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Ecological relationships of the aquatic macroinvertebrates of the Cascade Springs area

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ECOLOGICAL RELATIONSHIPS OF THE AQUATIC MACROINVERTEBRATES OF THE CASCADE SPRINGS AREA

A Thesis

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Master of Science

by

Eugene C. Devenport

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This thesis by Eugene C. Devenport is accepted in its present form by the Department of Zoology and Entomology of Brigham Young University as satisfying the thesis requirement for the degree of Master of Science.

Typed by Berna B. Allred

Frontispiece. View of Cascade Springs, cascades, and terraces, looking northwest, Spring, 1966. (Photo courtesy, Pleasant Grove Ranger District, Uinta National Forest)

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Appreciation is also given to Robert Sandgren who was my companion and fellow collector for the many trips to Cascade Springs.

Permission to collect in the springs area was given by the Pleasant Grove Ranger Station, Uinta National Forest, Utah. District Ranger John R. Glenn and others of his staff cooperated in every way possible.

To my wife, Vivi-Ann, I give special thanks for the encouragement, help, and understanding she constantly offered.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Figure | Page

INTRODUCTION

Statement of the Problem

The U. S. Forest service, recognizing the scenic, scientific, and educational value of the Cascade Springs area near Mount Timpanogos, has set aside and begun development of this spot for the use of the general public. As part of their preparatory work they have asked that examination be made of the flora, fauna, and physical features which may in part be incorporated into public informational facilities being constructed at the springs.

The purpose of this study, which was carried on from May, 1964, to July, 1966, is to determine some of the more important aquatic habitats of the springs region, to determine what macroinvertebrates are present, and to relate them to these various habitats. Some additional factors relating to behavior, seasonal distribution, and other ecological information are included.

Review of Literature

General information on streams, including springs, is available in texts covering the broad scope of limnology such as those by Reid (1961), Macan (1963), and Welch (1952). Information is available on many of the larger springs of the United States. Florida, which contains many large springs, has had considerable research done on its springs, including a general bulletin of nearly 200 pages by Ferguson, et al. (1947). Teal (1957) discusses the community metabolism of a cold spring in Massachusetts, while the hot springs fauna of the western United States has been studied by Brues (1928).

Welch (1948) reviews in detail the available methods known for sampling chemical and physical factors and discusses types of equipment. Some alternate methods and equipment are listed by Peterson (1947). Specific methodology in a spring stream study is given in the monograph of Doe Run Spring Stream by Minckley (1963).

There is no apparent published information on Cascade Springs, except that which is on maps. A topographic map of the Aspen Grove Quadrangle (U. S. G. S., 1950) shows the nature of the slopes of the surrounding terrain and a U. S. Geological Survey map and accompanying folder describes the nature of the bedrocks of the same area (Baker, 1964). The U. S. Forest Service has furnished a topographic map of the springs and terraces which shows the details of water flow, direction, and degree of drop of the water. The history and other features of the area were developed through personal communication with several individuals. Dr. D Elden Beck furnished general information on the history of the Cascade Springs area. Dr. Vasco M. Tanner gave additional information and the U. S. Forest Service provided information on history, land use, and present and future plans for the area. The Forest Service also supplied botanical information collected by the Brigham Young University Botany Department in 1965. Deanna Bunting McCoard, a graduate student in the Brigham Young University Botany Department, provided additional information on physical conditions of the springs and on the mosses and algae. Dr. Jess R. Bushman of the Brigham Young University Geology Department furnished information on the chemical and geological aspects of the springs area.

A multitude of references are available on the ecology and taxonomy of specific aquatic invertebrate groups. Usinger's Aquatic Insects of California (1956) contains information on general collecting methods, keys to both the adults and immature stages of all groups of insects that contain aquatic representatives during some stage of their lives, and ecological information on all of the orders and most of the families listed. The keys are especially valuable inasmuch as there are keys to the families and genera for both adult and immature aquatic insects of all of North America, as well as species keys to insects of California. Edmundson (1959) (often referred to as "Ward and Whipple") and Pennak (1953) contain extensive keys to genera of the aquatic stages of invertebrates, with additional keys for the aquatic vascular and lower plants being found also in Edmundson (1959). These two texts also have general ecological information on the larger groups contained in the key. Borrer and DeLong (1954) have a large key to adult insects, while an extensive key to adult insects with additional extensive bibliography to each group is found in the text by Brues, Melander, and Carpenter (1954). Peterson (1956, 1957) has published a key to larval orders and families of the holometabolous insects including a considerable number of plates that are helpful in the keying.

Specific groups of invertebrates have also received much attention. Curran (1934) published a key to the adults of the families and genera of Diptera. There are unpublished theses at the University of Utah on the Ephydridae of Utah (Jorgenson, 1956) and the Simuliidae of Utah (Peterson, 1958), while Stains' (1941) thesis at Utah State University deals with the Simuliidae of the western United States. Arnette (1960) has published a key to all of the adult beetles of the United States, while the aquatic and semi-aquatic beetles of Utah are discussed in a thesis at Brigham Young University by Chandler (1941), and the Dytiscidae of Utah are examined in a doctoral dissertation at the University of Utah by Anderson (1960). An extensive text on the dragonflies of North America is that of Needham (1955), with two University of Utah theses supporting this; Larsen (1952) discussing the taxonomy of Utah dragonflies, and Musser (1961) the taxonomy of dragonfly nymphs. Hemiptera are covered in a University of Utah thesis by Woodbury (1950). Several families of primitive Trichoptera are classified to species in Ross's (1956) book. A very thorough treatise on the Ephemeroptera was published by Needham, Traver, and Hsu (1935); this includes classification of all stages of mayflies, including eggs. A master's thesis at the University of Utah by Edmunds (1946) discusses both adults and immature of the mayflies. Claason (1931) published two volumes on the adult and immature Plecoptera. A taxonomic study of the Plecoptera of Utah by Dr. Arden R. Gaufin is now at the press, being published through the University of Utah (Richard Baumann, University of Utah graduate student, personal communication). Chamberlain and Jones (1929) prepared a descriptive key to the molluscs of Utah which emphasizes shell characteristics. Brinkhurst (1964) published a study and key to the North American Naididae and Opistocystidae (Oligochaeta) and he published similarly on the Tubificidae in 1965.

Description of the Study Area

The Cascade Springs are located near Provo Deer Creek* four miles up from the entrance of this stream into the Provo River, at an elevation of 6263 feet above sea level. The springs are in the Orem, Utah, quadrangle on the 15' series map and in the Aspen Grove Quadrangle on the 7.5' series map. This latter quadrangle also includes part of Mount Timpanogos to the southwest. While the springs are in Wasatch County, Utah, the boundary line between Wasatch and Utah counties is less than two miles to the west. Access is possible by automobile on good summer roads from Midway to

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*Provo Deer Creek is the name used on the U. S. Geological Survey maps but the common name given by local residents of this area is Little Deer Creek.

the east and from Wasatch State Park to the north. The United States Forest Service is currently making final arrangements to develop a good road connecting the upper Alpine Scenic Loop on Mount Timpanogos with Cascade Springs. Presently a poor quality road extends to the Springs from Provo Canyon northward along Provo Deer Creek. Because some private land and leased state land is involved problems have arisen which have prevented, up to the present time, the development of a good road through this scenic canyon (Vasco M. Tanner, personal communication). From the road near the terraces a path along the terraces leads up a slope to the mouth of the springs, a distance of about two hundred meters.

The whole springs area is located on moraine and glacial outwash formed during the Quaternary Period. This glacial deposit also extends over three miles north along the edge of Mill Canyon Peak. On both sides of the springs, approximately one tenth of a mile each way, run the Charleston Thrust Fault and Upper Charleston Thrust Fault (U. S. G. S. map, 1964). It is the presence of glacial gravels and the two parallel faults that results in the accumulation of water which comes to the surface as the springs (Dr. Jess R. Bushman, personal communication).

The springs are located at the top of a catchbasin that faces in a general southeast direction, at the base of a rather steep slope. Only one orifice about 30 centimeters high, 15 centimeters wide, and rock-choked within, is evident. While much water issues from this orifice, a far greater amount flows out all along the base of the slope from the rock bed and a slight amount comes up directly from the floor of the basin within two meters of the slope. These seeps are evident because of the occasional air bubbles that come to the surface. The entire basin floor is composed of rocks and gravel of various sizes. Over this base are intermittently spaced larger rocks and boulders that protrude above the shallow water (Fig. 1). A sand deposit occurs over the base in two places; two peninsulas of grasses and partially decayed organic matter mixed with soil extend down from the center of the mouth, and the entire top half of the springs is profusely covered with vegetation in the summer, mostly *Mimulus guttatus*, a mixture of mosses, and the alga *Spirogyra* (Fig. 2). The depth of the water in the catchbasin varies from one to more than 15 centimeters in places. At a point where the pear-shaped basin narrows to approximately 12 meters, an old beaver dam

Fig. 1. Springs basin showing large emergent rocks, facing north, early spring, 1966. (Photo courtesy, Pleasant Grove Ranger District, Uinta National Forest)

extends across, backing the water up for about 10 meters with a depth of about .7 meter in the deepest part (Fig. 3). Below this the banks narrow until a stream has formed. From here the gradient quickly drops and the water rushes down a gorge as a series of cascades, varying in width from more than 4 meters in places near the top to less than one meter in one area. The depth of the cascades varies from a few centimeters to more than .5 meter in some of the pools (Fig. 4). As the water reaches the base of the cascades it spreads out over an ever-widening circle of terraces (Fig. 5), reminiscent on a smaller scale of the Mammoth Hot Springs terraces in Yellowstone National Park. Each terrace, semi-circular in shape, is composed of a rather flat basin. The deepest water is invariably at the point where most of the water enters that terrace (one pool measured over a meter deep), and it shallows out near the rim. The hard rim is composed of a travertine tufa, similar in appearance to the deposits at the Midway hot pots (Dr. Jess R. Bushman, personal communication), and the floor is fine gravel and sand interspersed with numerous shells of the watercress snail, *Paludestrina longingua*, and of Trichoptera larvae and their cases. Watercress (*Rorippa nasturtium-aquaticum*) is

Fig. 2. Mimulus guttatus at the top of the springs basin, June, 1966.

Fig. 3. Old beaver dam at the bottom of the springs basin, facing north, June, 1966.

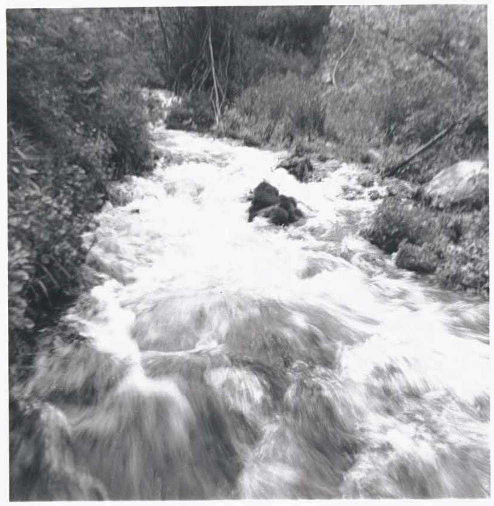


Fig. 4. Torrential portion of the cascades, facing north-west, June, 1966.

