the gill lamellae to form a sucker. The first and last pair of gills overlap on the mid ventral line and the first pair is enlarged so they project well up under the thorax. The seven pairs of gills are somewhat enlarged and project posterior-laterally with each pair overlapping each succeeding pair. The body is considerably more flattened than in any other nymph taken.

The point of major interest observed in connection with this species is, that full advantage is not taken of its ability to inhabit rapidly flowing water. As has been pointed out, it can quite commonly be seen maintaining itself in currents up to eight feet per second, but the numbers found in such environments are insignificant when compared with numbers found on the bottom where the current is much slower.

_Ephemerella inermis_ Eaton

This small nymph showed quite a general distribution over the stream bed and was found on the bottom over a range of surface velocities,
of 0-8 feet per second. It was found in greatest abundance where shallow ripples precipitated an abundance of organic debris and, although it occurred on the bottom in very swift water, its presence there depended to some extent on the presence of organic material. It is strictly a bottom dwelling form and in no instance was it found to occur on the boulders, but only in the gravel and trash around the base.

**Ephemeroptera yosemite Traver**

This large nymph was taken quite generally in regions one and two. Its habits are much like those of *E. inermis* except that it was occasionally taken in deep swift water where the bottom was comparatively clean and free of debris. The preferred type of habitat, however, is a shallow ripple with an accumulation of organic material.

In the discussion of Table one the distribution of this nymph is pointed out. The complete elimination of this species from regions three and four is significant because it has taken place where identical conditions of stream flow exist for all four regions studied. The general distribution of this species in regions one and two, as regards stream flow, depth and bottom type, further emphasizes the fact that stream velocity is of no apparent significance in setting limits to the distribution of this species along the stream course.

**Ephemeroptera doddsii Needham**

A current-resisting organ of interesting structure is found in this species of *Ephemeroptera*. A disc of hairlike protuberances forms a ring around the entire lateral edges of the sterna and is complete anteriorly. This sucker is very efficient when the nymph is on a smooth surface, but
in spite of the potential ability of this nymph to move up rocks into levels of high velocity it was not observed to do so. It was found where the surface velocity measured up to eight feet per second but was always on the bottom or "stuck" on the side of a large boulder. The distribution of the "finger quill" was general both as to position in the stream bed and distribution along the course of the stream. It occurred in greatest numbers in clean bottomed deep rapids where it was most generally found clinging to the underside of stones. It is the only species of Ephemereilla taken which avoided regions rich in precipitated organic material.

Ephemereilla sp. (near cognata)

This small bluish nymph of the serrata group had a general distribution over the stream bed in all velocities and its position appeared to be governed mainly by the presence or absence of trash on the bottom. It was observed only on the bottom around the trash and between stones.

Ephithopogena virilis McD.

This nymph is another of the strictly bottom dwelling types. In no case was it found to climb up the boulders around the bases of which it usually occurred. It was taken on the bottom in a range of velocities of 0-6.25 feet per second. The gills in this species project laterally and overlap to form an adhesive device comparable to that found in Ironopsis sp. The gills are smaller in size than those found on Ironopsis sp., however, and in general do not appear to form as efficient a disc as is found in that species. Its distribution over the course of the stream and its position in the stream bed is general. It was taken more often
in the rubble beds occurring around the bases of large boulders.

*Rhithrogena doddsi* McD.

The gills of this form are modified to form a sucking disc as in the preceding species. These nymphs show a general distribution in the stream bed but show preference for somewhat different bottom types than do that of *R. virilis*. The greatest numbers were found adhering to the surface of large rocks in both shallow and deep water. The nymph moves freely about over the bottom and along the base of large stones but was not observed to venture upward into the swift water near the surface.

*Leptophlebia adoptiva* McD.

This nymph occurred throughout the course of the stream studied and was found on the bottom in all surface speeds (0-8 feet per second). The extremely fragile nature of this nymph and the fact that it was taken from the bottom where the surface speed was torrential illustrates the small part stream speed seems to have in governing the distribution of mayfly nymphs. The gills on this species are very delicately articulated to the body. Preserved material of this species demonstrates this fact since but very few complete specimens can be found in the several vials of specimens. In spite of this fact, the insect by keeping to the bottom and moving along behind and under stones is able to invade portions of the stream where the top flow is extremely swift.

