1944

An investigation of the behavior of trichopterous larvae

John W. Adams
The University of Montana

AN INVESTIGATION OF THE BEHAVIOR

OF TRICHOPTEROUS LARVAE

by

John W. Adams

B.A., Intermountain Union College, 1933

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

Montana State University

1944

Approved:

Gordon B. Castle
Chairman of Board of Examiners

Charles W. Waters
Chairman of Committee on Graduate Study

AN INVESTIGATION OF THE BEHAVIOR OF TRICHOPTEROUS LARVAE

A THESIS

PRESENTED TO

the Faculty of the Department of Zoology

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

John W. Adams

May 22, 1944

TABLE OF CONTENTS

Among the aquatic insects, few attract more attention in the larval stage than the Trichoptera. These forms, found in both quiet and flowing waters, are of interest because of the portable cases built by the larvae of the majority of the species.

Much of the literature concerning these insects has dealt with the larval cases, emphasizing their protective value. Lutz (1932) and Dodds and Hisaw (1925) state that there is a correlation between the shape, size and composition of each case and the swiftness of water in which it is found. Milne (1938) suggests that the cases are important in respiration. A naked larva waving its abdomen up and down, churns the water in its immediate vicinity without bringing fresh water to it. When in a case, the larva is continually bathed in a current of fresh water created by this motion. This motion is also important in obtaining food since the current it creates brings with it planktonic portions of its environment.

In commenting on the importance of current in the distribution of the larvae, Dodds and Hisaw (1925) drew the following conclusions:

1. The case rather than the body, exhibits the peculiarities of form which fit each species for its environment.

2. The size, form and material of the cases are the chief factors in relation to the strength of the current.

3. Absence of portable cases must be considered an adaptation to swift water.

4. Most species living in swift streams live there in spite of the mechanical force of the current, rather then because of it.

5. Some species in swift water not only tolerate the current, but have utilized it in such a way as to make it necessary for their existence.

6. Secondary effects of current are important factors in determining distribution of caddis fly larvae.

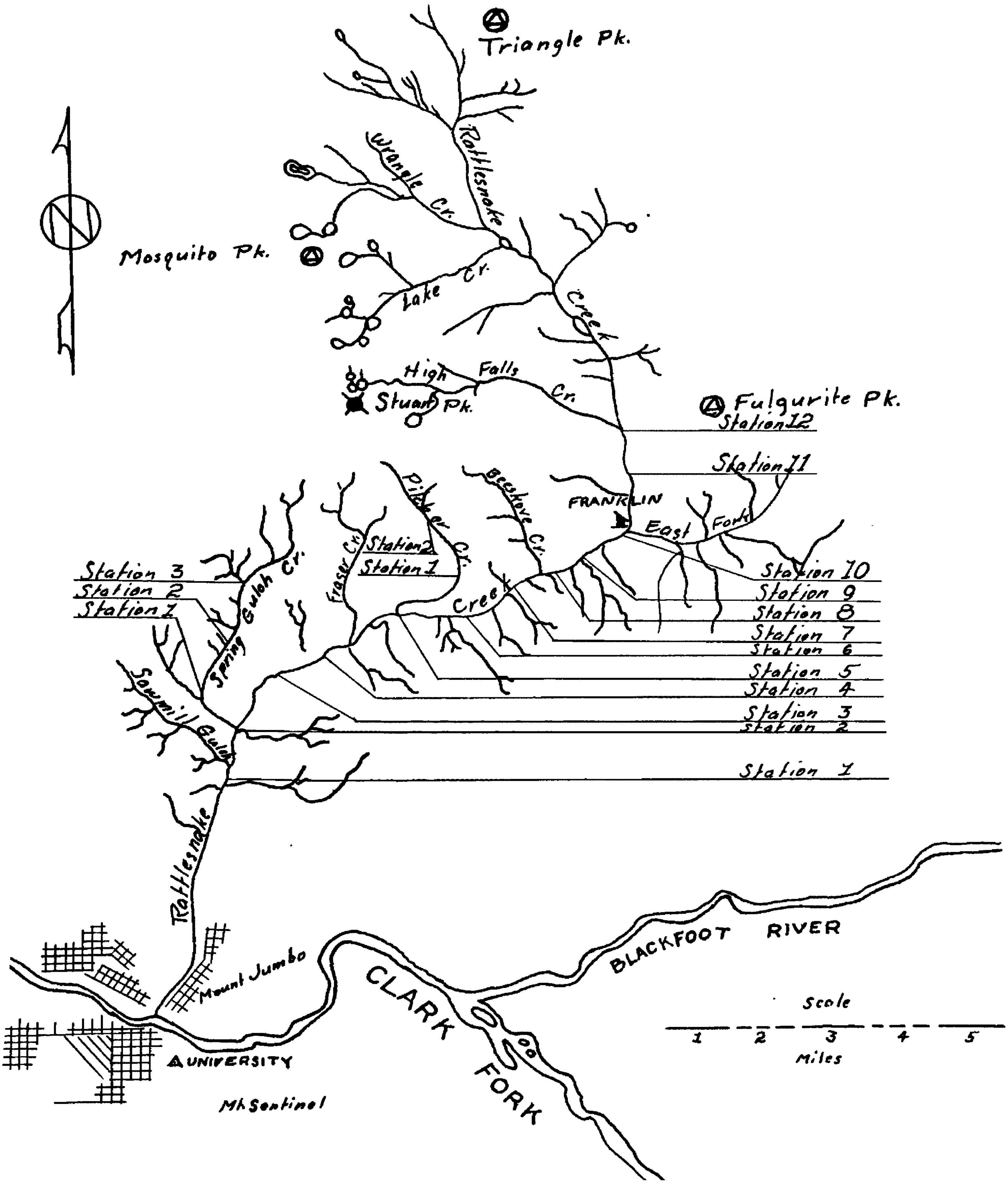
In a later paper (1925a) the authors stress the importance of the type of bottom on distribution, and also state that temperature is one of the main limiting factors.