Fig. 5. Terraces, showing watercress mats and channels, early spring, 1966, facing southwest. (Photo courtesy of the U. S. Forest Service)

continuous over large parts of the terraces, while many other plants grow along the rims. The northeast section of the terraces differs, however, in that the vegetation is primarily composed of rushes (*Juncus saximontanus*), and the bottom deposits are of mud and organic matter (Fig. 6). Provo Deer Creek flows south along the base of the terraces and the terrace waters flow into the creek in many places (Fig. 7). A longitudinal profile of the Cascade Springs stream is shown in Fig. 8.

The dominant vegetation of the surrounding area is *Quercus gambelii*, though immediately around the springs are a variety of trees and shrubs, including an open sagebrush flat to the northeast. A dense stand of stinging nettle (*Urtica gracilis*) extends along most of the width of the spring mouths, and a stand of rayless coneflowers (*Rudbeckia occidentalis*) is evident along the northeast bank. Both pink sticky geranium (*Geranium fremontii*) and white geranium (*G. richardsonii*) are noticeable along the banks of the cascades, while within the oakbrush fringe are clumps of holly-grape (*Mahonia repens*), Siberian onion (*Allium* sp.), and yarrow (*Achillea millefolium*). The roadside weeds, dock (*Rumex crispus*), mullein (*Verbascum thapsus*) and Canada

Fig. 6. Terrace rushes, Juncus saximontanus, facing west toward cascades, June, 1966.

Fig. 7. Provo Deer Creek immediately above the point where terrace water enters. Metal rod is one meter high. Facing north, June, 1966.

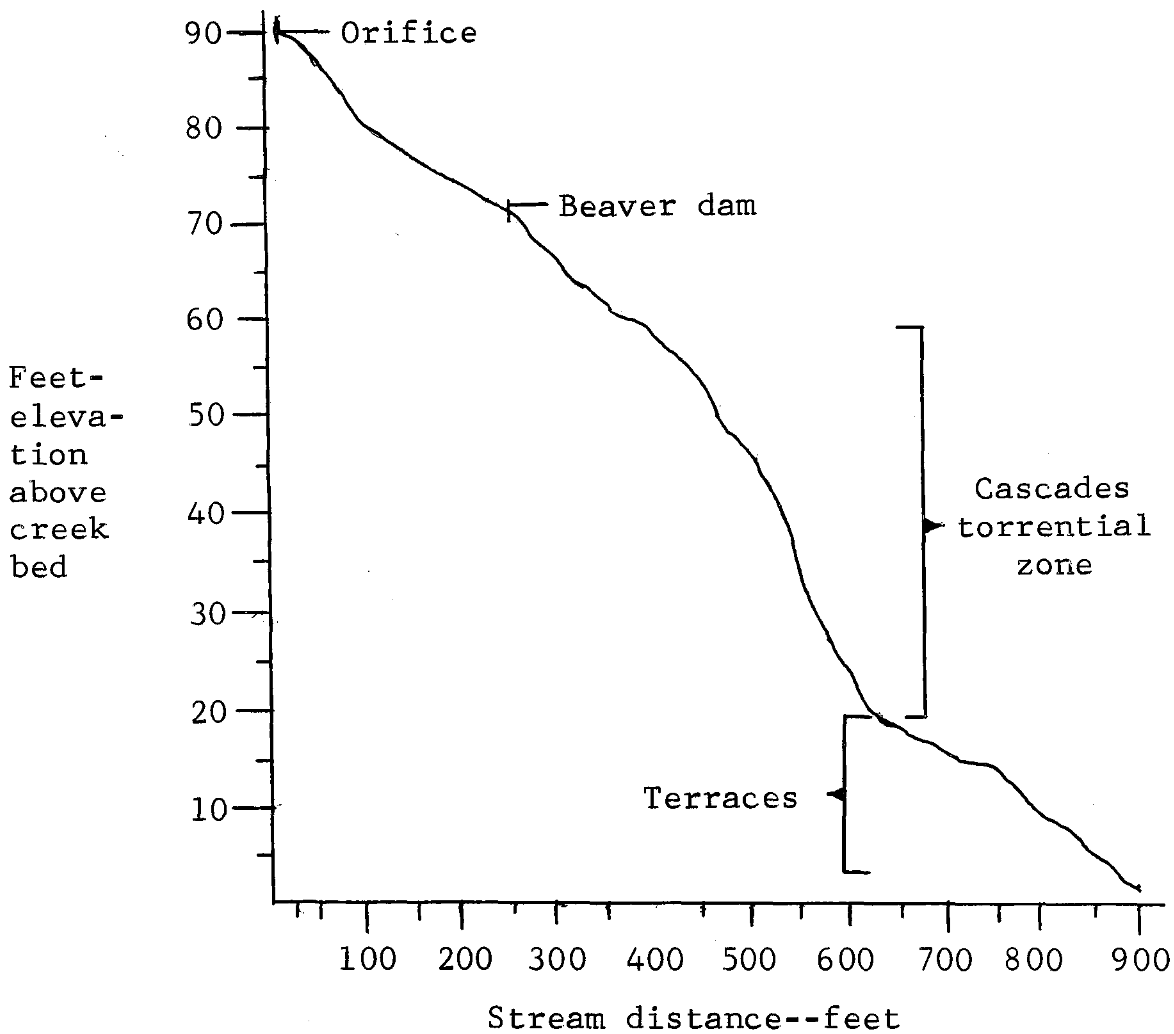


Fig. 8. Longitudinal profile of the Cascade Springs stream from source to mouth.

thistle (Cirsium arvense) have invaded areas around the terraces, although many beautiful herbs are also in evidence including monkshood (Aconitum columbianum), and the columbine, Aquilegia formosa, which is scattered along the rims of the terraces along with the willow, Salix myrtillifolia. Appendix II lists identified vegetation of the Cascade Springs area.

Bald-faced hornets are especially abundant and their nests have been seen in several locations around the springs region, although the usual scourge of aquatic environments, the biting and sucking flies, were seldom encountered. Fish known to be present in the terrace water are rainbow trout (Salmo gairdnerii) and German brown trout (Salmo trutta) (Ralph G. McDonald, General District Assistant, U. S. Forest Service, personal communication). I have seen fish more than 15 centimeters long in both the terrace pools and in the back waters of the beaver dam at the lower end of the springs basin.

Several kinds of birds have been observed including hawks, ducks, woodpeckers, robins, and a hummingbird which built a nest in a tall boxelder by the terraces, but was unsuccessful in incubating any eggs. No amphibians were observed at any time, though small garter snakes (Thamnophis sp.) were seen both near the terraces and along the banks of the springs. Various rodents were observed in grass along both springs and terraces many times, and rodent tunnels through the grass were occasionally encountered. Deer were never seen at the springs or terraces, although many were observed in the general vicinity and deer tracks were almost always present in the mud at the top of the springs. Jackrabbits were seen occasionally.

This area is popular with human visitors, even more so now that good roads have increased its accessibility. Several old campfires, garbage, partly chopped trees, and an occasional path through watercress or reeds all testify to the impact humans have upon this locality.

History of the Study Area

The primeval condition of the springs obviously is not known, but apparently even the watercress has recently arrived for it is listed by Welsh, Treshow, and Moore (1964) as introduced into Utah. The earliest white visitors of record were sheepherders and cowboys, for these springs were known as a major watering hole, containing clear, good water all year long. The sheep and cattle were freely grazed around and watered at the springs until about 1935 when control was exercised by the Federal Government (Ralph G. McDonald, General District Assistant, U. S. Forest Service, personal communication). Fishermen, hunters, picknickers, and campers have all utilized the springs area consistently in the past. From approximately 1950 to 1955, Dr. D Elden Beck brought a large class of conservation-oriented Brigham Young University students to the springs each year for a two day study of the habitats. He reported that excessive use and abuse of the area was resulting in a rapid deterioration of the area. The U. S. Forest Service also mentioned abuses involving garbage disposal and general disfigurement (John Glenn, District Ranger, U. S. Forest Service, personal communication). During one trip to the springs in the summer of 1965, I discovered a smouldering fire in the dead branch of a tree over ten feet above the ground. The fresh remains of picnics were often observed.

Recently the U. S. Forest Service built improved roads into the springs, as mentioned in the physical description. The Service is presently in the process of building a series of paths, bridges, and informational guideposts on and around the springs similar to the self-guiding paths found in the National Parks and other public recreational and educational areas, and even more facilities are planned for future development. As a campground is located nearby, no camping or picnicking is to be permitted in the immediate vicinity of the springs. The Utah Fish and Game Department has been requested to close the waters of the terraces and nearby portions of Provo Deer Creek to fishing (John R. Glenn, personal communication), and the Department has expressed a willingness to comply with this request (Utah Fish and Game Department, Provo office, personal communication).

METHODS AND MATERIALS

Mapping

An excellent topographical map of the Cascade Springs area was provided me by the Pleasant Grove Ranger District, Uinta National Forest, Utah. I determined placement of the orifice and seeps on the map by measurement of distances between them and to landmarks shown on the map. Vegetational areas were determined in the same way, and by estimation.

Sampling of Macroinvertebrates

A variety of methods were tested. Except where noted the specimens collected were placed in 70% ethyl alcohol in small glass jars.

1. Mosses, *Mimulus*, and watercress were pulled up and broken away from the surrounding plants, placed in air-tight plastic bags, and taken into the laboratory where a Berlese funnel was utilized in removing the organisms. A higher concentration of alcohol was used (85%) to compensate for the diluting effect of the samples.

2. The above plants and the substrate beneath were examined in the field for large invertebrates that could be

easily removed. An alternate laboratory procedure was to place the sample in a large white enamel pan and examine it with a hand lens and a binocular dissecting microscope. The vegetation was then agitated in the pan and the water poured through a number 40 brass screen. Water was then run backwards through the screen and the organisms caught in a second white enamel pan. The invertebrates were easily observed and removed and the particles of vegetation discarded. The vegetation in pan number one was agitated and the water decanted several times, with progressively stronger agitations each time. When invertebrates were no longer found in the decanted water the vegetation was examined one last time for tightly clinging specimens, then discarded.

3. A semi-quantitative method utilized a number 10 fruit can with both ends cut out and one rim removed. The can was quickly brought down tight on the vegetation and then twisted back and forth with a rotary motion to cut through the plants and into the substrate. A small-mesh sieve was used to scoop up the substrate within the can; rocks were picked out by hand. The vegetation sample was placed in one airtight plastic bag, and the rocks and other

substrates were placed in another. In the laboratory the rocks were individually examined and the other materials examined as in method number two above. This method was used for a variety of types of bottom and is called the "round can" method.

