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A COMPARISON OF RIFFLE INSECT POPULATIONS IN THE GIBBON RIVER ABOVE AND BELOW THE GEYSER BASINS, YELLOWSTONE NATIONAL PARK

by

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VITA

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ABSTRACT

A study was made comparing the aquatic insect populations of two riffles, one above and one below the effluents of major geyser basins on the Gibbon River, Yellowstone National Park from June through September 1963 and from October 1964 through September 1965. Eight ¼ m^2 samples were taken from each riffle during each of the 21 collection dates. Water depths, current velocities and bottom types were similar in both riffles. Maximum and mean temperatures were greater in the lower riffle. Alkalinity and ionic concentrations of K, Na, Cl, PO_4 and SO_4 were markedly greater in the lower riffle. In the upper riffle 50 taxa were encountered, while 45 were present in the lower. The total number of individuals and biomass were slightly greater in the lower riffle. Ephemeroptera and Coleoptera occurred in greater numbers and biomass in the upper riffle, while Trichoptera and Diptera occurred in greater numbers and biomass in the lower riffle. Plecoptera were about the same for both riffles. Seven of the most abundant organisms in the upper riffle and two in the lower riffle comprised about 68% of the total numbers for each riffle. Ephemeroptera was the dominant order in the upper riffle, while Trichoptera dominated the lower. The thermal and chemical effluents entering the Gibbon River from surrounding geyser basins changed the lower riffle, so that it was less diverse; contained a greater standing crop of aquatic insects; and was more favorable to Trichoptera than the upper riffle.

INTRODUCTION

A study was done on the insect populations of two riffles in the Gibbon River in the west-central part of Yellowstone National Park during 1963, 1964 and 1965. One riffle was located above the effluents of the major geyser basins and the other one below. Some earlier studies showed the influence of geyser water on aquatic invertebrates in Yellowstone National Park. Armitage (1958) correlated temperature and alkalinity with average annual standing crops of aquatic insects in the Firehole River, Gardiner River and Lava Creek. Muttkowski (1929) did some descriptive work on the ecology of aquatic insects in various streams. Brues (1924) made a few general observations on aquatic organisms in various thermal areas.

A considerable amount of work has been done concerning the effect of temperature on aquatic insect populations. Dodds and Hisaw (1925) attributed aquatic insect altitudinal zonation to temperature differences. Ide (1935) found that the increase in the number of mayfly species downstream was due to the higher temperatures which exist in the lower regions of the Nottawasga River system. Sprules (1947) reported a direct correlation between the total change of species at successive stations and the average summer water temperature in a study on the Madawaska River, Ontario, Canada. Coutant (1962) stated that during the hot summer months there was a decrease in number, diversity and total biomass of a macroinvertebrate riffle population which was in the path of a heated water effluent from a steam electric plant on the Delaware River, Pennsylvania.

METHODS

Bottom samples were taken with a net patterned after the Surber sampler. It had a square frame which enclosed an area of ¼ m^2 and a nylon collecting net with 7.9 meshes/cm. A total of 42 collections, two on each sampling date, were taken during the study period. A collection consisted of eight ¼ m^2 samples of bottom materials from each riffle on a sampling date. These were taken as follows: every two weeks from 26 June to 26 September 1963 and in October 1964; once a month from November 1964 to February 1965; and every two weeks in April 1965 and from 1 July to 15 September 1965. No collections were made during March 1965 because roads were impassable or during May and June because of high water from the spring runoff. Collections were preserved in 5% formalin immediately after being taken. Aquatic organisms were sorted and preserved in 70% alcohol in the laboratory. They were classified to order and to lesser categories including species when practical. The number of individuals in each category was counted. Volume to the nearest 0.1 ml was determined by displacement in 70% alcohol. The term biomass is used for total volumes. The volumes in milliliters are approximately equal to grams damp weight.

Four ¼ m^2 samples of bottom materials were collected in each riffle with a sampling net having 30 meshes/cm. Materials were dried and put through a series of Tyler soil screens to separate different sizes of material. The volume of each material size class was determined by displacement in water and its percent of the total was calculated. All material was then placed in one of three major categories and one of seven minor size groups as follows: rubble-2, gravel-2 and sand-3. Volumes of the different size classes of bottom materials from both study riffles were compared statistically by using a two-way analysis of variance test using the seven minor size groups, except for the largest (127-305 mm) which was not adequately sampled. Eight discharge measurements were computed for each riffle during the period of study by using average current velocity, mean depth and channel width. Current velocities were secured with a Gurley Current Meter. Temperature measurements were taken with maximum-minimum thermometers placed in each riffle and read on each sampling date. These thermometers were accurate to the nearest 0.5C. Mean temperatures were computed to the nearest degree from maximum and minimum temperature readings between sampling periods. A thermograph was used to check mean temperatures. Methyl orange alkalinities were taken on each sampling date. pH values were secured on two dates using the Beckman Model G pH Meter.