In the summer of 1941 a survey of the trichopterous larvae of Rattlesnake Creek and two of its tributaries (Spring Gulch Creek and Pilcher Creek) was begun. Collections were made between July 5 and August 10 at regular intervals in as many kinds of habitats as possible. In the summer of 1942 some of the more common forms of case building larvae were brought into the laboratory in order to study their case building behavior under various environmental conditions. It was thought that by correlating the findings of these studies, the relative importance of different ecological factors could be determined with respect to the local distribution of trichopterous larvae.

In this study of Rattlesnake Creek, some of the conditions found in still water and in streams with bottoms of silt (which undoubtedly influenced some of the above statements) do not occur. However, the streams studied by Dodds and Hisaw are to a great extent similar to Rattlesnake Creek and the comparison of findings should be interesting.

Rattlesnake Creek originates about 16 miles north of the point where it enters the Clarks Fork of the Columbia River. It is formed by two main forks and a number of small tributaries most of which dry up in the summer months. The smaller or East Fork drains the southern side of Sheep Mountain and the larger fork, retaining the name of Rattlesnake Creek, drains the Missoula Hills, a portion of the southward extension of the Mission Range.

The water comes from melting snows, and especially during the summer, from numerous springs. Because of the mountainous terrain through which it flows, the bottom is rocky and in some places formed from bed rock. The average fall per mile is 100 ft. giving the creek a relatively rapid flow, velocities of better than 5 ft. per sec. being easily found. The water flowing over a rocky bottom with many rapids becomes so well aerated that oxygen deficiency is, in all probability, not a limiting factor. The stream shows generally small rapids alternating with broad riffles and occasional pools of quiet water. In no place was a bottom of silt found. The lack of silt and the strong current give grasses little opportunity to grow. Precipitated organic debris is found between and behind rocks throughout the length of the stream. Algae and moss-like plants grow on the rocks in varying degree, and in regions of quiet water, leafy plants such as Elodea and Myriophyllum are found.



Triangle Pk.
Mosquito Pk.
Wrangle Cr.
Rattlesnake
Lake Cr.
Creek
High Falls Cr.
Stuart Pk.
Fulgurite Pk.
Station 12
Station 11
FRANKLIN
East Fork
Beeskove Cr.
Pilcher Cr.
Fraser Cr.
Station 2
Station 1
Station 3
Station 2
Station 1
Spring Gulch Cr.
Creek
Station 10
Station 9
Station 8
Station 7
Station 6
Station 5
Station 4
Station 3
Station 2
Station 1
Sawmill Gulch
Rattlesnake
Mount Jumbo
BLACKFOOT RIVER
CLARK FORK
UNIVERSITY
Mt. Sentinel
Scale
1 2 3 4 5
Miles

About four miles from the mouth is a small dam for the purpose of impounding water for city use. The area studied lies between this dam and the point where High Falls Creek enters the stream. Twelve stations approximately one mile apart were studied as were three in Spring Gulch Creek and two in Pilcher Creek. Each station was divided into as many substations as differing conditions in the stations would permit. Notes on the surrounding region of each station as well as the characteristics of each substation were taken.

Because of probable daily fluctuations of stream temperature (caused by changing weather conditions during the 37 days of the investigation) and the impossibility of taking daily temperature readings at each station, no temperature records were kept. It was thought however that the large amount of shade throughout the course of the stream kept the temperature reasonably uniform for its entire length.

The distances to the various stations also prohibited taking accurate measurements of sunlight several times a day with a photometer. Notes were kept on the area immediately surrounding each station in an attempt to get significant information on the effect, if any, of shade on the distribution of larvae. The data at hand does not indicate any limitations and is sometimes contradictory so is not included in this paper.

Records on depth of water of each substation were kept. The rapid rise of water level in the spring and the constant drop in water level during the summer made these records valid only for a short period of time after being recorded. For this reason and also because nothing significant was obtained from them, these records are not being used.

Velocity of water was measured by means of a pitot tube. This was constructed by fastening two glass tubes on a board marked off in equal units. The tops of the two glass tubes were connected with a U tube, removable so that water could be poured into the tubes. The bottoms of the tubes were connected by means of rubber tubing to copper tubes. The copper tubes, each with a ninety degree bend at the fore end, were fastened together with the bent ends facing in opposite directions. When the copper tubes were placed in a current with the glass tubes half full, one column of water rose, and the other fell, giving a differential dependent on the strength of the current. This instrument was callibrated by timing the speed of a cork floating in currents measured by the instrument.

Notes were kept on both the organic and inorganic characteristics of the bottom. The inorganic characteristics were roughly grouped into four classifications. By boulders is meant rocks 18 inches or more in diameter; by rocks is meant rocks approximately 6 to 18 inches in diameter: and gravel means rocks under 6 inches in diameter. In the few cases of a sandy bottom, sand is meant to indicate that there are no rocks larger than 1/4 inch in diameter.

Larvae were collected largely by means of a fourteen mesh copper screen attached to a two foot square frame made of 3/8 inch iron wire. This screen held in the stream with one hand caught the larvae dislodged above it with the other hand. Since roiling the bottom does not dislodge all larvae, especially net spinners, rocks and plants were taken from the stream and examined. All larvae were put into 70% alcohol for later study.