4. Mud and partly decayed vegetation of the springs and terraces were sampled by the round can method. However, the mud was mostly removed in the field by placing the sample in a number 40 brass screen, placing the screen in shallow water, and agitating the screen until the mud was washed off.

5. An aquatic net was pushed through the surface water of the terrace rushes and then examined for macroinvertebrates.

6. Rocks and boulders were picked up where possible or rolled over and macroinvertebrates were removed with fingers or tweezers. Where there was sufficient current an aquatic net was placed below to catch specimens that swam or were washed away. Logs and sticks of the small beaver dam were moved while the aquatic net was placed below and the animals were removed in the manner given above.

7. A surber sampler was placed on the bottom in

moving water. Rocks from within the area of the sampler were removed and placed in a box screen. The bottom within the sampler was stirred thoroughly and organisms were caught in the attached net downstream. This was also used as a semi-quantitative method.

8. An apron net was pushed through vegetation, the organisms and finer trash passing inside. This was then dumped into a white enamel pan and the organisms were picked out.

9. An aerial insect net was used to catch flying insects, a beating net was used to brush insects off vegetation, and insects were picked off rocks, soil, and vegetation by use of fingers and forceps. Some of the flying insects were placed in cyanide or ethyl acetate, but the majority were placed in 70% ethyl alcohol.

10. Two kinds of homemade emergent traps were utilized. The simplest consisted of a number 10 fruit can with both ends removed and mosquito netting tied tightly over one end. A second type was made from an orange crate lined with mosquito netting. The trap was placed in various areas of the springs and was examined every week or two.

11. Vertebrates were recorded as observed.

Identification of Plants and Sampling of Physical Factors

Information concerning important aquatic and surrounding terrestrial plants was obtained from the U. S. Forest Service office in Pleasant Grove through District Ranger John R. Glenn and by my own personal determinations.

Temperature was recorded by use of an air-water centigrade thermometer. Oxygen determination was by means of the Winkler method. PH was determined by use of pH papers and with a color comparison pH kit. A rough estimation of water flow (discharge) was made in two ways. A chip was thrown into the cascades and timed for 50 feet. This was repeated three times and an average taken as the velocity in feet per second. Velocity was multiplied by average depth times width resulting in water flow as cubic feet per second. For an alternate method the same procedure was used in Provo Deer Creek both above and below the entrance of the water from the springs. Water flow above the entrance subtracted from water flow below was equivalent to water flow from the springs.

Geological information of the springs region was obtained from the Geology Department of Brigham Young

University and from a U. S. Geological Survey map of the region.

Sorting and Classification of Invertebrates

All sorting of organisms into specific classificatory units was done in the laboratory using a dissecting microscope. Small, labeled specimens were put in the typical dental anaesthetic vials while larger specimens were placed in laboratory screw cap vials of varying sizes. Cyanide and ethyl acetate specimens were pinned or, if very small, were tipped.

Preliminary identification of all specimens was done by myself. Those who made a final check on this and made further identifications are:

Douglas Andrews, BYU Zoology Department Graduate student, Araneae

Dr. Lee Braithwaite, BYU Zoology Department, Planaria and the Gastropod, *Paludestrina*.

Dr. George W. Byers, University of Kansas, Tipulidae

Dr. George F. Edmunds, University of Utah, Ephemeroptera

Dr. Oliver S. Flint, Jr., Curator, Division of

Neuropteroids, Smithsonian Institute, Washington D. C., Trichoptera

Dr. Arden R. Gaufin, University of Utah, Plecoptera

Dr. Clive D. Jorgensen, BYU Zoology Department, Acarina.

While I used these determined specimens to further identify other specimens it is assumed that any errors of identification and interpretation are my own.

RESULTS AND DISCUSSION

Habitats Sampled

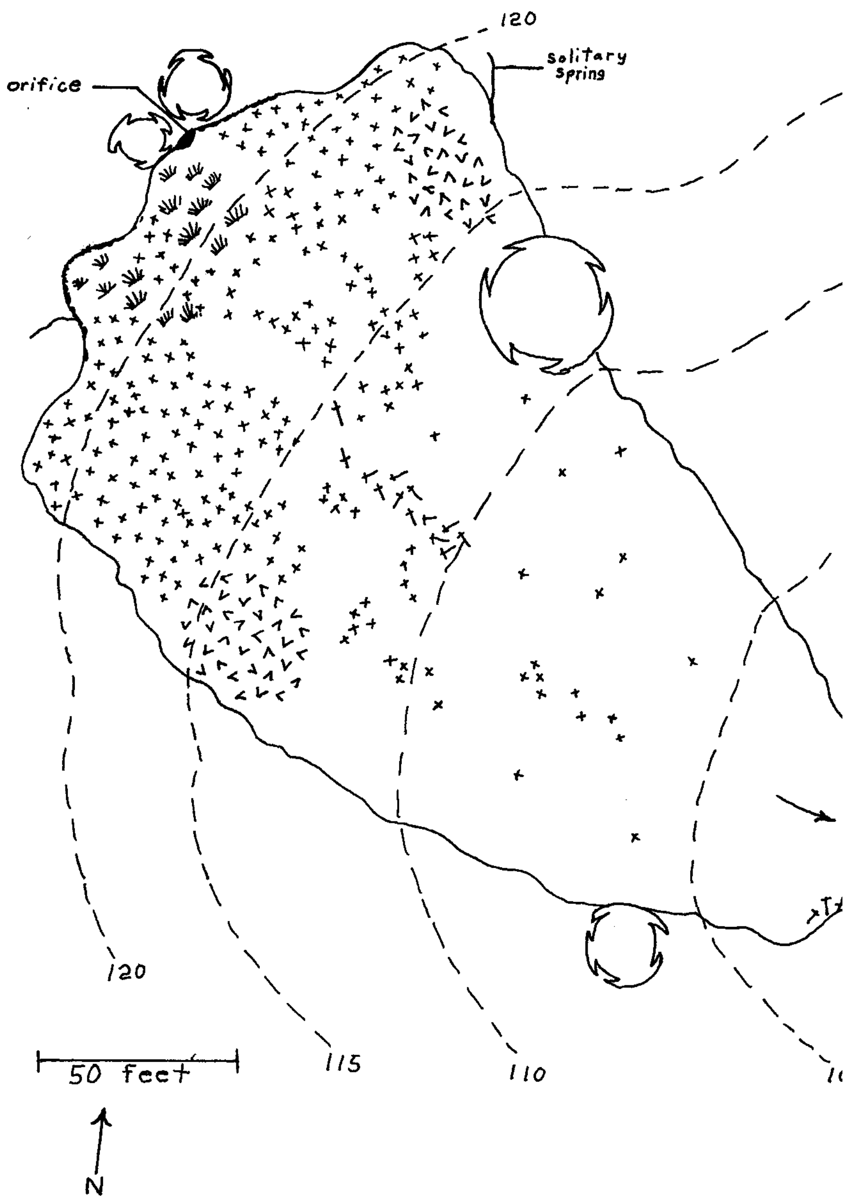
During the two-year period of this study of the Cascade Springs region, an attempt was made to sample every possible aquatic habitat that might offer important differences in environmental conditions. Enough locations were sampled to allow certain generalizations concerning major habitats. A habitat map (figs. 9-10) shows the distribution of major kinds of vegetation at Cascade Springs.

A) Springs basin habitats

A large variety of habitats were sampled in the general area of the springs mouth, including: Under rocks of varying sizes and varying distances from the top of the basin, in large mats of mosses, in mosses of quiet water and moss adjacent to moving water, in *Mimulus* stands, and in the substrate beneath rocks and moss. Inasmuch as equivalent kinds and numbers of macroinvertebrates were found irrespective of distance from the orifice, I concluded that this in itself is not an important factor.

Because of the uniform gravel beneath the rocks and various vegetational groups, there was not as much

Fig. 9. Map of the Cascade Springs basin and the upper cascades region showing the major vegetational types of the springs basin. (Modified from a map obtained from the Pleasant Grove Ranger Station, Uinta National Forest, Utah.)