DESCRIPTION OF STUDY AREA

The Gibbon River originates in Grebe Lake at an elevation of 2447 m (8028 ft) m.s.l. and flows 47 km in a southwesterly direction to join the Firehole River at an elevation of 2075 m (6806 ft). The upper study riffle was approximately 7 km above and the lower study riffle was 18 km below the entrance of major geyser effluents. The river above the upper study riffle drains a high mountain area with several small tributaries fed by melting snow and cold springs. Tributaries entering the river between the two study riffles include the following: those fed by melting snow and cold springs as Solfatara Creek, Canyon Creek and Secret Valley

Creek; effluents from geyser basins as Norris, Gibbon and Monument; and effluents from hot springs as Sylvan, Beryl and Iron (Fig. 1).

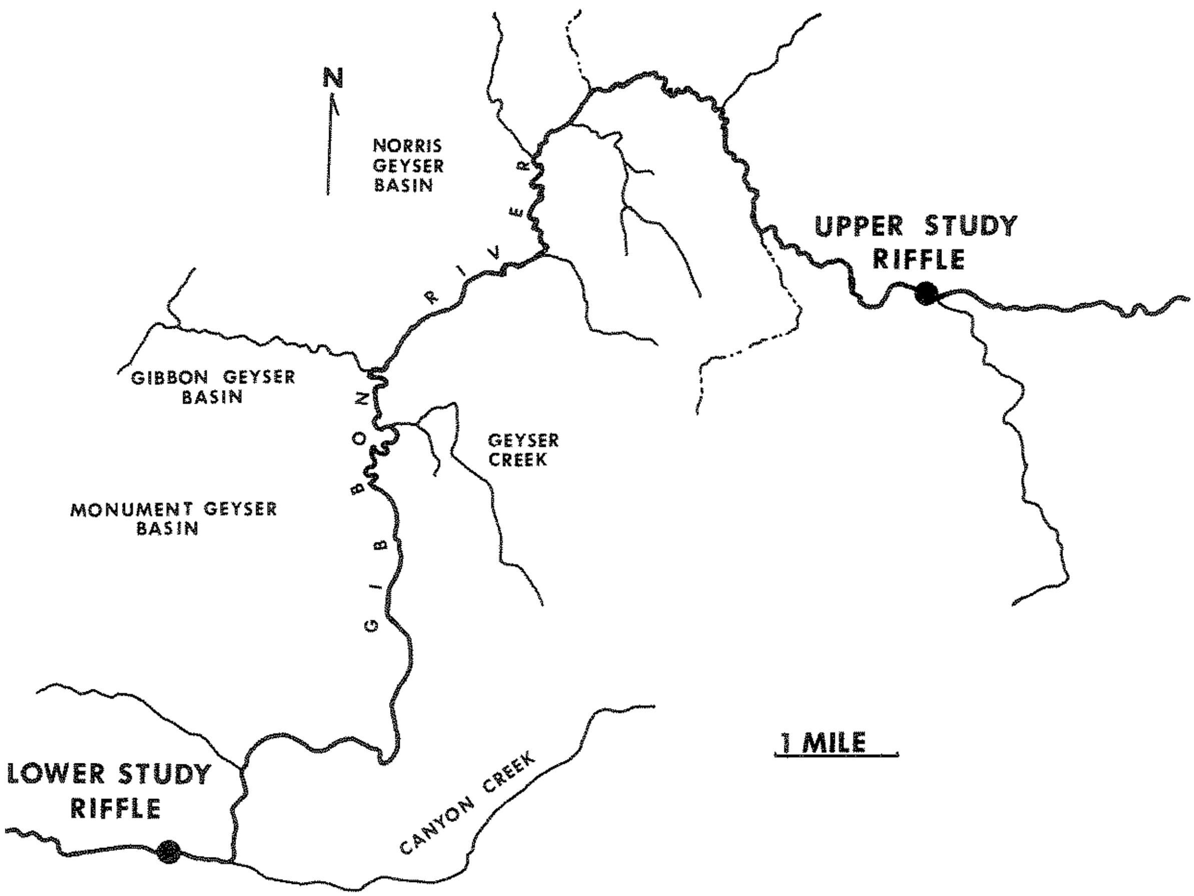

Figure 1. Study area.