An accurate quantitative record of the sampling was not attempted, but an estimation of the relative abundance of each type of larva in the various habitats was recorded. Three symbols are used to indicate the relative abundance. The symbol A, indicates found in abundance; the symbol C, means common or easily found but not in large numbers, and the symbol P, means present in small numbers. The symbols indicate roughly the ratio 3:2:1.

A total of thirteen different types of larvae were found. A definite attempt was made to identify each larva. Because of the scarcity of taxonomic work on these larvae, especially in the west, little headway was made in determining the generic names. In no case was a specific name determined. Attempts were made to capture the adult Trichoptera from foliage bordering the stations at the time of collection, with no success. Pupae were brought into the laboratory and put into aquaria. Only one adult, a female emerged and it was tentatively determined to genus. In most cases the larvae are referred to as log cabin larvae, oblique stick larvae, etc. the names referring to the type of case inhabited.

The following is a description of the larvae found:

Cases of sticks and strips of leaves placed parall   to the long axis of the case. Longitudinal stick, Limnephilidae A.

Cases of sticks placed perpendicular to the long axis of case in haphazard manner. Log cabin, Limnephilidae B.

Cases of sticks or sticks and sand. Sticks placed in caudad-ventral direction. Relative amount of sticks and sand varies. Oblique stick, Limnephilidae C.

Cases of sand grains, sometimes with ballast rocks. Neophylax, Limnephilidae D.

Cylindrical cases made of pieces of bark and wood. Bark case, Limnephilidae E.

Minute cylindrical cases of fine sand. Limnephilidae F.

Cases made of sand resembling turtle shell in shape. Glossosoma.

Freely crawling larvae building nets supported by rock trusses or by plant material. Hydropsychidae.

Freely crawling larvae that build tubular nets of silk not braced by sticks or rocks. Philipotamidae.

Larvae building square case of sticks in shape of steep pyramid. Brachycentrinae.

Minute curved trumpet shaped cases of silk and sand. Horn shaped.

Freely crawling larvae. Psychomyidae.

Large, green, freely crawling larvae, no evidence of nets. Rhyacophila.

Table I

Bottom Type, Current & Larvae of each Substation

Station & substation	Date 1941	Bottom type	Current	Log cabin	Longitudinal stick	Oblique stick	Neophylax	Bark case	Limnephilidae F	Glossosoma	Hydropsychidae	Philopotamidae	Brachycentrinae	Horn shaped	Psychomyidae	Rhyacophila
I-1	7/5	Sandy, organic debris *Myriophyllum*	Little or none	P	C	P	A	P								
I-2	"	Rocky, not much algae	3'/sec			P	C				C°					P
I-3	"	Boulders	8'/sec				P			C	C°				C°	A
II-1	7/12	Rocky	2'/sec	A		P	A				P°					
II-2	"	Rocky	4'/sec			C	P					C°	P			
II-3	"	Boulders	4½'/sec							A°						A
III	"	Small rocks & gravel	3'/sec	C							C°	A				
IV-1	"	Rocky, few boulders, much moss and algae	6½'/sec	A			A				C					A
IV-2	"	Rocks and boulders covered with algae	2'/sec	P							C°					
V-1	7/15	Rocky, sand, fine organic debris, Myriophyllum	Trace	C	C	C	C	P								
V-2	"	Rocks, sand & gravel covered with algae	4½'/sec			C				C		C°				P
V-3	"	Rocks, gravel & sand	1½'/sec	C		A	C									P
VI-1	"	Rocks and gravel	2½'/sec	C						A						C
VI-2	"	Boulders, rocks & gravel fine humus	None	P		P	P									
VII	7/22	Gravel & rocks slimy	2'/sec			A	A			C		C				

Note; (°) refers to pupae

Station & substation	1941 Date	Bottom type	Current	Log Cabin	Longitudinal stick	Oblique stick	*Neophylax*	Bark case	Limnephilidae F	*Glossosoma*	Hydropsychidae	Philopotamidae	Brachycentrinae	Horn Shaped	Psychomyidae	*Rhyacophila*
VIII-1	7/22	Rocky	1½'/sec.	C		C	C									
VIII-2	"	Rocks & sand	Trace	A		A		C								
VIII-3	"	Boulders	7'/sec.							P	A	C				A
IX	7/24	Boulders & rocks	4½'/sec.							A	C	C				P
X	"	Sand & gravel, moss growing on sticks and rocks	1½'/sec.			P			A		C	A				P
XI-1	8/10	Gravel, heavy growth of leafy plants	Trace		A											
XI-2	"	Gravel & small rocks	2½'/sec.							A	A					P
XI-3	"	Rocks & boulders	6½'/sec.							A						P
XII	"	Rocks & gravel covered with algae	2'/sec.			P					C	P				
SGC-1	7/26	Gravel & sand	1'/sec.				A			A						
SGC-2	"	Large rocks, much sand	2½'/sec.				C			C		A				
SGC-3	"	Large rocks with sand	2½'/sec.				C			P	C					P
Pil-1	7/29	Bedrock, boulders, sand	5½'/sec.			P	P				A	P		C		
Pil-2	7/31	Bedrock, boulders, sand	5½'/sec.			P	P				A					

Note: SGC refers to Spring Gulch Creek
Pil refers to Pilcher creek

Table II lists the seven species most commonly found. The relative abundance of each kind of larva is indicated for each substation examined and for each velocity indicated. Thus in the upper left hand block, the Log cabin larvae were found where there was little or no current, to be abundant once, common once and present twice. The bottom row indicates the number of substations examined for each velocity indicated in the table.