orifice
120
solitary spring
120
115
110
50 feet
N

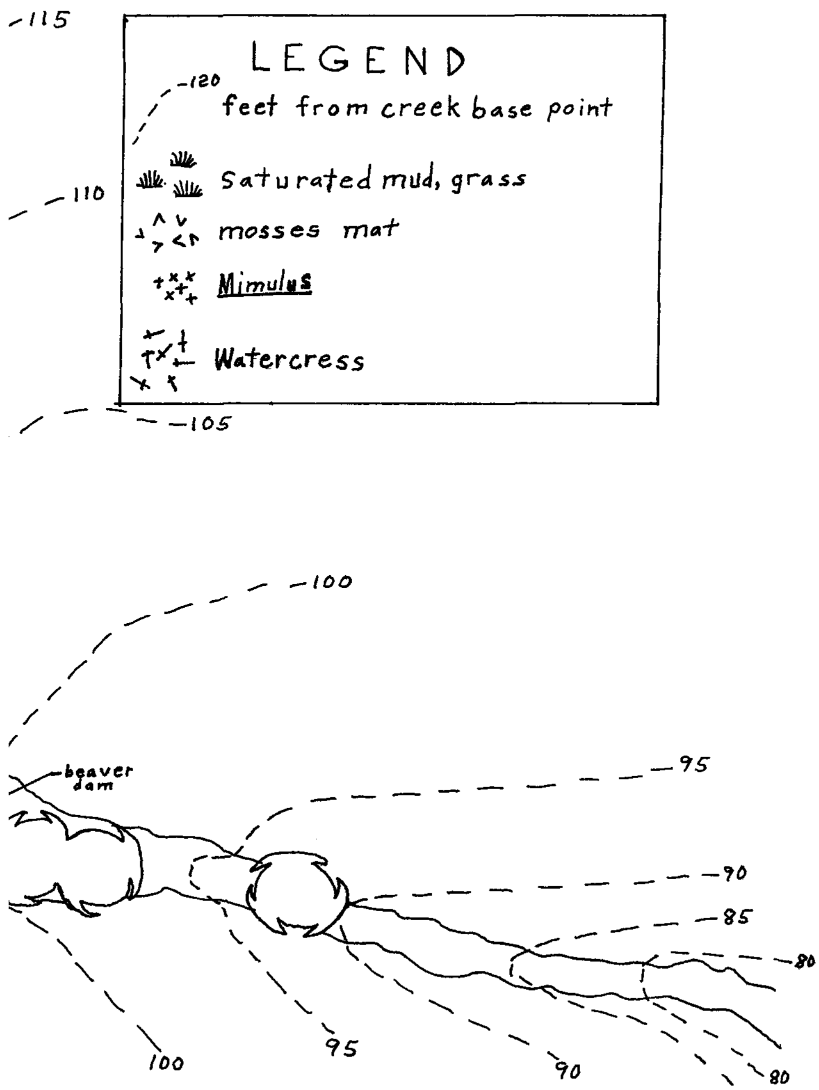
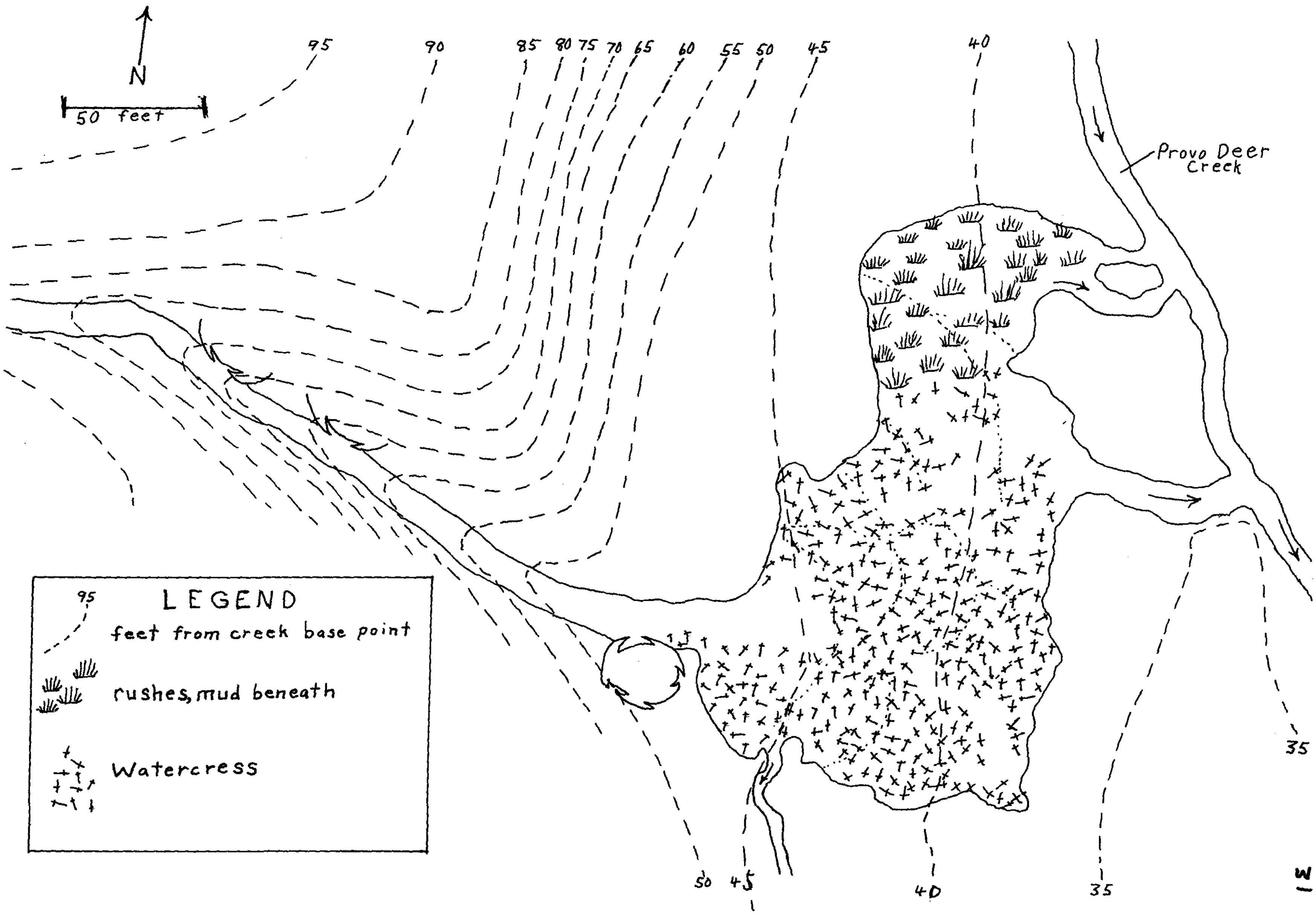

LEGEND
-120 feet from creek base point
Saturated mud, grass
mosses mat
Mimulus
Watercress
115
110
105
100
95
90
85
80
beaver dam
100
95
90
80
85

Fig. 10. Map of the Cascade Springs terraces, cascades, and adjacent section of Provo Deer Creek showing the major vegetational types of the terraces. (Modified from a map obtained from the Pleasant Grove Ranger Station, Uinta National Forest, Utah.)


N
50 feet
95
90
85
80
75
70
65
60
55
50
45
40
Provo Deer Creek
LEGEND
95
feet from creek base point
rushes, mud beneath
Watercress
50
45
40
35
35
W

difference in this under-rock habitat as I had expected. However, the finger net spinning caddisfly, *Dolophilodes*, was found exclusively beneath the edge of rocks of the springs, cascades, and Provo Deer Creek, and stoneflies of the genus *Acroneuria* were in greatest numbers here.

The large moss mat in the northeast part of the springs basin was found to be similar in content to moss and *Mimulus* stands in other parts of the springs, but had a slightly higher species diversity. Table 1 lists aquatic insects found in various situations at the springs.

The isolated spring in the northeast section of the springs basin grossly appears to furnish an entirely different habitat from the main springs, but closer scrutiny reveals the same gravel bottom and watercress completely covering the water. Table 1 demonstrates that this is only slightly different ecologically from the rest of the springs. The watercress, however, contains organisms most similar to the moss of the springs, rather than the watercress on the terraces.

Just to the west of the main springs orifice a mud bar extends out into the basin for a few meters. The mud bar, grass covered, is only about twelve to fifteen

Table 1. Presence list of aquatic insects at various springs basin locations.

Taxa	Springs-seep	Vegetation-choked spring	Moss mat	*Mimulus* and moss
Acroneuria	X	X	X	X
Alloperla	X	X	X	X
Nemoura			X	
Neothremma	X	X	X	X
Oligophlebodes		X		
Lepidostoma		X	X	X
Micrasema			X	
Ryacophila			X	
Tendipedidae	X	X	X	X
Euparyphus	X		X	X
Tipula			X	X
Stilobezzia				X
Dicranota				X
Baetis	X			X
Ephemerella			X	
Heterlimnius	X	X	X	X
Limnebius			X	X
Helophorus			X	
Hygrotes	X	X	X	

centimeters deep, a hard gravel substrate occurring below this. While there is no surface water over the mud, it is nevertheless completely water-saturated. The limited fauna includes Tipula, Euparyphus, Stratiomys, and Tendipedid larvae, an occasional Pisidium and semi-aquatic Oligochaetes.

No factors concerning the orifice appear to introduce any special conditions into the local environments. A nearby seep does show a tremendous increase in Heterlimnius and Neothremma populations, with otherwise normal results in the remainder of the fauna (Table 2).

About ten meters down from the top of the basin and on the northeast side is a short region containing a sandy bottom. Sampling of this showed a reduced species diversity when compared to surrounding areas. In fact, this and the beaver dam were the only aquatic areas of the basin completely devoid of Plecoptera larvae in the samples taken.

Another species-deficient area of the basin was the sand-gravel bottom of the fairly quiet water backed up by the old beaver dam. Acroneuria, Neothremma, Euparyphus, and Baetis were present. The Neothremma were in very large numbers, averaging over five hundred larvae per square meter. The dam itself contained a large variety of organisms,

Table 2. Populations of macroinvertebrates in four minor habitats using the round can sampler.

Taxa	Invertebrates per square meter			
	Seep	Moss mat, springs	Saturated soil, springs	Mud of rush bed, terraces
Acroneuria	102	204		
Alloperla	68			
Nemoura		68		
Baetis	204			
Limnephilus			136	
Tipula		68		
Stratiomys			272	
Euparyphus	34	714	238	
Tendipedidae[1]	68	204	136	34
Tendipedidae[2]	34			
Ceratopogonidae				34
Bittacomorpha				1020
Heterlimnius[1]	1904	68		
Heterlimnius[3]	2142			
Limnebius[1]		34		
Pisidium			34	204
Ostracoda	408	782	34	102
Oligochaeta			476	

[1]Larvae

[2]Pupae

[3]Adults

Plecoptera being the only major group not represented. Even the rather specialized net-spinning *Dolophilodes* were observed. Water rushes through the tangled sticks and branches in places and, as a result, *Ephemerella* and *Epeorus*, which seem to favor moderate to strong current velocity, are found here. This is the farthest upstream that they were found to occur.

B) Cascade habitats

Because the cascades are wide in places resulting in slower water movement, and torrential in others, a large variety of organisms live in the different parts of the cascades. Even in the torrential portion, where it might be expected that the water would wash away all organisms, a moderate number are found (Table 3).

C) Terrace habitats

The terraces as a whole contain most of the species of aquatic invertebrates found at Cascade Springs but the watercress region itself, although it extends over a major part of the terraces, is more exclusive in its inhabitants. The only Plecopteran found was *Nemoura*, although this occurred in great numbers, while *Paraleptophlebia* was the

Table 3. Presence list of aquatic insects found in some cascade and terrace habitats.

Taxa	Cascades-torrential	Terraces-watercress	Terraces-under rocks	Terraces-open bottom
Acroneuria	X		X	
Alloperla				X
Nemoura	X	X	X	
Neothremma	X	X	X	X
Ryacophila	X	X	X	
Hesperophylax		X	X	
Parapsyche	X		X	
Baetis	X		X	X
Ephemerella		X		
Heptagenia			X	
Epeorus			X	
Paraleptophlebia		X	X	
Tendipedidae	X	X	X	X
Ceratopogonidae		X	X	X
Tipula		X	X	
Dicranota	X	X		X
Euparyphus		X		
Simuliidae	X			
Heterlimnius	X	X	X	X
Dixa		X		
Laccobius		X		
Tropisternus		X		

only mayfly naiad consistently found here. Two beetles of the family Hydrophilidae were found to occur, representatives of the genera Laccobius and Tropisternis; no Dytiscids were observed in this vegetation at all. Table 3 lists the watercress organisms that were found.

The rocks of the channels and pools covered quite a diverse assemblage of organisms despite the apparent lack of vegetation, as shown in Table 3. Even the open bottom of a terrace pool contained several species.

One sample was taken from the moss, Fissidens grandifrons, behind a miniature waterfall, about 15 centimeters high, formed by water spilling over a lip of one of the terraces. This specialized habitat contained eight kinds of macroinvertebrates. All of these species are found in the immediately surrounding area, either in watercress or on the open bottom and beneath rocks, with the exception of Limonia and the semi-aquatic oligochaetes.