Differences and similarities in the physical and chemical factors between the upper and lower study riffles are shown in Table 1. Bottom

Table 1. Physical and chemical factors at each study riffle.

Environmental Factors	Upper	Lower
Physical		
Width (m)	4.5	15.3
Depth (cm)	25-45	25-45
Current velocity (m/sec)	0.73-0.90	0.67-0.90
Bottom materials (size mm)		
Rubble 305-127	3.0 1/	10.6
126-76	24.5	29.4
Gravel 75.0 -25.4	45.3	38.2
25.3 - 4.7	20.4	16.8
Sand 4.6 - 0.58	6.3	4.5
0.57- 0.30	0.4	0.4
0.29	0.1	0.1
Discharge (m^3/sec)	0.25-1.52	1.78-4.97
Temperature (C)		
Max-Min	18-0	24-0
Mean	14-1	18-3
Chemical		
Ion (ppm)		
Ca	2.81- 2.00 2/	3.21- 2.00
Fe	0.27- 0.22	0.31- 0.30
K	4.69- 1.56	11.73- 3.91
Mg	1.50- 0.00	1.70- 0.00
Mn	0.28- 0.20	0.46- 0.20
Na	17.24- 5.06	74.72-22.99
NH_3	0.15-	0.25-
Cl	3.33- 2.00	54.96-26.00
PO_4	0.14- Tr	0.40- 0.06
SiO_3	69.6 -58.6	86.0 -67.6
SO_4	6.00- 4.00	12.00-10.50
pH (range)	6.81- 7.45 3/	7.00- 7.54
M. O. Alk. (ppm)	25-21	68-55

1/ Expressed as percent of total volume.

2/ First figure taken during low flow (11 April 1964 and 5 May 1965) and second figure taken during peak flow (June 1964 and 5 August 1965).

3/ Taken over a 24 hr. period.

materials composed primarily of volcanic rhyolite were similar at both riffles, except that more large rubble (127-305 mm) was found in the lower riffle. Gravel constituted the greatest percent of total volume in both riffles. Depths and current velocities were similar in both study riffles. The stream width was about three times greater at the lower riffle. Discharge at both riffles had similar flow patterns. The high water period started in mid-April with a rapid increase in flow due to melting snow runoff. Flow reached a peak by mid-June and then decreased rapidly until mid-July. During the remainder of the year flows were low and relatively constant, except for small fluctuations in September due to heavy rains. The discharge at the lower riffle was about four times greater than the upper and contained approximately 0.1 m^3/sec of geyser and hot spring effluents (Allen and Day 1935). The geyser and hot spring effluents contribute about 2% of the total discharge at the lower riffle during the high water period and 6% during low water. Temperatures in both riffles had the same seasonal trends with the lowest readings in December and the highest in late July and early August (Fig. 2). However the lower riffle had higher maximum and mean temperatures throughout the year. Maximum temperature was 18C at the upper riffle and 24C at the lower riffle. Both riffles had a minimum temperature of OC. Chemical composition of the water showed that the total ion concentration was two times greater in the lower riffle (Table 1) and all individual ions had greater concentrations there. Ions with marked concentration differences showed the following ratios (lower riffle:upper riffle): K-3:1, Na-4:1, Cl-17:1, PO_4-3:1 and SO_4-2:1. Allen and Day (1935) reported AsO_4, B_2O_4 and H_2S in Norris