*Iron longimanus* Eaton

Although showing no striking modifications to sustain itself in swift water, this was another of the few nymphs observed which occasionally left the bottom and took a position on rocks and boulders where it was directly
exposed to water speed of two to three feet per second. The gills on
this nymph are somewhat enlarged but neither the first nor last pair
meet at the mid line as has been described for *Ironopsis* sp. The first
pair of gills point almost directly backward and are not enlarged anter-
iorly so as to project back under the thorax as was the case in
*Ironopsis* sp.

Its distribution over the course of the stream and in the stream
bed showed no limits. Great numbers of these nymphs were occasionally
taken in region one near the edge of the stream where the stream flow
was less than two feet per second. Some precipitated material was
usually present in this preferred situation and the nymphs in these
cases were on the bottom and clinging to the underside of stones.

*Baetis intermedius* Dodds

This was the commonest *Baetis* nymph taken and although it never
occurred in great numbers its very general distribution was striking.
It was observed on the surface of boulders resisting water speeds of
five to eight feet per second and was taken from the bottom in the same
situation. Shallow ripples consistently yielded a few in each collection
made. The data obtained during this investigation, however, indicates
that little advantage is taken of this ability to invade the swift flow-
ing water, and regions of moderate depth and flow are the preferred habi-
tats. The nymph was found in greatest abundance associated with *Iron
longimamus* in areas described as being most heavily populated by this
species, i.e., along the stream edge where a depth of eight to twelve
inches, gentle flow, and rocks sparsely covered with silt, characterized
the area.
Dodds and Eisaw (1924) and Sunder Lal Hora (1929) in their studies of torrential streams observed *Bactis intermedius* Dodds living in water flowing as much as eight feet per second. During the present study confirmatory observations have been made on this species. Further observations of considerable interest show the nymph to be surprisingly agile under such extreme conditions. Stimulation, by gentle probing, proved they were capable of rapid but limited movement over the surface of the boulder. The body was always kept parallel to the current and movement was invariably at an angle, seldom straight forward, backward or sideways.

This study has shown the number of nymphs in such a situation to be small. Far greater numbers are found on the bottom where conditions are not so severe. The well developed powers of retention in this species appears to be but little used.

*Bactis vagans* McD.

This *Bactis* was usually found in collections which also contained specimens of *Bactis intermedius* and *Iron longimanus*. The three species were commonly found together. This nymph and *Bactis intermedius* were undoubtedly the most active nymphs taken and they could be seen darting about the bottom and crawling over the stones. The distribution over the bottom was general but they were never observed to maintain themselves in the water speeds which *Bactis intermedius* and *Iron longimanus* occasionally invaded.

Discussion:

This study has indicated that stream flow, as such, is not a primary
factor governing the distribution of mayflies in a stream. The foregoing observations seem to warrant this conclusion, principally in two ways. First, it has been shown that a complete elimination of one species and a partial elimination of two others has taken place in parts of a stream even though identical conditions of stream flow were present in both areas; second, it has been demonstrated that a number of species not morphologically adapted to maintain themselves under torrential conditions were, nevertheless, able to invade parts of the stream where the flow was torrential by keeping to the bottom and avoiding the full force of the flow.

Ide (1935) p. 69 (under discussion and conclusions) says, "In the alpine stream there are two main factors, the swiftness of the current and the temperature of the water, both of which will exclude certain elements of the fauna from the streams and both of which will be tolerated by other elements. Oxygen content of the water, in cases where it is variable, will also be important. Thus an insect very well adapted to hold its position in the current might not be able to survive in cold water at the higher altitudes, and hence would not be able to extend its range there. On the other hand, a species might be well adapted to the temperature conditions of the torrent streams but not morphologically adapted to maintain itself in the swift water, and so could not extend its range. But if there were a place in the stream where the water was less swiftly flowing, and there are probably many such places, such a species could maintain itself here and so on up to the highest altitudes. The insect taken in our first example could not possibly find a suitable
location at the higher altitudes unless the source of the water were some hot spring. The temperature reaction of the organism, therefore, seems to be of primary importance to the population of alpine streams, and morphological adaptation secondary." This study has shown that there are many places in torrential flows where the water is less swiftly flowing and that these places are utilized by many species in making up the mayfly fauna of such a stream. It has been further shown that in a rough-bottomed, torrential stream such as Rattlesnake creek, the entire bottom presents a region of moderate flow, so that even species entirely lacking in morphological adaptation to maintain themselves in swift water, are nevertheless able to populate such a stream. The conditions existing on the bottom and between stones are quite constant in all parts of the stream which might explain the general distribution of most of the species studied.