The most specialized major aquatic habitat of the entire springs area appears to be the northeast section where shallow water only one to two centimeters deep overlies mud and partly decayed vegetation that is more than a meter deep. Rushes of the species Juncus saximontanus, cover most of the entire area. Evidence of the special habitat here is the exclusive presence of *Gerris*, *Sigara*, *Aeschna*, *Amphiagrion*, *Bittacomorpha*, and the so-called "bloodworms" (Tendipedidae), and the near absence of Plecoptera.

D) Provo Deer Creek

Provo Deer Creek averages about two meters wide and eight centimeters deep above the entrance of the springs water, and below the terraces it increases to an average of about three meters wide and twenty centimeters deep. A considerable amount of silt and debris is carried by the creek, and the substrate of the stream itself is mostly mud, with some areas of rocks and pebbles. The fauna of Provo Deer Creek adjacent to the terraces is similar to that of various parts of the springs, cascades, and terraces. No new species were observed here although only limited collecting was done.

A comparison of species diversity of some minor habitats is shown in Fig. 11, and a comparison of species diversity between the springs and terrace habitats is in Fig. 12.

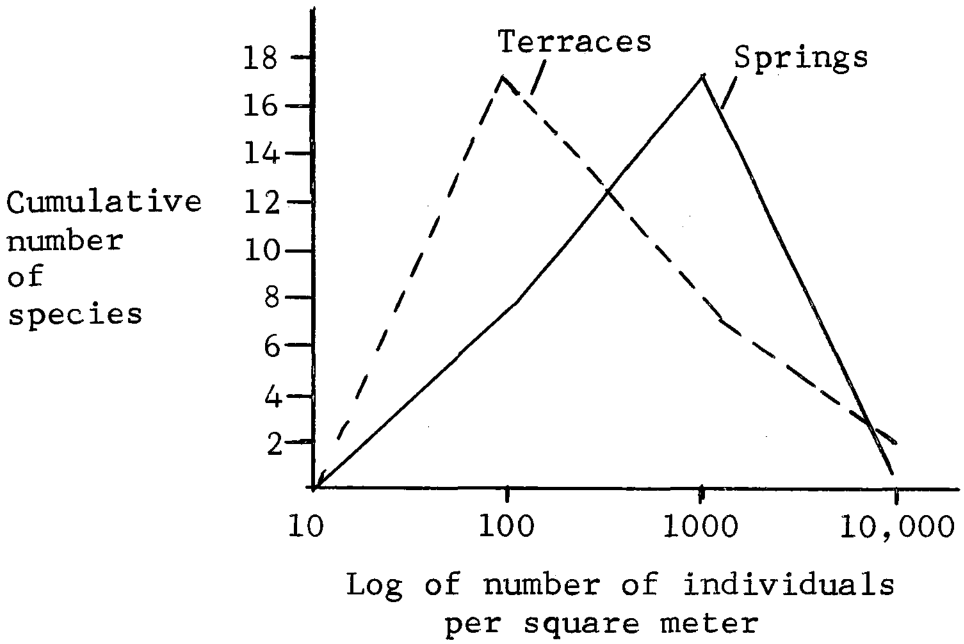


Fig. 12. Species diversity index of macroinvertebrates of the springs and terraces habitats.

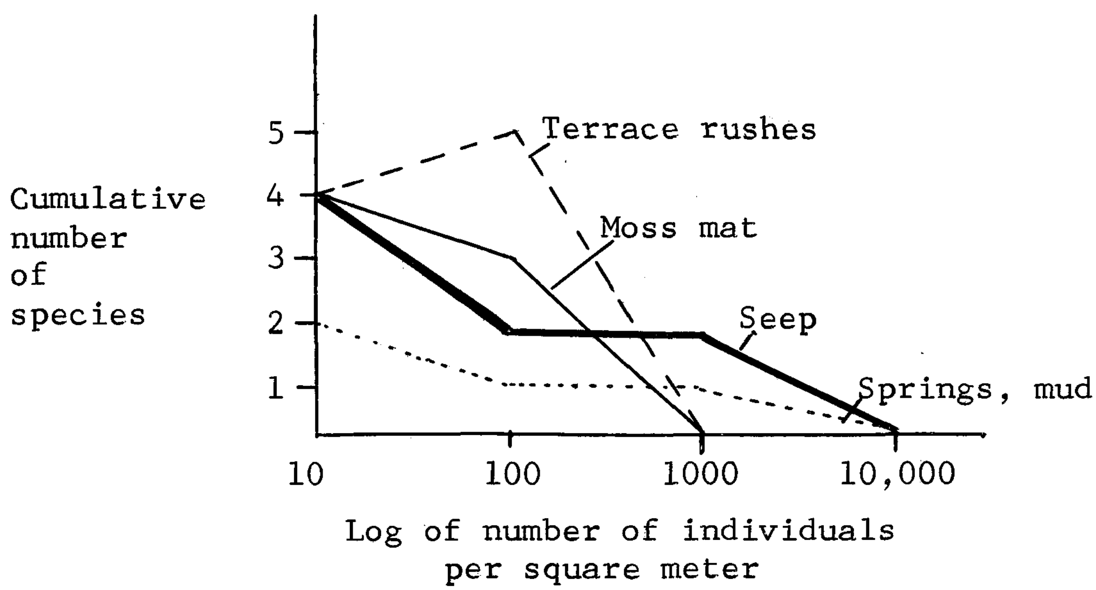


Fig. 11. Species diversity index of macroinvertebrates for some specialized minor habitats.

Methodological and Quantitative Results

An emergent trap designed from an orange crate was used from August 29, 1964, to the end of October, 1964, at the springs mouth. Seven species of insects emerged in the trap during this time, as summarized in Table 4. In retrospection, I feel some dissatisfaction with this trap because it was so dark inside. This altered the natural environment and may have affected the emergence of some insects. Despite a sign on the trap explaining its purpose there was still evidence that people had disturbed it. If a trap were made of fine-mesh screen I feel that it would tend to alter less of the environment, and as an added bonus it would be lighter and more portable.

A Berlese funnel was utilized on three occasions in 1964 and a surprisingly large number and diversity of organisms was found. Despite the fact that this method is not even mentioned in most texts that discuss aquatic sampling, I feel that this method has much merit in sampling of vegetation. One important advantage is the time saved by the person sampling, who would otherwise have to hand pick through quantities of plant material, a process that may take hours. A drawback to this method is the fact that only one

Table 4. Insects that emerged inside emergent trap on various dates during 1964.

Taxa	Dates and numbers of adult insects found in emergent trap				
	19 Sept.	3 Oct.	17 Oct.	24 Oct.	31 Oct.
<u>Acroneuria</u>	4	15	2	2	4
<u>Alloperla</u>		3			
<u>Nemoura</u>		2			
<u>Oligophlebodes</u>			3	1	2
<u>Ryacophila</u>	3		1		
<u>Micrasema</u>	1		1		
<u>Lepidostoma</u>			1		

sample may be prepared at a time, for each sample requires forty-eight to seventy-two hours in the Berlese. Unfortunately, Ephemeroptera naiads do not seem to come through the Berlese properly and cannot be sampled in this way.

I attempted to use an apron net in various habitats but was completely unsuccessful in all but one. The substrate is too solid for the apron net to be used in bottom sampling, the springs are too shallow for successful use with moss, and the rushes are too close together for it to be used in the terrace mud region. Partial success was obtained in passing the apron net through watercress, although even here few organisms were caught, except large quantities of Paludistrina longingua, the watercress snail.

The Surber sampler is a common limnological tool for quantitative determination of populations. I used it upon two occasions but feel it has limited use in the springs area. The sampling area of the Surber sampler is one square foot.

The round can method was used for the majority of collections made. Table 2 summarizes some of the quantities of organisms per unit area found in various habitats. Obviously, several of the habitats are not as large as a square meter; these statistics merely equate them so that comparisons of populations can be made. Of special interest are the findings that there were up to two thousand each of Heterlimnius larvae and adults per square meter in the terrace mud and rushes area. This method is not without drawbacks for in the uneven surface of a gravel bottom it is hard to get a good seal. The terrace water was generally too deep, preventing the use of this particular method, for some organisms could simply swim or float over the top rim of the can. Before an accurate quantitative measurement is possible, it is necessary that the top rim of the can stick up out of the surface of the water.

Physical and Chemical Data

Temperature at the springs was very consistent during the entire year. The reading at the orifice was 9.4° C in tests that were taken during all seasons except winter. The water warms very little by the time it reaches Provo Deer Creek, a distance of almost three hundred meters, as demonstrated by readings at various locations along the stream (Table 5). Most of the terrace water passes directly into Provo Deer Creek; only a small amount first passes

Table 5. Water temperature and pH at various locations in the Cascade Springs area on June 18, 1966.

	Temperature in degrees centigrade	pH
Springs orifice	9.4	7.5
15 meters down from mouth		7.6
50 meters down from mouth		7.8
Beaver dam	9.4	
Bottom of cascades	9.6	8.0
Terrace rushes, mud beneath	15.6	7.8
Provo Deer Creek, above terraces	17.0	8.3
Provo Deer Creek, below terraces	12.8	8.2

through the terrace rushes and mud where it might be subjected to warming.

The acidity-alkalinity was found to be slightly basic at the orifice and increasingly basic farther down (Table 5).

Sampling evidence suggests that the macroinvertebrates are mainly distributed according to the presence or absence of specific vegetation, appropriate substrate, or velocity of current, rather than chemical factors. The vegetation itself, however, may be significantly affected by one or more chemical factors.

Because of my agreement with the U. S. Forest Service not to seriously disturb the springs area, only rudimentary means for determining water flow were possible. The flow at the cascades was determined by measurement of velocity multiplied by area of the stream bed in cross section and resulted in 27.1 cubic feet per second. The springs flow as determined by subtraction of volume in Provo Deer Creek above the entrance of the springs water from total water volume below the terraces was found to be 16.5 cubic feet per second. The first method involved stream flow through an area that varied considerably in width and depth. Differences in width varied from three feet to 14 feet within a short distance. As a result this was probably a much less accurate determination than the second method.

Oxygen concentration at the orifice was recorded at unexpectedly high levels which correlates with my observation that an obstruction within the mouth of the orifice causes aeration of the water as it flows out. I obtained readings of 6.5 and 7.4 on two occasions. Deanna B. McCoard (personal communication) also reported unexpectedly high levels of oxygen concentration at the orifice.

Ecological Observations of Aquatic Insects

A taxonomic summary of the aquatic and semiaquatic macroinvertebrates appears as Appendix I.

Thirteen orders of insects contain aquatic and semiaquatic representatives in North America according to Usinger (1956), and all of these are represented at Cascade Springs except Orthoptera, Megaloptera, Neuroptera, Lepidoptera, and Hymenoptera. Excluding the Megaloptera, all of the above orders are virtually terrestrial with only a few uncommon species having aquatic preferences.