Table II effect of Current on Distribution

Current-Ft/sec.	Trace	1	1.5	2	2.5	3	3.5	4	4.5	5.5	6.5	7	7.5-8
Log cabin	PC PA	C C	C C	AP	C	C					A		
Oblique stick	CP PA		A CP	P AP		P		C	C	P P			
Neophylax	A CP	A	C C	AA	CC	C		P		P P	A		P
Glossosoma		A		C	AA CP				AC A		A	P	C
Hydropsychidae			C	C CP	CA	C C			C	A A	C	A	C
Philopotamidae			A	CP	A	A		C	CC	P		C	
Rhyacophila			PP		C PP	P			A PP		P A	A	A
No. of sbsts. obtaining	5	1	3	4	4	2	0	1	3	2	2	1	1

Of the seven types of larvae listed, the first four are case builders and the last three do not build cases. The Hydropsychidae and Philopotamidae construct nets but no nets were observed in connection with the Rhyacophila, the last type of larva being completely unencumbered until the time of pupation. The chart indicates in general that the case building larvae are found most frequently in slow or medium velocities while the non case-builders are never found in quiet water and often in water of rapid flow. Of the case-builders only one type appears to be restricted to the slower currents, namely the Oblique stick larvae. The other three case building larvae were found to be abundant in substations with a velocity of 6 ft. per sec.

Table III is a representation of the distribution of larvae with respect to the physical type of bottom. Divisions of bottom type based on plant life were not attempted because no clear, accurate way of measuring and indicating differences was found. As has been stated before, precipitated dead plant matter was present in all substations in fairly constant quantities, the only governing factor being the number of crevices and back eddies formed by rocks etc. The table is divided into three parts. The first part of the table is similar to the table of stream flow. The second part of the table substitutes numerical values for the letter symbols. This was done by giving "A" the numerical value of three, "C" the numerical value of two, and "P" the numerical value of one, and totaling these values in each block of the table. The third part of the table is an attempt to equalize the numerical values in proportion to the number of times each type of bottom was investigated. To keep the values above small fractions or decimals each sum in the second part of the table was multiplied by four, and was then divided by the number of times the type of bottom, which each represents, was investigated.

Table III effect of Bottom Type on Distribution

	Boulders	Rocks	Gravel	Boulders	Rocks	Gravel	Boulders	Rocks	Gravel
Log Cabin	APP	ACC	P CCC	5	7	7	2.0	2.5	3.5
Oblique stick	P	AACC CCPPP	AP	1	17	4	0.4	6.1	2.0
Neophylax	AP PPP	CCCP AAAC	AAC	7	18	8	2.8	6.5	4.0
Glossosoma	AAP	CCCP	AAA	7	7	9	2.8	2.5	4.5
Hydropsychidae	AAA ACP	CC	CCA	15	4	7	6.0	1.4	3.5
Philopotamidae	CCP	ACP	AA	5	5	6	2.0	2.1	3.0
Rhyacophila	AAA APP	PP	CC PPP	14	2	7	5.6	0.7	3.5
No. of sbsts.	10	11	8	10	11	8	10	11	8

Table III does not indicate the general difference in distribution between the case building forms and the non case building forms that was noted in Table II. The table does however indicate some rather striking differences in distribution of the various larvae, based on the inorganic differences of bottom type. The Oblique stick larvae were found to be pretty evenly distributed over all types of bottom while Glossosoma was found most often on a bottom of gravel.

PART II

Several studies have been published concerning experiments on reconstruction and reparation of cases by caddis larvae. Most of these investigators (Dembowski 1933, Frankhauser 1935, Gorter 1931, Iwata 1928, Lutz 1930, and Moretti 1934) find that the larvae employed are capable of making cases out of materials not normally used. It is also generally reported that loose provisional cases are made first, being cast off after the finished case has been added to them (Dembowski 1933, Frankhauser and Rick 1935, Iwata 1928, and Gorter 1931). The general assumption is that each species has a preference in the kind of material to be used in the construction of its case. Iwata (1928) and Frankhauser and Rick (1935) state that this choice is not changed by the presence of other materials. Moretti (1934) found that color did not enter into selection but found that weight, shape, and dimensions are important factors in the choice of materials.

Dodds and Hisaw (1925) and Lutz (1932) have correlated case types with stream flow. Webster and Webster (1943) report that the larvae of Goera calcarata built significantly heavier cases in running water than in stagnant water. No other published experiments have been found demonstrating the effect of current on case building behavior. Such experiments might present facts to confirm existing views about the importance of current on the distribution of caddis fly larvae or secure information which would shed a different light on the subject.

Four kinds of larvae were used in these experiments. They were all found in the lower reaches of Rattlesnake Creek where it flows through Greenough Park. The fact that they have been found above the dam in the area surveyed and the fact that they were easily obtained were major reasons for selecting them. The Bark case larvae and the Oblique stick larvae had been found most frequently in quiet water while the Log cabin larvae and Neophylax had been found in very rapid as well as in quiet water.

The experiments were carried on in the animal house at Montana State University. One and a half liter beakers containing about two inches of water were placed on bricks in a large running water aquarium so that the level of water in the beakers was the same as the level of the water in the aquarium. The large amount of running water kept the water in the beakers at temperatures varying from 13°C. to 16°C. The temperature was usually between 14°C. and 15°C. To simulate a stream habitat, a wooden trough was made, subdivided by galvanized wire screens into eight compartments, each three inches long, three and one half inches wide, and four inches deep. To insure a smooth flow of water into the trough and to do away with splashing, a can of about one quart capacity was used as a buffer tank with a two inch galvanized iron tube placed loosely in it. Water entering the can by way of the tube lost its turbulence and flowed out well aerated. The flow of water in the trough could not be kept constant because of changing pressures at the tap and because the choking of the screens (in the trough) changed the water level (in the trough).