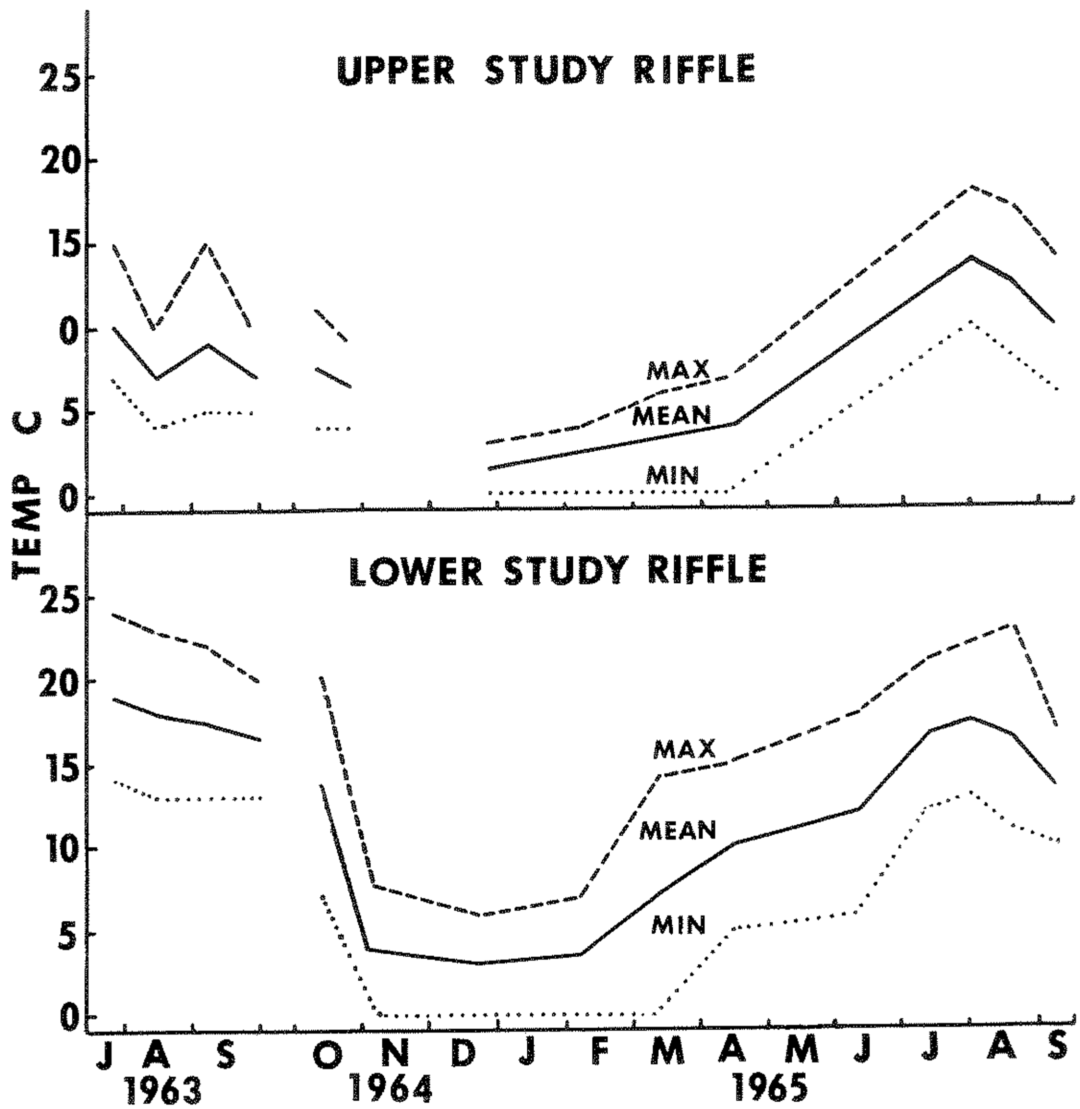

Figure 2. Seasonal fluctuations in water temperature during the study period.

Geyser Basin waters. pH values were similar in both riffles. Methyl orange alkalinity was about three times greater in the lower riffle. There was less rooted aquatic vegetation in the upper riffle and the species present were not the same as those in the lower riffle. No benthic samples were taken in rooted aquatic vegetation because of these differences.

RESULTS

Distribution of Taxa

The majority of aquatic organisms found were aquatic insects, however occasional Nematodes, Oligochaetes, *Margaritana margaritifera* and *Pisidium* spp. were encountered. The same taxonomic distinctions were made for the organisms of each riffle.

Of the 54 taxa encountered, 41 were common to both riffles. Differences were observed in the distribution of 13 taxa. Nine were found only in the upper riffle and four were confined to the lower riffle (Table 2). Taxa found less than four times were not used in the comparisons. Those which occurred rarely are as follows: *Hydroptila* spp., *Neophylax* spp. and *Helicopsyche* spp. (Trichoptera), *Bezzia* spp. (Diptera), Nematoda, Oligochaeta, *Margaritana margartifera* and *Pisidium* spp. (Pelecypoda) were common to both riffles; *Ephemerella coloradensis* (Ephemeroptera) and *Pericoma* spp. (Diptera) were found only in the upper riffle; and *Protophila* spp. (Trichoptera) was found only in the lower riffle.