A) Collembola

Although not aquatic in the true sense of the word

(Usinger, 1956, p. 75), Collembola are nevertheless a part of the fresh-water community, acting as scavangers and forming one of the basic links in the food chains. Sminthuridae, Poduridae, and Entomobryidae have been collected at the springs, occurring in vegetation and on other protruberances in the springs, cascades, and terraces.

B) Ephemeroptera

Seven species of mayflies were identified from the springs region. Baetis appears to be ubiquitous, being found in samples from all aquatic habitats sampled. While its preferred habitat seems to be under rocks, it was also found in quiet water of the moss mats, watercress, and terrace rush beds, and in the fast water of the cascades. Eighty five percent of all mayfly naiads in the samples were Baetis. Epeorus and Heptagenia species are dorso-ventrally flattened, resulting in a lessening of the current's drag in the swift water where they live. They were found only in samples from the swift water of the cascades, dam material, and in Provo Deer Creek. Paraleptophlebia appears to be confined to the terraces region, being found there, however, in a variety of habitats, including watercress, under rocks of the open terrace channels, and even in the terrace rushes where the water depth averages only two centimeters. Adult mayflies live only for a few hours or a few days (Usinger, 1956, p. 79), and thus their presence is itself indicative of the time of year that emergence is occurring. The vast majority of mayflies observed were again Baetids, of the species *B. tricaudatus*, and were observed in flight from March to June. The males of this species are especially striking, having divided eyes with the dorsal part turbinate and colored red-orange. Specimens were observed emerging in April of two different years. A swarm of *Epeorus* was observed above the cascades on January 29, 1966. *Cinygmula mimus* was seen on July 1, 1965, and *Paraleptophlebia debilis* adults occurred from July through October, being especially numerous around the terraces on October 17, 1964.

Mayflies, being herbivores, form an important part of the basic consumer trophic level. They have little means of defense, their large numbers being the main reason perpetuation of their species continues.

C) Odonata

Naiads of dragonflies and damselflies were discovered only in the water of the terrace rush beds, and even here they were seldom encountered. One Aeshnid and two

Amphiagriids were recorded in samples taken in August. While adults were more common, only a few of each species were ever observed. On a few occasions dragonflies and damselflies were seen at the springs, usually as casual visitors which departed swiftly.

The odonata are voracious carnivores and it is only because they occur at the springs in such few numbers that they are relatively unimportant secondary consumers.

D) Plecoptera

The largest aquatic invertebrates of the springs area are stoneflies of the family Perlidae which commonly reach a length in the immatures of three to four centimeters, not including the caudal cerci. The preferred habitat is beneath rocks, although an occasional one may be found on an open gravel bottom or in the gravel beneath a moss mat. Only one Perlid was taken from the cascades proper, and this was from near the top where the water is slower and the channel wider. The largest specimens of Perlidae were found beneath rocks in Provo Deer Creek. The large mats of terrace watercress were devoid of Perlids but contained large numbers of another stonefly, Nemoura californica, which can be readily identified because of the four gill tufts posterior to the ventral surface of the head. Nemoura is another ubiquitous species of the springs complex, specimens appearing in samples from the entire range of aquatic habitats sampled, including terrace rushes and mud and the torrential cascades. Nymphs of this species showed a distinct habitat preference for vegetation of various kinds, in contrast to the preference of Perlids for the underside of submerged rocks and boulders.

Although less abundant in all habitats, two species of Alloperla were consistently picked up in samples from the spring, and with less consistency from cascades, terraces, and Provo Deer Creek. The specimens from the cascades were in slower, more shallow water, and all Alloperla occurred in areas of well vegetated, shallow water. The greatest numbers were consistently produced by a shallow spring in the northeast section of the main springs, where the water was only a centimeter or two deep and completely filled with watercress.

The adult Perlid, Acroneuria, was first observed during July, quickly increased in density and achieved maximum numbers in the period from August to October. The emergent trap demonstrated that Acroneuria was still emerging at the end of October. No sampling took place during November and

December and no Perlids appeared during a check of the springs taken the last part of January. In fact, no stoneflies were found at all in the January check, although three species of Nemouridae (two *Capnia* and one *Nemoura*) were found on snow within one-half mile of the terraces, along Provo Deer Creek. Species of Alloperla were found during all seasons of the year except winter, occurring from April through October at least, and the family Nemouridae appeared to have representatives during the entire year, although the January species were all different from any found during the other months sampled.

Adult Perlids were found only on the yellow monkey flower, *Mimulus guttatus*, which forms a one-half meter high canopy over much of the top of the springs in the summer. About equal numbers were on the top and underside of the leaves throughout the plants, but upon being disturbed they would quickly drop down into the bottom foliage. On the other hand *Nemoura* and *Alloperla* were observed to remain generally at lower levels in the foliage, occasionally walking out over the moss mats. No stoneflies were ever observed in flight. In fact, the Perlids have short and apparently nonfunctional wings. This could, in part, account for their distribution, being observed only on the springs vegetation. Other stoneflies appear to have functional wings, and the lack of nocturnal observations may be the reason no flights were observed.

The Plecoptera showed considerable sensitivity to habitat changes. The evidence for this consists of the following observations: (1) *Nemoura californica* was the only species found in terrace watercress; (2) no Plecoptera were found in dam material or on a sand bar of the springs basin; (3) only the Perlidae were found in the relatively still water above the beaver dam; (4) Chloroperlids were not found in samples from all parts of the terraces, except one lone specimen found on open bottom gravel; (5) no Plecoptera were found in the terrace rushes except one specimen of Nemouridae.

E) Hemiptera

Aquatic Hemiptera were not observed at the springs proper, but two families are represented in the rushes area of the terraces. *Gerris* occurs throughout the reeds, where both adults and nymphs were collected; it is common also in the adjacent sections of Provo Deer Creek. In all of the collections made at Cascade Springs only one adult Corixid bug was discovered, this appearing in a terrace rush collection taken in August, 1964.

While the Gerridae are carnivorous, the Corixids are considered omnivores, eating, among other things, algae, protozoans, rotifers, and small Dipterous larvae.

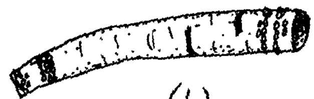
F) Trichoptera

Two genera of caddisflies, Lepidostoma and Neothremma, were found to be abundant throughout the springs area and occurring in all of the major habitats sampled. It has not, however, been possible to determine with certainty whether more than one species is involved in the distribution of each of them. Larval Ryacophila are well distributed in all areas except the muddy substrate of the terrace rushes. They are generally found under the edge of rocks or under moss rather than out in the open. Dolophilodes was recovered from springs, cascades, and Provo Deer Creek, exclusively under the edge of rocks where long finger nets can extend with the current, and in the dam material. These caddisflies can be recognized by the extreme flexion of their abdomen. Parapsyche was found in fast and slow water of the cascades, under rocks of the terrace channels, and in Provo Deer Creek. Most specimens came from the cascades. Hydropsyche was found only under rocks in the creek adjacent to the terraces. Hesperophylax was only rarely discovered, occurring in the terrace watercress samples and the terrace rushes. Limnephilus was also rarely found, the mud and decayed vegetation at the springs orifice being the only positive sampling location. Oligophlebodes minuta was recovered from samples only in the springs mouth locality, occurring in gravel from an open seep, and also in gravel from beneath rocks. Micrasema appears in most of the samples containing Neothremma, and in most cases constitutes a small minority, but large numbers were found in one sample from slower water of the cascades. Only adult Ochrotrichia were found.

Ryacophila, Parapsyche, and Hydropsyche are mostly free living, though one specimen, identified by Dr. O. S. Flint as "Ryacophila species," was found in a curious case made almost entirely of shells of the snail, Paludestrina longingua. This is in direct contradiction to statements made by Usinger (1956, p. 243) and Pennak (1953, p. 569), that Ryacophila are exclusively free-living, although Dr. Flint gave no indication that this was unusual. Immovable finger nets are constructed by Dolophilodes under the edge of rocks, beneath the water's surface. These nets are at most only about a centimeter wide, but may extend down through the gravel and vegetation for seven or eight centimeters. Colonies of a dozen or more individuals may live next to each other if the overlying rock is large enough. All of the other caddisfly larvae found make portable cases of various materials. The most typical case is that of Neothremma which is a long curved cone with the small end extending up into the current and an open bottom through which the larva extends to grasp onto the substrate (Fig. 13a). The longest cases I recorded were about twelve millimeters long. Members of several other genera, some even of other families, make similar cases. I have found them to differ in the following ways: The Neothremma case, described above, is made of very small crystal particles glued together but appearing smooth and dull. Micrasema cases are about the same size but have a microscopic texture of yellow birch-bark, including dark "rings" and "lenticels." Also the large end of the Neothremma case extends forward dorsally as a slight "hood" over the larva, while the Micrasema case ends abruptly dorsally. Often a few crystals are found on the Micrasema case, especially near the bottom and rimming the top (Fig. 13b). Lepidostoma pluvialis cases are very

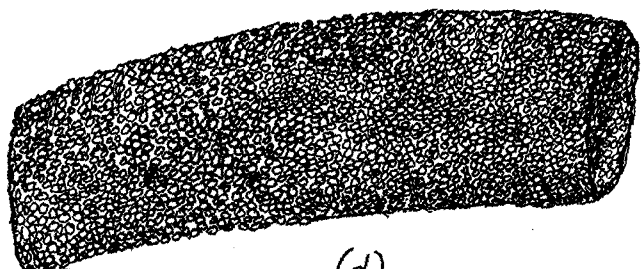
Fig. 13. Cases of several Trichoptera (a through e) and of a Tendipedid (f) of the Cascade Springs area. (a) *Neothremma alicia* 4X; (b) *Micrasema bactro* 4X; (c) *Oligophlebodes minuta* 4X; (d) *Limnephilus* sp. 4X; (e) *Hesperophylax* sp. 4X; (f) *Tendipedidae* 4X.

(a)

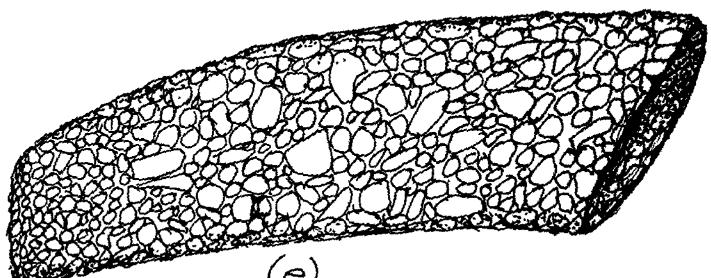


(b)

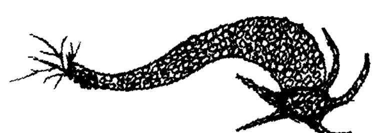
(c)



(d)



(e)



(f)

similar in size and texture to the Neothremma case but appear smoky or dirty with a few white crystals scattered throughout. Oligophlebodes cases are also similar except they are shorter, the longest being six millimeters, and they are more stocky (Fig. 13c). The Limnephilus case may extend to a maximum of 13 millimeters and is only slightly longer than that of Neothremma, but it is three times as wide. It is shaped like a slightly bent cylinder and the case is composed of dull, fine crystals (Fig. 13d). Hesperophylax makes a case similar in size and shape to Limnephilus except it is more coneshaped. The case is, however, composed of coarse crystals, bits of snail shell, and in one specimen, even a few Isopod exoskeletons (Fig. 13e). Probably the case most easy to identify is that made by Lepidostoma unicolor. Bits of vegetation, especially of what appears to be moss stems, are interwoven transversely in no apparent pattern. The largest cases may be a centimeter long. One Lepidostoma was found to have constructed a case from what seems to be bits of watercress leaves.