Sand was graded by Tyler Standard Screens into $-\frac{1}{4}$ inch +9 mesh, -9 mesh +16 mesh, -16 mesh +32 mesh, and -32 mesh +60 mesh sizes. Plus 9 mesh and +32 mesh sand were put into two beakers and two compartments in the trough. Plus 16 mesh and +60 mesh sand were put into two beakers and into two compartments in the trough. Organic debris gathered in the creek at the time of collecting the larvae was placed into two beakers and into two compartments in the trough. In the last two compartments in the trough was placed a mixture of sand and organic debris.

Lutz (1930) had found that larvae build new cases much more rapidly than they will repair old ones. Naked larvae were used exclusively in these experiments. Also it was thought that the construction of new cases might present more pertinent evidence with regard to larval behavior in different environments. It was found that the easiest and safest method of removing the larvae from the cases was that used by Gorter (1931), namely to push them from their cases by gently inserting a blunt probe into the posterior end of the cases, whereupon the larvae usually released their hold on the cases and were easily pushed out. These naked larvae were then placed in environments differing in the size and kind of bottom and differing also in the flow of water.

In preliminary experiments it was found that naked larvae do not survive very readily in water not constantly aerated. Incessantly aerating the water with an electric air pump reduced considerably the number of fatalities. It was also found that the bark case larvae and the oblique stick larvae could not be placed in the same beakers or compartments with the smaller larvae, or with each other because of predation. This cut in half the number of experiments that was expected to be completed in the time available. The fact that there was no simple method of telling the difference between the log cabin larvae and Neophylax made it impracticable to put them both in the same containers.

In giving the results of the various experiments, tables have been made when the data could be presented clearly in that form. When more than one experiment was carried on with one type of larvae in one habitat the results of the experiments have been summarized in one table.

Table I

Log Cabin Larvae in Still Water on Bottom of +9 & +32 Sand

	CASES OF +9	CASES OF +9 &+32	CASES OF +32	NUMBER NAKED	NUMBER DEAD
1 day	15 in construction			1	0
2 days	1	2	9	3	1
3 days	0	2	10	1	3
4 days	0	2	9	2	3
5 days	0	2	7	3	4

Table II

Log Cabin Larvae in Still water on Bottom of +16 & +60 Sand

	CASES OF +16	CASES OF +9 & +32	CASES OF +60	NUMBER NAKED	NUMBER DEAD
1 day	2	1	1	1	0
2 days	2	1	1	1	0
3 days	2	0	1	2	0
4 days	2	0	1	2	0
5 days	1	1	1	2	0

It was observed that the naked larvae, when put into the beakers, had difficulty in moving. The naked larvae were observed writhing helplessly on the bottom and occasionally floating to the surface, where they stayed until forcibly submerged again. Larvae in normal cases, put into the same beakers, displayed none of this difficulty in staying on the bottom and in moving about on the bottom. At the earliest opportunity the naked larvae buried themselves in the sand, more easily in the +9 mesh sand than in other sizes of sand apparently because of the larger spaces between the sand grains. When buried, the surrounding sand grains were fastened together forming loose and flimsey cases. These temporary cases were added to with sand grains, carefully fitted and tightly fastened in place. They were not able to pull cases of +9 mesh sand around with them on the substrate available. One larva which retained a very short case of +9 mesh sand spent most of its time in a vertical position unable to topple over its case and get its legs on solid bottom. These cases of +9 mesh sand were soon discarded.

It is seen from an examination of the tables that +32 mesh sand was used more frequently than the other sizes. Twelve of the twenty-one larvae made cases. Of the twelve making cases, seven were of +32 mesh sand while two more were basically of +32 mesh sand. Four of the cases constructed were pupal cases. Two more, because of the inactivity of the larvae and because of the narrowed anterior openings, were thought to be in the process of being converted into pupal cases. At the end of one day only two of the twenty-one larvae were without some sort of case and none were dead. At the end of five days five larvae were without cases and four had died. Several discarded cases were found in each beaker.

Five naked larvae were put into the quiet water of a beaker containing plant material. All five had completed normal cases within two days. Six of the larvae with sand cases and the pupal cases were moved to quiet water with plant material. All of the larvae that had not completely closed their pupal cases added plant material to the anterior end of the sand cases the first day. By the end of five days complete typical log cabin cases had been built and the sand on the posterior end had been cut off.

To see if a current would modify this choice of plant material in favor of sand, two naked larvae were put into each of four compartments in the trough. The first compartment contained only plant material, the second +9 and +32 mesh sand, the third +16 and +60 mesh sand, and the fourth a mixture of sand and plant material. It was observed that the larvae, without their cases, were unable to maintain a position on the sand because of the current. Consequently two rocks were put into each compartment containing sand to provide areas of reduced current. On the next day four larvae were found in the compartment with plant material, one in each of the sand bottom compartments, one in the mixed compartment, and one was missing. Those in the compartment with plant material had normal cases of that material. Those in the sand bottom compartments had started cases of sand but had finished very flimsey cases with small bits of plant matter washed through the screens. The one larva in the last compartment had a full normal cas e of plant material. Because the larvae did not stay in the compartments into which they were put, a new and tighter lid was made for the trough. The experiment was tried again in the same manner with larvae again escaping the compartments. Again four larvae were found in the plant compartment, one in each of the sand bottom compartments, and one in the mixed compartment. The larvae in the plant compartment had completed normal cases in one day. In the sand bottom compartments there was no evidence of sand cases. The larvae were crawling over the screen partitions searching out bits of plant material with which, in the course of several days, they made flimsey cases. The larva in the mixed compartment had a normal log cabin case by the end of the first day.