The elimination of one species from the upper portions of the stream and the great differences in the numbers of two more species between the upper and lower regions of the stream might also be explained on the basis of the work done by Ide. The lower portion of Rattlesnake creek was found to average several degrees warmer in summer than the higher region and it appears that this temperature difference may be the primary factor setting limits to the distribution of mayflies.

During the course of the study a number of species were observed which are morphologically adapted to maintain themselves in torrential water. The number of individuals of these species found in such stream speeds was low, however, when compared to the far greater numbers of the same
species found on the bottom where the current was negligible. Clemens (1917) in his study of Chirotenetes albomarginatus Needham found that even though this nymph could maintain itself in velocities of 4.5 feet per second, "the nymphs live in a very much diminished current beneath the stones and rubble of the stream." He further states, "the nymphs of Chirotenetes show a very decided habitat preference for the lower surfaces of stones and rubble as against small stones." It appears then, from the data of Clemens and also from the present study that this ability to withstand a strong current is little used and any advantages derived from these adaptations are apparently of small importance.

The positions habitually or occasionally assumed by the various species over the creek bed have been described under separate discussions of the commoner species taken. It has also been pointed out that the preferred position for all the species is on or near the bottom where the current is greatly reduced. The relative ability of the various species to invade swift water is, however, impressive and was shown to a good advantage in several instances. Observations made on large boulders in torrential parts of the stream showed that localization of various species on boulders was quite constant in nearly all cases. The top surface of the boulder, for instance, would be inhabited by nymphs of Ironopsis sp., Baetis intermedius and Baetis bicaudatus. The stream velocity at this point might be from five to eight feet per second. These species might have had a general distribution over the rock surface but were the only ones found on the top of the boulder where the
speed is greatest. Midway on the sides of the boulder, where the stream speed might measure from two to four feet per second would be found species of *Iron longimanus* and *Ephemera doodsi*. These two species could occasionally be seen near the surface of the boulder but on the down stream side where the current was negligible. The nymphs of *Rhithrogena doodsi* and *Baetis vagans* if found on the boulder were confined to the lower sides where the current did not exceed two feet per second. The nymphs of the remaining species were invariably taken only on the smaller stones on the bottom and between and under the stones around the boulder. Nymphs of *Cinygmula* sp., and *Rhithrogena virilis* were observed only on the bottom between and under stones. Nymphs of *Ephemera inermis* and *E. yosemita* occupied the trash and silt which usually gathered around the base of boulders. This zonation of species demonstrates the part stream speed plays in bringing about what might be termed vertical distribution due to varying degrees of ability of different species to withstand current. It is apparent then that even though stream velocity has little direct effect on limiting the mayfly fauna of a stream, it is of primary importance in determining the position some species can occupy in the stream.

Summary:

1. The speed of the current, as such, is not a primary factor governing the local distribution of mayfly nymphs.

2. Species not morphologically adapted to maintain themselves in swift water are, nevertheless, able to invade regions of torrential flow by keeping to the bottom where the water velocity is greatly reduced.
3. Other species observed to be capable of holding fast in swift water were found in far greater numbers on the bottom and behind and under rocks, indicating a pronounced preference for these less severe environments.

4. The complete elimination of one species and partial elimination of two others from portions of the stream where identical conditions of stream flow prevailed, indicates some factor other than water velocity to be of paramount importance in their distribution.

5. No significant change in the fauna of environments of highly different water velocities in any one region was evidenced.

6. Most of the species studied, while not entirely limited to a given bottom type, did show a decided preference for certain conditions apparently associated with particular bottom types.
Literature Cited


Dodds, G. S., and F. L. Hisaw, Ecological Studies of Aquatic Insects.