Trichoptera cases are useful as an indication of trophic level for as a general rule the case-makers are phytophagous and the free-living caddisflies are carnivorous

(Usinger, 1956, p. 240). The cases would be expected to provide some safety which, it is expected, the carnivores would need less.

Pupation was observed to occur in the cases of the case-making species while Ryacophila and Parapsyche pupae were covered by small pebbles which had been cemented together and attached to the underside of boulders. Pupae of Neothremma were observed from the first of April until the last of October. One Hesperophylax pupa was observed on July 8, 1965, as well as Parapsyche elsis and Ryacophila acropedes on the same day. On May 15, 1964, one Micrasema pupa was found.

Because I was not able to make species identifications of the adults the seasonal distribution has less meaning. Table 6 records the monthly presence of each genus.

G) Coleoptera

Heterlimnius is by far the most ubiquitous of the aquatic beetles found in the springs region, occurring in all major habitats except the mud and decayed vegetation of terrace and springs. It exists in the swift torrential water of the cascades and in the moss behind the miniature terrace falls. While both adults and larvae were recovered

Table 6. Seasonal monthly occurrence of Trichoptera at the Cascade Springs Area.

Month and year	*Ryacophila*	*Dolophilodes*	*Ochrotrichia*	*Neothremma*	*Oligophlebodes*	*Lepidostoma*	*Micrasema*
Jan., 1966					X		
Mar., 1965	X				X		
Apr., 1964	X	X		X	X	X	
Apr., 1965	X	X	X			X	
May, 1964				X		X	
May, 1965				X		X	X
June, 1964	X	X		X	X	X	
June, 1965				X		X	
June, 1966	X			X		X	
July, 1964				X		X	X
July, 1965	X	X		X	X	X	X
Aug., 1964			X				
Aug., 1965	X	X		X	X	X	X
Sept. 1964	X	X	X	X	X	X	X
Oct., 1964	X	X		X	X	X	X

from these various habitats the great preponderance of specimens were collected in the general region of the spring mouth, especially in a seep near the main orifice where the population was determined to be several thousand per square meter (Table 2). While it could be postulated that low oxygen content, which is typical for springs, might be the factor most responsible for the population size at the seep, this is apparently not so for Usinger (1956, p. 357) states that water of low oxygen content will have fewer Elmidae.

One Agabus adult was discovered near the orifice in moss and on different occasions, both males and females were seen in the water of the terrace rushes. Hygrotus adults were found in several locations, especially in association with moss, and larvae of either the genus Hygrotus or Hydroporus were also recovered from similar vegetation. One larva of the family Hydrophilidae, genus Tropisternus, was found in a berlese sample from watercress of the terraces. One adult Laccobius was also found associated with watercress and one Helophorus came from a sample of moss from the springs. One large Hydraenid larva of the genus Limnebius and several smaller individuals came from various moss samples taken at the springs.

While the families Carabidae and Staphylinidae are terrestrial in nature, observation and sampling demonstrated that some species are intimately associated with the aquatic environment; thus certain Staphylinids are found in moss and Carabids occur in vegetation on rocks that are surrounded by water.

H) Diptera

Two genera of Tipulidae have larvae that are fairly widespread locally. Tipula was found not only in moss samples, terrace watercress, and Provo Deer Creek, but also in the mud and half-decayed vegetation sampled at the springs mouth. Dicranota was in all of the same samples except the mud and was also commonly found in both swift and slow waters of the cascades. The only other aquatic Tipulid larva discovered was Limonia which occurred in the rather specialized location behind the miniature waterfall, in algae. Several other genera of adult Tipulids were found (Appendix I) but it is not known whether their larval stages are aquatic or terrestrial. The wingless cranefly, Chionea, was found on snow along Provo Deer Creek in January, but its larvae are known to be terrestrial, occurring in leafmold (Usinger, 1956, p. 378).

Larvae of the false crane fly, Bittacomorpha, were found in great numbers in one July sample from the terrace mud. Several samples have been taken since and a careful search made to determine if these curious larvae were again present but none has been found. Living in the mud they have solved the problem of respiration with a long breathing tube which extends up out of the mud.

Adult midges (Tendipedidae) occurred in this area all year long. In January some were seen flying, mating, and lying on the snow. The larvae were perhaps the most ubiquitary of all insects observed, occurring in all sampled habitats. "Bloodworms," larvae of certain of the Tendipedinae, were not common but were found in the terrace mud and rushes where their presence attested to a probable low oxygen concentration level. Very small curved, trumpet-shaped cases (Fig. 12f) were found to contain one of the Tendipedids. Pupae were recovered from berlese and other samples during May, June, July, and August.

A Ceratopogonid, Palpomyia, was also found in all habitats except for the two with mud and decayed vegetation. Pupae were recovered from samples of June 10, 1964, the terrace watercress containing a Culicoides pupa and pupae of

Dasyhelia and *Stilobezzia* being found in moss near the springs orifice.

Dixa larvae were recovered on two occasions from the terrace watercress while an Ephydrid larva was found in moss at the springs and larvae of two different genera of Sciomyzidae, *Sepedon* and *Dictya*, were in a sample from the terrace mud. Simuliids occur in the fast and slow water of the cascades and in Provo Deer Creek but apparently in none of the other habitats.

Euparyphus larvae (Stratiomyidae) were found in all habitats sampled, except for the terrace mud and rushes, but including the mud and vegetation of the spring mouth. The posterior spiracular chamber of this larva is lined with long hairs which are commonly held above the surface film. On one occasion large numbers of these larvae were observed lying on moist moss actually above the surface of the water. Larvae of another genus, *Stratiomys*, were found in mud and decayed vegetation at the springs mouth.

A great number of adult Diptera were netted but only those genera known or suspected to contain aquatic larvae are included in the appendix list.

Ecological Observations of Invertebrates Other Than Insects

A) Turbellaria

Planaria occur in all major habitats of the springs area, being especially numerous, however, in several samples taken from a small vegetation-choked spring to the northeast of the main springs. They are generally scavengers (Pennak, 1953) and were observed at various times clumped on dead and decaying insects and other animals. The planaria were identified by Dr. Lee F. Braithwaite as a new species; the same one he has described in a publication now in press.

B) Nematoda

Male and female roundworms were taken in samples from all vegetated regions of springs and terraces, though in few numbers. It is possible that, because of their small size, almost all being less than a centimeter long, they were merely not noticed. One nematode was observed protruding through the prosternum of a Heterlimniid.

C) Oligochaeta

The Lumbricidae were observed only in the mud of springs and terrace but Naididae and Enchytraeidae were found in various locations, especially in the roots of water-cress plants.

D) Hirudinea

The only leeches observed were from the terraces, although they occurred both near the cascades in watercress as well as in the mud-rush zone.

E) Gastropoda

The small watercress snail, *Paludestrina longingua*, was present in all habitats, occurring in moss and *Mimulus* in especially large numbers. Its densest populations were in the watercress of the terraces where a rather incomplete apron shoveler sample showed more than 400 snails in two hundred square centimeters. A large number of shells of this snail occur on the bottom of the terrace pools and in the hard substrate (Dr. Lee F. Braithwaite and Dr. Jess R. Bushman, personal communications). Habitat distribution of the snails is shown in Table 7.

F) Pelecypoda

The seed clam, *Pisidium*, occurred in all major habitats, although a larger and probably different species was found in the terrace rushes.

Table 7. Distribution of Gastropods in various habitats of the Cascade Springs area.

Habitat	*Carinifex*	*Physa*	*Lymnaea*	*Paludestrina*
Spring- moss sample	X		X	X
Spring- sandy bottom			X	X
Cascades- slower water	X			X
Terraces- watercress	X	X	X	X
Terraces- under rocks			X	X
Terraces- mud and rushes		X	X	X
Provo Deer Creek		X		X

G) Crustacea

Amphipods, Gammarus limnaeus, were extremely numerous in samples from most major habitats except the terrace rushes and mud where they were less common. They were entirely absent in the springs mud and vegetation, owing to the fact that this area contains no free surface water.

At least two species of Ostracods were observed, both occurring in all aquatic habitats.

H) Arachnida

While the spiders of the area are probably not aquatic in the true sense, I nevertheless included in the appendix species that were found in wet moss and in other "semi-aquatic" locations.

CONCLUSIONS AND SUMMARY

The springs basin, cascades, terraces, and Provo Deer Creek form four natural habitats, differing from each other in dominant vegetation, factors of water flow, and type of bottom. Dominant in the springs basin are Mimulus guttatus and several mosses, while the moss, Fissidens grandifrons, forms a solid mat over boulders in the torrential cascades, watercress mats (Rorippa nasturtium-aquaticum) are dominant over much of the terraces, and a variety of aquatic vegetation occurs in Provo Deer Creek. The torrential zones of the cascades are in contrast to the steady, shallow water flow over gravel and around rocks in the springs basin and the deeper, sandy-bottomed pools and the channels meandering through stands of terrace watercress. The creek bottom of mud and rocks is replaced by stretches of coarse sand lined with waving filaments composed of Spirogyra, Zygnema, and Tribonema.

Despite these differences many of the macroinvertebrates are found in most or all of these four major habitats, with population size being the varying factor according to the more favorable or unfavorable habitat conditions.

Within these four large categories occur specialized minor habitats. On the terraces is one large section of close-growing Juncus saximontanus, over a soft substrate of mud, fine sand, and partly-decayed vegetation. Here the water temperature is much higher than surrounding terraces and pH is lower, while dissolved oxygen is at relatively low concentration. Other specialized habitats and microhabitats are found under rocks, in moss mats, and in deep, quiet water.

It is possible to associate certain macroinvertebrates with some specialized habitats and niches. The snail, Paludestrina longingua, occurs in tremendous quantities throughout the watercress stands. The stonefly, Acroneuria pacifica, is almost always found beneath rocks in springs, terraces, and the creek. Moss samples from the springs basin invariably yield many of the amphipod, Gammarus limnaeus.