It can be seen from the foregoing experiments that although log cabin larvae will build cases of sand, plant material is used in preference to sand even in a current. The fact that sand is an unsatisfactory building material in order of preferance is demonstrated by the number of larvae leaving sand cases and by the selection of diminutive pieces of plant material in preference to sand. It would be interesting to know why these larvae pupated in the apparently unsatisfactory sand cases while none pupated in their cases composed of plant material.

Neophylax larvae are about the same size as the log cabin larvae, both being approximately 1 cm. in length. These larvae were very active when put into various environments but did not exhibit the versatility of the log cabin larvae.

Table III

Neophylax Larvae in Quiet Water on +16 & +60 Sand

	CASES OF +16	CASES OF +16 +60	CASES OF +60	NUMBER NAKED	NUMBER DEAD
1 day	5	0	0	7	0
2 days	8	0	0	4	0
3 days	10	0	0	1	1
4 days	10	0	0	1	1
5 days	9	0	0	2	1

Table IV

Neophylax Larvae in Quiet Water on +9 & +32 Sand

	CASES OF +9	CASES OF +9 & +32	CASES OF +32	NUMBER NAKED	NUMBER DEAD
1 day	0	7	0	3	0
2 days	0	7	0	2	1
3 days	0	7	0	2	1
4 days	0	7	0	1	2
5 days	0	7	0	1	2

Table V

Neophylax Larvae in Quiet Water on Plant Material

	NUMBER OF CASES	NUMBER NAKED	NUMBER DEAD
1 day	3	21	0
2 days	4	18	2
3 days	3	17	4
4 days	3	15	6
5 days	4	13	7

Of twenty-two larvae put on sandy bottoms, sixteen built cases. The most typical cases were the ones built of a combination of +9 and +32 mesh sand. No cases were built of either size alone. Cases were built of +16 mesh sand but no +60 mesh sand was observed in any of the cases. From comparing the normal cases with the graded sand, it appeared that the sizes used in natural environments ranged from +9 mesh through +32 mesh.

Of twenty-four larvae put with plant material in quiet water, five built cases and one of these was discarded. It was observed in the first experiment with plant material that the Neophylax larvae did not cut sticks but tried to use them as found. In the next experiment with plant material, plant stems and needles were cut into one-quarter inch lengths and put into the beaker. Twigs taken from log cabin cases were also added. The one case built in the second experiment was made completely of the twigs from log cabin cases. These twigs were easily identified by the notch in the middle of each, formed by the log cabin larvae rounding out the interior of their cases. Most of the sticks used in the other cases were sticks taken from log cabin and oblique stick larval cases. They were not arranged in any definite manner. One case had the appearance of a porcupine, the sticks being attached by one end, protruding at an angle caudally. In another case the sticks were arranged in a manner similar to that found in the oblique stick case. In other cases no definite arrangement was seen. The lack of cases was not due to a lack of effort. The larvae when put into an environment of plant material immediately buried themselves as they do in sand, rearranging the sticks about them. After a few days a considerable tangled mass of plant material was fastened together having no resemblance to a case. In the last experiment after eight larvae remained naked for ten days, a mixture of sand was added to the beaker. Six of the naked larvae built cases in the following two days.

The behavior of Neophylax in flowing water in the trough was similar to that of the log cabin larvae. Some of the larvae placed in compartments with plant material escaped. No cases of plant material were built by Neophylax in flowing water and no evidence of attempts at building were found. Those in the sand compartments and in the compartment where there was the choice of plant material or sand readily built cases of sand.

The bark case larvae, when naked, are cannibalistic, making it necessary to use only one or two at a time. They did not react as readily to changing environments as the log cabin larvae so the results are more readily narrated than put into a chart.

In three experiments five naked bark case larvae from 1.5 cm. to 2. cm. in length were put into quiet water in beakers containing +16 and +60 mesh sand. Two of the larvae started cases of +16 and +60 mesh sand, continually improving them for eight days when they were removed. One after five days started a case and left it after working on it intermittantly for five more days. Two larvae died the third day. Two larvae were put into quiet water in a beaker containing +9 and +32 mesh sand. One of them died on the second day and the other on the fifth day after both made feeble attempts at building cases. Thus out of seven larvae put into quiet water on sandy bottoms two made cases and four died.

Three naked larvae were put into quiet water with plant material. Two of them were put into the beakers directly from their cases, the other was transferred from a sandy bottom where it had been for ten days without building a case. All three had cases made of leaves by the end of one day. These cases were all well formed but flimsey since building material of normal weight was not available. When put into a large aquarium containing some willow stems they added well built sections to their cases made of sheets of bark and wood chewed from the willow stems.

One naked bark case larvae was put into each of the types of bottom with flowing water in the trough. The two in the presence of plant material had cases built in one day while those on sandy bottoms made no attempt to build cases. One on a sandy bottom died on the second day, the other on the fifth day. The two larvae that made cases of +16 mesh sand in quiet water were put into the trough on a bottom of plant material and sand. By the end of two days one larva was adding bark to the anterior end of its sand case, By the end of three days, both larvae were adding bark to their cases.