Comparison of Numbers and Biomass of Aquatic Insects

Comparisons were limited to aquatic insects. Both study riffles had

Table 2. Total numbers/m² and volumes (ml) of aquatic insects in the upper (U) and lower (L) study riffles for each sampling period (Volumes in parentheses). T=Trace.

	1963 June U	June L	July U	July L	Aug. U	Aug. L	Sept. U	Sept. L
EPHEMEROPTERA	384.0 (1.6)	77.0 (0.8)	294.9 (1.2)	45.0 (0.3)	259.2 (0.8)	17.8 (0.1)	291.6 (0.4)	16.9 (T)
Ephemerella aurivilli	12.0 (T)	9.0 (T)	42.7 (0.1)	7.8 (0.1)	23.4 (0.2)	2.5 (T)		
E. doddsi	3.0 (0.2)		0.3 (0.1)		55.5 (T)		107.6 (0.1)	0.3 (T)
E. flavilinea	7.0 (T)	20.0 (0.3)	7.2 (0.1)	4.3 (0.1)	0.6 (T)	0.2 (T)		
E. grandis ingens								0.6 (T)
E. heterocaudata		3.0 (T)		0.8 (T)				
E. hystrix			0.3 (T)		5.7 (T)		4.3 (T)	
E. inermis	2.0 (T)	4.0 (T)	0.3 (T)	0.8 (T)	10.2 (T)	2.2 (T)	49.4 (T)	2.5 (T)
E. spinifera	1.0 (T)		0.3 (T)		10.5 (T)	1.3 (T)	30.5 (T)	
Baetis spp.	66.0 (0.3)	18.0 (0.3)	64.5 (0.3)	26.8 (0.1)	41.0 (0.1)	10.5 (0.1)	27.0 (0.1)	13.5 (T)
Cinygmula sp.	114.0 (0.3)		86.9 (0.2)		64.0 (0.3)		29.6 (0.1)	
Paraleptophlebia sp.	5.0 (0.1)	1.0 (T)	0.8 (T)	0.3 (T)	0.5 (T)	0.3 (T)	2.6 (T)	
Iron longimanus	158.0 (0.4)	21.0 (0.2)	90.0 (0.3)	3.9 (T)	26.6 (0.1)	0.8 (T)	19.0 (T)	
Ironopsis grandis					1.2 (T)			
Rhithrogena hageni	16.0 (0.3)	1.0 (T)	2.0 (0.1)	0.3 (T)	20.0 (0.1)		21.6 (0.1)	
PLECOPTERA	13.0 (0.3)	17.0 (2.3)	15.5 (0.7)	8.7 (1.0)	30.5 (1.3)	25.9 (1.7)	33.6 (0.5)	22.9 (0.9)
Nemoura spp.	1.0 (T)		0.8 (T)		3.2 (T)		1.1 (T)	
Leutra sp.	1.0 (T)				0.8 (T)		5.4 (T)	
Brachyptera sp.								
Pteronarcys californica		3.0 (0.9)		0.5 (0.4)	0.7 (0.4)	0.5 (0.5)		1.1 (T)
Arcynopteryx spp.					5.3 (T)	1.5 (T)	13.0 (0.1)	0.5 (0.3)
Isogenus spp.	6.0 (0.1)		3.2 (T)		1.0 (T)		0.3 (T)	
Isoperla spp.								0.6 (T)
Alloperla spp.	4.0 (T)		5.1 (T)	0.5 (T)	10.6 (0.1)	2.0 (T)	10.5 (0.1)	2.7 (T)
Acroneuria theodora			5.0 (0.5)		5.7 (0.5)		2.2 (0.2)	
Acroneuria pacifica	1.0 (0.2)	2.0 (T)	1.4 (0.2)	5.0 (0.3)	3.0 (0.2)	4.7 (0.3)	1.1 (0.1)	6.5 (0.3)
Claassenia sabulosa		12.0 (1.4)		2.7 (0.3)	0.2 (0.1)	17.2 (0.9)		11.5 (0.3)