It is to be expected that herbivorous animals will be more abundant than the carnivores (Kendeigh, 1961, p. 230); the large populations of herbivorous Paludestrina, Baetis, Lepidostoma, and Neothremma attest to this fact.

Because there is no evidence that the large carnivorous species such as the Acroneuria naiads are themselves preyed upon in any great amounts we can assume that other unknown factors may be responsible for population control of these species.

Flying insects, even if they have aquatic stages, are not necessarily indigenous. A future study of winged insects might determine which species are merely visitors to the springs. However, adult _Acroneuria pacifica_ are indigenous inasmuch as their wings are vestigial.

Only immature insects are found submerged in the water of the springs area with the exception of the various Coleopterans and the Corixidae.

Although watercress is the most extensive vegetation at Cascade Springs and exerts considerable control over the local environment, it is still not to be expected that new or relict species will be found in association with this plant, for it is an introduced species.

Quantitative sampling is difficult to accomplish in very swift water such as occurs along stretches of the cascades. A net can be placed below the sampling area to catch organisms and debris but the difficulty is in moving the rocks to be sampled without having the other rocks move also.

This study was made with the primary goal of determining major habitats and the distribution of macroinvertebrates within these habitats. Future studies might undertake projects concerning food chains, importance of various physical factors, or perhaps a determination of microinvertebrate population dynamics in the differing habitats and microhabitats.

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APPENDIX I

A SYSTEMATIC LIST OF THE AQUATIC AND SEMIAQUATIC MACROINVERTEBRATES OF THE CASCADE SPRINGS AREA

Platyhelminthes

Turbellaria	Planariidae	*Polycelis* (new species)

Nemathelminthes

Nematoda		

Mollusca

Gastropoda	Physidae	*Physa* sp.
	Lymnaeidae	*Lymnaea* sp.
	Planorbidae	*Carinifex newberri*
	Amnicolidae	*Paludestrina longingua* (Gould)
Pelecypoda	Sphaeriidae	*Pisidium* sp.

Annelida

Oligochaeta	Lumbricidae	*Eiseniella tetraedra*
	Naididae	*Naidium breviseta*
	Enchytraeidae	
Hirudinea	Glossiphonidae	*Helobdella stagnalis*

Arthropoda

Amphipoda	Gammaridae	*Gammarus limnaeus* Smith

Ostracoda		
Araneae	Tetragnathidae	*Tetragnatha laboriosa* Hentz
	Clubionidae	*Phrurotimpus* sp.
	Gnaphosidae	
	Lycosidae	
Acarina		
Collembola	Sminthuridae	
	Poduridae	
	Entomobryidae	
Ephemeroptera	Heptageniidae	*Cinygmula mimus* (Eaton)
		Epeorus (Iron) longimanus Eaton
		Heptagenia criddlei McD.
	Ephemerellidae	*Ephemerella coloradensis* Dds.
	Leptophlebiidae	*Paraleptophlebia debilis* (Walker)
		Paraleptophlebia heteronea McD.
	Baetidae	*Baetis tricaudatus* Dds.
Odonata	Aeschnidae	*Aeshna* sp.
	Libellulidae	*Brachymesia* sp.
	Coenagrionidae	*Amphiagrion* sp.
Plecoptera	Nemouridae	*Nemoura californica* Claasen
		Nemoura cinctipes Banks
		Capnia gracilaria
		Capnia lemoniana
	Chloroperlidae	*Alloperla borealis* (Banks)
		Alloperla lamba
	Perlidae	*Acroneuria pacifica* Banks
Hemiptera	Corixidae	*Sigara* sp.
	Gerridae	*Gerris* sp.
	Saldidae	*Saldula* sp.
Trichoptera	Ryacophilidae	*Ryacophila oreta* Ross

		Ryacophila acropedes Banks or near
	Philopotamidae	Dolophilodes novusamericanus (Ling)
	Hydropsychidae	Parapsyche elsis Milne
		Hydropsyche sp.
	Hydroptilidae	Ochrotrichia sp.
	Limnephilidae	Neothremma alicia Bks.
		Oligophlebodes minuta (Bks.)
		Hesperophylax sp.
		Limnephilus sp.
	Lepidostomatidae	Lepidostoma unicolor (Bks.)
		Lepidostoma pluvialis (Milne)
	Brachycentridae	Micrasema bactro Ross
Coleoptera	Carabidae	
	Dytiscidae	Hygrotus sp.
		Agabus sp.
	Hydraenidae	Limnebius sp.
	Hydrophilidae	Tropisternus sp.
		Helophorus sp.
		Laccobius sp.
	Staphylinidae	
	Elmidae	Heterlimnius sp.
Diptera	Tipulidae	Chionea sp.
		Tipula sp.
		Holorusia sp. ?
		Ormosia sp.
		Dactylolabis sp.
		Pseudolimnophila sp.
		Dicranota sp.
		Limonia sp.
		Erioptera sp.
		Polymeda sp.
		Pedicia sp.
		Ulomorpha sp.
	Ptychopteridae	Bittacomorpha sp.
	Psychodidae	Psychoda sp.
		Telmatoscopus sp.
	Culicidae	Culex sp.
	Dixidae	Dixa sp.

Simuliidae	*Simulium* sp.
Tendipedidae	*Tendipes* sp. ?
	Tendipedinae (blood worms)
Ceratopogonidae	*Palpomyia tibialis*
	Culicoides sp. ?
	Stilobezzia sp.
	Dasyhelia sp.
Stratiomyidae	*Euparyphus* sp.
	Stratiomys sp.
Tabanidae	*Apatolestes* sp.
Empididae	*Chelipoda* sp.
	Clinocera sp.
Ephydridae	*Ochthera* or *Neoscatella* or *Scatella* sp.
	Phylatelma sp.
Sciomyzidae	*Sepedon* sp.
	Dictya sp.
	Pherbellia sp.

APPENDIX II

A SYSTEMATIC LIST OF PLANTS OBSERVED AT THE CASCADE SPRINGS AREA

Algae[1]

Plectonema sp.
Chara sp.
Vaucheria sp.
Cladophora sp.
Spirogyra sp.
Zygnema sp.
Tribonema sp.
Closterium sp.

Mosses[2]

Amblystegium compactum (C. Muell.) Aust.
Cratoneuron filicinum (Hedw.)
Didymodon tophaceus (Brid.) Jur.
Eucladium verticillatum (Brid.) B. S. G.
Fissidens grandifrons Brid.
Hygrophypnum luridum (Hedw.) Jennings forma

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[1]Contributed by Deanna Bunting McCoard, BYU Dept. of Botany.

[2]Contributed by Dr. Seville Flowers, University of Utah Dept. of Botany.

Sphenopsida[1]

	Equisetaceae	*Equisetum kansanum* Schaffn.

Pteropsida[1]

Dicotyledonae	Aceraceae	*Acer negundo* L.
		Acer grandidentatum Nutt.
	Berberidaceae	*Mahonia repens* Don
	Betulaceae	*Betula occidentalis* Hook.
	Boraginaceae	*Hackelia leptophylla* (Rydb.)
	Compositae	*Artemisia tridentata* Nutt.
		Achillea millefolium L.
		Aster engelmannii (D. C. Eat.) Gray
		Aster chilensis Nees ssp.
		Aster foliaceous Lindl.
		Cirsium arvense L.
		Cirsium lanceolatum (L.) Hill.
		Erigeron annuus (L.) Pers.
		Rudbeckia occidentalis Nutt.
		Senecio serra Hook.
		Solidago sparsiflora A. Gray
	Cruciferae	*Cardamine cordifolia* O. Gray
		Rorippa nasturtium-aquaticum (L.) Schinz. & Thel.
	Fagaceae	*Quercus gambelii* Nutt.
	Geraniaceae	*Geranium fremontii* Torr. ex A. Gray
		Geranium richardsonii Fisch. & Trautv.

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[1]Collected in 1965 under the direction of the BYU Dept. of Botany plus my own personal observations.

	Labiatae	*Agastache urticifolia* (Benth) Kuntze
		Leonurus cardiaca L.
		Mentha arvensis L.
	Leguminosae	*Medicago lupulina* L.
		Melilotus officinalis (L.) Lorn.
		Trifolium repens L.
	Malvaceae	*Sidalcea neomexicana* A. Gray
	Onagraceae	*Epilobium adenocaulon* Hausskn.
		Epilobium paniculatum Nutt. ex. T. & G.
	Plantaginaceae	*Plantago major* L.
	Polemoniaceae	*Collomia grandiflora* Dougl.
		Polemonium coeruleum L.
	Polygonaceae	*Rumex crispus* L.?
	Ranunculaceae	*Aconitum columbianum* Nutt.
		Aquilegia formosa Fisch.
		Ranunculus macounii Britt.
	Rosaceae	*Geum macrophyllum* Willd.
		Potentilla pentinisecta Rydb.
		Amelanchier alnifolia Nutt.?
		Rosa woodsii Lindl.
	Salicaceae	*Populus angustifolia* James ex Longs
		Salix myrtillifolia Anderss.
	Scrophulariaceae	*Mimulus guttatus* Fisch.
		Verbascum thapsus L.
	Umbelleferae	*Berula erecta* (Huds.) Coville
	Urticaceae	*Urtica gracilis* Ait.
	Violaceae	*Viola nephrophylla* Grene ?
Monocotyledonae	Liliaceae	*Allium* sp.
		Smilacina stellata (L.) Desf.?
	Juncaceae	*Juncus saximontanus* A. Nels.

ABSTRACT

From May, 1964, to July, 1966, a study was conducted at the Cascade Springs near Mount Timpanogos in central Utah. Important aquatic habitats were determined and a survey was made of the macroinvertebrates. A study was made on macroinvertebrate geographic distribution, and of various other ecological factors.

Both qualitative and quantitative methods were utilized, including Surber samplers, Berlese funnels, apron-net methods, and a quantitative round-can sampler. Preliminary identification of macroinvertebrates was made by the author and several groups were sent to specialists for verification and further identification.

The springs basin, cascades, terraces, and Provo Deer Creek form the four major habitat regions, differing from each other in dominant vegetation, factors of water flow, and type of bottom. Within these major regions occur specialized minor habitats. On the terraces is one large area in which *Juncus saximontanus* grows profusely over a substrate of mud, fine sand, and partly-decayed vegetation.

Other specialized habitats are: under rocks and boulders which were especially numerous in the springs basin, in moss mats, and in deep, quiet water of the terrace pools.

The snail, Paludestrina longingua and the stonefly, Nemoura californica, occur in large numbers throughout the watercress stands of the terraces. The stonefly, Acroneuria pacifica, is almost always found beneath rocks and boulders, and moss samples invariably yield many of the amphipod, Gammarus limneaus.

While some macroinvertebrates were rather ubiquitous, as a general rule species diversity and population density were found to be controlled by specific environmental factors, notably those associated with vegetational distribution.