The number of bark case larvae available was limited. Because of this and also because so few could be put in one environment at the same time not many figures concerning their behavior are available. The rapidity with which plant material cases were built as contrasted to the building of sand cases permits the conclusion that plant material is used more readily than sand, even if the plant material is not the kind normally used even if it is in a current.

While the bark case larvae were not very sociable, the naked oblique stick larvae were very pugnacious. Their behavior indicates that they rely on a tactile sense rather than on eyesight. When put on a sandy bottom in quiet water they inevitably come in contact with one another in their explorations. When one larva touches the leg of another, both lift their heads, open their mandibles and violently fight with their thoracic legs. When a larva is put into quiet water with plant material, the reactions to tactile stimuli are further demonstrated. A larva in crawling around assumes all of the fighting characteristics when a stick moves under its weight. It takes a naked larva some time to quiet down in a beaker with many sticks. This behavior is much less pronounced when the larvae are in their cases.

Table VI

Oblique Stick Larvae in Quiet Water on Bottom of +16 & +60 Sand

	CASES OF +16	CASES OF +16 &+60	CASES OF +60	NUMBER NAKED	NUMBER DEAD
1 day	1	0	0	3	3
2 days	1	0	0	2	4
3 days	2	0	0	1	4
4 days	2	0	0	1	4
5 days	2	0	0	1	4

Table VII

Oblique Stick Larvae in Quiet Water on Bottom of +9 & +32 Sand

	CASES OF +9	CASES OF +9 & +32	CASES OF +32	NUMBER NAKED	NUMBER DEAD
1 day	1	1	1	0	4
2 days	0	2	0	0	5
3 days	0	2	0	0	5
4 days	0	2	0	0	5
5 days	0	2	0	0	5

Of fourteen naked oblique stick larvae put on sandy bottoms in quiet water, four had completed cases, one remained naked, and nine died. The sand used was largely +16 and +32 mesh sand, very little +9 mesh sand being used. The number of cases completed would have probably been larger had time permitted putting the larvae into the beakers one at a time. The casualties (seven on the first day) were due in large part to cannibalism.

One of the larvae with a sand case was put, along with a naked bark case larva, into quiet water in a beaker with plant material. By the end of one day the sand case was empty and oblique stick larva was dead. Five naked oblique stick larvae were later put into the same beaker after the removal of the bark case larva. By the end of one day three larvae had good plant cases, one had taken over the empty sand case, unintentionally left, and one was gone.

In one experiment one larva was put into each compartment of the trough, or two in each kind of environment in the trough. The two in the plant environment immediately made cases of leaves and small stems. These were flimsey cases of leaves indicating a lack of suitable stems. Of those in the +9 and +32 mesh sand compartments, one remained naked and one built a good case of +32 mesh sand with a small amount of +9 mesh sand added. Both of the larvae in the +16 and +60 mesh sand compartments built cases largely of plant fibers drifting down to them with a small amount of +16 mesh sand. One of the larvae in the mixed compartment remained naked, the other built a case of leaves supplemented with a few grains of sand. To make the plant environment more suitable some fir needles were added. Many of these washed thru the screens lodging in the rocks placed in the sandy bottom compartments. Two larvae were put into the plant compartment, four were put into a compartment of +9 and +32 mesh sand supplemented with fir needles, and two were put into a compartment of +16 and +60 mesh sand. Both larvae in the plant compartment had built good cases by the end of the first day. Of the four larvae in the + 9 and +32 mesh sand compartment, two had plant cases the first day, one was naked, and the only evidence of the fourth was the head and a few of the thoracic legs. By the end of the fourth day one larvae was still naked and one of the plant cases had been added to with +32 mesh sand. At the end of one day in the compartment containing +16 and +32 mesh sand, one larva had a case of sticks: the other larva was naked, having discarded a small case of sticks supplemented with +16 mesh sand.

The oblique stick larvae did not show the versatility in construction that their original cases would indicate, because of the use of sand in their normal cases, one would expect that more cases of sand would be built. It would also be expected that sand would have been used with plant matter when both were available. Perhaps this behavior can be explained by examining the occurance of their normal cases. In the early summer the only cases found were small cases made entirely of plant fragments. As the summer went on it was noticed that the cases were larger and sand was included. It may be that there is a behavior pattern requiring a plant case onto which sand is added. It is certain that naked larvae much more frequently make cases immediately of plant matter rather than of sand grains.

The larvae used in this investigation reacted much as other investigators have found similar forms to react except that they were not as responsive to new environments as some of the larvae discussed in previous studies. Each type of larva used demonstrated more or less ability to construct cases out of material not normally used. Loose provisional cases, reported by other investigators were observed in these experiments. All sandy cases constructed were started by these preliminary cases, which were later discarded. Many larvae however constructing cases of plant material did not discard the flimsey beginnings but strengthened them by additions to complete the finished cases. These experiments demonstrated also that the larvae, given a choice of normal material and materials not ordinarily used, will never use strange material in building their cases, regardless of the environment.

On the basis of observations made on the larvae during these experiments, the cases appear to have three purposes. The first function observed is that of equilibrium or buoyancy as observed previously when naked larvae could not crawl on the bottom of a beaker or stay on the bottom. The second function observed is that of protection. Several of the oblique stick and bark case larvae were killed and devoured. In no instance was a larva killed after it had succeeded in making a case. The third function of a case is that of respiration, which might be an explanation for the non-violent deaths of the log cabin and Neophylax larvae that did not build cases in quiet water. The absence of mortalities of naked larvae in running water is probably due to the current of the water, and likewise the absence of mortalities of larvae in cases in quiet water is probably due to the circulation of water thru the cases.