	1964 Oct. U	Oct. L	Nov. U	Nov. L	Dec. U	Dec. L
EPHEMEROPTERA	241.1 (0.7)	43.3 (0.1)	303.0 (0.7)	55.0 (0.1)	220.5 (0.8)	57.0 (0.2)
Ephemerella aurivilli						
E. doddsi	28.3 (0.2)	1.8 (T)	34.0 (0.1)		26.5 (0.3)	
E. flavilinea						
E. grandis ingens		0.8 (T)		0.5 (T)		0.5 (T)
E. heterocaudata						
E. hystrix	59.5 (0.1)	0.8 (T)	59.0 (0.1)	1.0 (T)	28.0 (T)	
E. inermis	41.5 (0.1)	6.5 (T)	76.0 (0.2)	31.0 (T)	42.5 (0.1)	43.5 (0.2)
E. spinifera	11.0 (T)		26.9 (T)		8.5 (T)	
Baetis spp.	9.8 (T)	32.8 (0.1)	6.5 (T)	22.0 (0.1)	13.5 (T)	13.0 (T)
Cinygmula sp.	4.7 (T)		32.5 (0.1)		28.0 (0.1)	
Paraleptophlebia sp.	4.5 (T)		1.0 (T)			
Iron longimanus	8.0 (T)	0.5 (T)	10.0 (T)		2.0 (T)	
Ironopsis grandis	1.5 (T)		5.5 (T)			
Rhithrogena hageni	72.3 (0.3)	0.3 (T)	52.0 (0.2)	0.5 (T)	71.5 (0.3)	
PLECOPTERA	22.5 (1.6)	18.0 (1.5)	25.9 (0.9)	16.5 (0.9)	73.5 (0.2)	16.0 (0.7)
Nemoura spp.	5.5 (T)		9.0 (T)		11.0 (T)	
Leutra sp.	0.8 (T)		3.0 (T)		20.5 (T)	
Brachyptera sp.					2.5 (T)	
Pteronarcys californica	2.3 (0.7)	1.5 (0.5)	1.0 (0.3)	2.0 (0.1)		0.5 (T)
Arcynopteryx spp.	1.0 (T)		4.5 (0.1)		1.0 (T)	
Isogenus spp.					16.5 (0.1)	
Isoperla spp.		0.5 (T)	(T)	0.5		6.0 (T)
Alloperla spp.	1.8 (T)	2.0 (T)	2.0 (T)	1.5 (T)	14.5 (T)	1.0 (T)
Acroneuria theodora	6.8 (0.7)		5.0 (0.4)		7.0 (0.1)	
Acroneuria pacifica	4.3 (0.2)	5.5 (0.5)	1.0 (0.1)	2.0 (0.3)	0.5 (T)	4.5 (0.6)
Claassenia sabulosa		8.5 (0.5)		10.5 (0.5)		4.0 (0.1)