Part III

In a discussion of the behavior of caddis larvae, many factors must be taken into consideration. Some of the factors making up the complete environment, which have been demonstrated to effect distribution of aquatic animals are omitted in this paper, namely oxygen content, pH., temperature, light and depth of water. Two measurable factors - current and inorganic bottom type - and one factor not measured - organic bottom type - have been included for consideration.

The most easily measured factor, velocity, indicates few limitations. The oblique stick larvae were never found in water of rapid flow. Hydropsychidae, Philopotamidae and Rhyacophila, non-case builders, were not found in still water. Hydropsychidae and Philopotamidae build nets, for the purpose of catching food, which would be useless in still water, making the reason for this limitation obvious. The log cabin larvae, Neophylax and Glossosoma all case builders were not conclusively limited by current.

The chart on the effects of the inorganic characteristics of the bottom on distribution indicates that rocks have much to do with the distribution of some types of larvae.

Hydropsychidae are found predominantly on a bottom of boulders. A bottom of boulders offers the large spaces needed for the type of nets they build, where a current of water will continually flow thru them.

Rhyacophila are predominantly found on a bottom of boulders. In Rattlesnake Creek, the boulders are usually found in an area of rapid stream flow. Since the current recorded is the maximum current for each substation which is not found in all positions around the boulders, and the larvae have been found in the sheltered portions of the rocks; and since this larva in quiet water was found almost always on large rocks or boulders, it is probable that the physical force of the current is not the limiting factor.

The oblique stick larvae were found predominantly on a bottom of rocks. The combination of rocks and a moderate stream flow produce a deposition of organic debris which is probably the reason for this distribution.

The only larvae found in significantly larger numbers on a bottom of gravel than on other bottoms was Glossosoma.

A sandy bottom was not mentioned in the table because in only one place was a truly sandy bottom found. Here there was no obvious living or dead plant life and also practically no animal life.

Although no method of classifying and measuring the organic characteristics of the bottom type was found, observations made during the investigations of the stations indicated that it was too important to be omitted from the paper. The organic characteristics of the bottom are dependent upon combinations of stream flow and inorganic characteristics. A current over a smooth bottom allows no deposition of organic debris and little chance for plants to grow. Rocks and boulders in a current create eddy currents which deposit organic debris in the crevices between the rocks and boulders.

In regions of little or no current, sand is deposited giving grasses and other plants more chance to grow. These organic factors are obviously important either directly or indirectly as a food supply, and also as a source of material for many types of cases.

The tables have indicated that both current and the inorganic characteristics of the bottom limit the distribution of some larvae and it has been observed that the organic characteristics of the bottom also limit the distribution of some larvae. For the most part a combination of two or more of these factors is the explanation of the distribution of each type of larva.

In discussing the distribution of the various larvae studied, it is difficult, if not impossible, to determine which factors of the environment are the determining factors for each individual occurence. The behavior of the larvae in building their cases, their constant rejection of strange building material in favor of normal material in all environments used, their abandonment of apparently good cases of strange materials to build cases of normal material when that material was offered, and their abnormal behavior while in cases of strange material, definitely indicates that bottom type is a more important part of the environment than current with case building larvae.

Summary

1. Current is a necessary part of the environment of net building larvae.

2. Inorganic bottom type is as important if not more important than current in the environment of many species of larvae.

3. Organic bottom type is important as food and case building material.

4. Many larvae can build cases out of materials not normally used.

5. The presence or absence of current does not alter their first choices of materials.

Literature Cited

Betten, Cornelius. 1934. The caddis flies or Trichoptera of New York state. N. Y. State Museum Bull. 292: 1-576.

Dembowski, Jan. 1933. Uber die plastizitat der tierishen Handlungen Beobachtungen und Versuche on _Molanna_ Larven. Zool. Jarb. Abe. Allg. zool. u. Physiol. 53: 261-311. (Biological Abstracts)

Dodds, G. S. and F. L. Hisaw. 1925. Ecological studies on aquatic insects. III. Adaptations of caddis fly larvae to swift streams. Ecology 6: 123-127.

1925a. Ecological studies on aquatic insects. IV. Altitudinal range and zonation of Mayflies, Stoneflies, and Caddisflies in the Colorado Rockies. Ecology 6: 380-390.

Frankhauser, Gerhard and Louis E, Rick. 1935. Experiments on the case building of a caddis-fly larvae, _Neuronia postica_ Walker. Physiol. Zool. 8: 337-359.

Gorter, F. J. 1931. Kocherbauversuche an Trichopterenlarven, Zeirschr. Wiss. Biol. Abt. A. Zeitschr. Morph. u. Okel. 20: 443-532. (Biological Abstracts)

Iwata, Masatosi. 1928. Observations on the formation of nests by larvae of _Molanna_ _angustata_ Curtis.Dobutzugaku Zasshi. 40: 1-12. (Biological Abstracts)

Lloyd, John Thomas. 1921. The biology of the North American caddis fly larvae. Bull. of Lloyd Lib. Ent. Ser. No. 1. 21: 1-124.

Lutz, F. E. 1930. Caddis fly larvae as masons and builders. Nat. Hist. 30: 276-281.

Milne, Margery J. 1938. Case building in Trichoptera as an inherited response to oxygen deficiency. Can. Ent. 70: 177-180.

Moretti, G. P. 1934. Experiments on the rebuilding of the larval cases of caddisflies. Mem. Soc. Ent. Ital. 12: 228-261. (Biological Abstracts)

Webster, Dwight A. and Priscilla C. Webster. 1943 Influence of water current on case weight in Larvae of the caddisfly Goera calcarata Banks. Can. Ent. 75:105-108.