	1965 Jan. U	Jan. L	Feb. U	Feb. L	Apr. U	Apr. L	July U	July L	Aug. U	Aug. L	Sept. U	Sept. L
EPHEMEROPTERA	401.0 (1.7)	77.5 (0.2)	427.0 (2.0)	228.0 (0.7)	459.1 (2.9)	259.6 (0.9)	172.4 (1.1)	38.7 (0.3)	174.2 (0.8)	20.9 (0.1)	392.8 (0.8)	27.5 (0.1)
Ephemerella aurivilli							10.0 (T)	2.6 (T)	12.0 (0.1)	1.0 (T)		
E. doddsi	36.0 (0.3)		38.0 (0.3)		35.0 (0.7)		2.3 (0.2)		15.0 (T)		46.5 (0.1)	
E. flavilinea			0.5 (T)	12.0 (T)	17.5 (T)	68.5 (0.2)	6.8 (0.1)	6.8 (T)	0.3 (T)	0.5 (T)		
E. grandis ingens					0.3 (T)	0.3 (T)	0.3 (T)	0.3 (T)				
E. heterocaudata		4.0 (T)		6.0 (T)		21.0 (T)		1.6 (0.1)		1.8 (T)		
E. hystrix	154.0 (0.5)	2.0 (T)	184.5 (0.6)		118.3 (0.7)		2.8 (T)	0.3 (T)	2.5 (T)		21.0 (0.1)	
E. inermis	46.0 (0.1)	52.0 (0.2)	38.5 (0.1)	117.0 (0.5)	59.8 (0.4)	59.5 (0.3)	0.3 (T)	0.8 (T)	0.3 (T)	1.3 (T)	10.5 (T)	0.5 (T)
E. spinifera	10.5 (T)		14.5 (T)		10.3 (0.1)				0.5 (T)	2.5 (T)	2.0 (T)	6.5 (T)
Baetis spp.	21.5 (0.1)	19.5 (T)	4.0 (T)	92.0 (0.2)	51.3 (0.1)	91.3 (0.3)	31.3 (0.1)	20.2 (0.2)	26.5 (0.1)	12.8 (0.1)	79.5 (0.2)	20.0 (0.1)
Cinygmula sp.	26.9 (0.2)		43.5 (0.5)		55.5 (0.4)		55.3 (0.2)		34.0 (0.2)		5.0 (T)	
Paraleptophlebia sp.	0.5 (T)				0.3 (T)			0.3 (T)			1.8 (T)	
Iron longimanus	1.5 (T)		1.0 (T)		22.0 (T)	18.5 (0.1)	53.5 (0.3)	5.8 (T)	46.5 (0.3)	1.0 (T)	19.5 (0.1)	
Ironopsis grandis	14.0 (0.1)		6.0 (0.1)		4.0 (T)				4.3 (T)		10.0 (T)	
Rhithrogena hageni	90.5 (0.4)		96.5 (0.4)	0.5 (T)	81.8 (0.5)	0.5 (T)	9.8 (0.2)		32.3 (0.1)		197.0 (0.3)	0.5 (T)
PLECOPTERA	49.0 (1.9)	20.5 (1.9)	18.5 (0.2)	48.5 (1.2)	33.8 (0.5)	24.0 (1.5)	12.9 (0.3)	6.1 (0.8)	11.9 (0.5)	8.5 (1.0)	29.5 (1.1)	30.0 (1.5)
Nemoura spp.	5.0 (T)		3.0 (T)		4.8 (T)		0.3 (T)		0.8 (T)		4.5 (T)	
Leutra sp.	16.0 (T)		4.0 (T)		5.3 (T)						2.0 (T)	
Brachyptera sp.	6.0 (T)		0.5 (T)		9.3 (0.1)							
Pteronarcys californica	0.5 (0.4)			2.0 (0.1)	0.3 (T)	1.8 (0.2)		1.4 (0.3)		1.0 (0.3)	1.0 (0.4)	2.5 (0.6)
Arcynopteryx spp.			1.5 (0.1)		0.5 (0.1)	0.3 (T)			1.0 (T)		4.0 (T)	2.5 (T)
Isogenus spp.	2.5 (T)		1.0 (T)		1.5 (T)		2.5 (0.1)		0.8 (0.1)		0.5 (T)	
Isoperla spp.		7.5 (T)		31.0 (0.4)		9.3 (0.1)		0.2 (T)				
Alloperla spp.	6.5 (T)	2.5 (T)	1.5 (T)	3.0 (T)	6.0 (0.1)	0.5 (T)	4.3 (T)		2.5 (T)	0.5 (T)	3.0 (T)	4.0 (T)
Acroneuria theodora	12.0 (1.5)		6.0 (0.1)		3.5 (0.1)		4.3 (0.2)		6.3 (0.4)		5.5 (0.5)	
Acroneuria pacifica	0.5 (T)	4.5 (1.4)	1.0 (T)	2.5 (0.2)	1.3 (0.1)	2.8 (0.7)	1.5 (T)	1.1 (0.1)	0.5 (T)	2.2 (0.1)	5.0 (0.2)	6.0 (0.2)
Claassenia sabulosa		6.0 (0.5)		10.0 (0.5)		9.3 (0.5)		3.4 (0.4)		4.8 (0.6)		15.0 (0.7)

Table 2 (Continued).

	1963 June U	June L	July U	July L	Aug. U	Aug. L	Sept. U	Sept. L	1964 Oct. U	Oct. L	Nov. U	Nov. L	Dec. U	Dec. L
COLEOPTERA Elmidae	174.0 (0.3)	46.0 (0.1)	161.0 (0.2)	30.8 (T)	212.8 (0.2)	54.2 (0.1)	138.5 (0.1)	60.5 (0.1)	92.0 (0.1)	47.3 (0.1)	117.0 (0.1)	20.0 (T)	94.0 (0.1)	42.5 (0.1)
TRICHOPTERA	56.0 (0.8)	103.0 (1.1)	45.6 (0.6)	91.8 (0.5)	234.4 (1.0)	616.8 (0.6)	149.9 (0.8)	1099.5 (3.4)	373.4 (1.2)	994.8 (1.6)	371.0 (1.3)	873.5 (1.5)	148.0 (0.7)	646.5 (1.9)
Rhyacophila acropedes	2.0 (T)	6.0 (0.4)	3.3 (T)	1.7 (0.1)	9.0 (0.1)	0.2 (T)	7.0 (0.1)	2.6 (T)	13.0 (0.2)	1.7 (T)	17.5 (0.2)	1.5 (T)	13.5 (0.2)	4.0 (T)
Rhyacophila spp.	20.0 (0.7)		8.6 (0.6)		8.1 (0.1)		11.6 (0.1)	0.3 (T)	11.5 (0.1)		29.0 (0.2)	0.5 (T)	27.5 (0.2)	
Glossoma sp.	5.0 (T)	83.0 (0.4)	24.4 (T)	61.3 (0.3)	147.4 (0.3)	505.7 (0.2)	85.1 (0.2)	587.3 (0.2)	274.0 (0.3)	660.3 (0.3)	238.5 (0.2)	669.0 (0.4)	90.0 (0.1)	300.0 (0.2)
Dolophilodes sp.				1.0 (T)	0.3 (T)	1.7 (T)	0.3 (T)		0.5 (T)		0.5 (T)		0.5 (T)	
Arctopsyche grandis			0.3 (T)	4.0 (T)	60.7 (0.5)	3.0 (0.1)	35.4 (0.4)	4.5 (0.3)	54.7 (0.6)	5.0 (0.1)	70.5 (0.7)	3.0 (0.2)	13.5 (0.2)	4.0 (0.4)
Hydropsyche sp.		10.0 (0.3)		9.8 (0.1)	0.4 (T)	95.3 (0.2)	2.9 (T)	456.7 (2.6)		304.5 (1.1)		175.5 (0.8)		318.5 (1.2)
Leptostoma sp.			0.5 (T)		0.8 (T)	0.3 (T)				4.0 (T)	1.0 (T)	17.0 (T)		3.5 (T)
Brachycentrus occidentalis	27.0 (0.1)	3.0 (T)	4.0 (T)	11.8 (T)	2.4 (T)	10.2 (0.1)	6.1 (T)	43.4 (0.3)	5.7 (T)	16.3 (0.1)	3.5 (T)	5.5 (0.1)	1.5 (T)	13.0 (0.1)
Micrasema sp.	2.0 (T)	1.0 (T)	4.5 (T)	2.2 (T)	5.3 (T)	0.3 (T)	1.5 (T)	4.8 (T)	14.0 (T)	3.0 (T)	10.5 (T)	1.5 (T)	1.5 (T)	2.5 (T)
DIPTERA	7.0 (0.3)	26.3 (0.2)	18.3 (0.2)	55.4 (0.5)	26.3 (0.5)	74.8 (0.4)	4.4 (0.7)	55.3 (0.6)	3.1 (0.2)	45.9 (0.8)	9.0 (0.2)	44.5 (0.4)	10.0 (0.3)	119.5 (1.5)
Antocha spp.		17.0 (T)		12.8 (0.1)		5.2 (T)	0.3 (T)	6.4 (T)		12.5 (T)	0.5 (T)	8.5 (0.1)	1.0 (T)	39.5 (0.1)
Cryptolabis spp.		4.3 (T)		0.3 (T)				5.9 (T)		4.3 (T)		3.0 (T)		8.0 (0.1)
Hexatoma spp.	5.0 (0.3)	3.0 (0.2)	3.3 (0.2)	4.2 (0.2)	2.5 (0.5)	4.2 (0.3)	3.4 (0.7)	5.3 (0.4)	1.3 (0.2)	5.8 (0.5)	2.5 (0.2)	0.5 (0.1)	1.0 (0.3)	10.0 (0.8)
Tendipedidae	1.0 (T)	1.0 (T)	7.2 (T)	18.5 (T)	21.2 (T)	58.8 (0.1)	0.5 (T)	25.2 (T)	1.0 (T)	7.7 (T)	4.5 (T)	8.0 (T)	4.5 (T)	5.0 (T)
Simulium spp.	1.0 (T)	2.0 (T)	7.3 (T)	11.2 (0.1)	2.1 (T)	2.5 (T)		0.9 (T)	0.8 (T)	0.5 (T)	1.5 (T)	1.5 (T)	2.5 (T)	30.0 (0.1)
Blephariceridae				0.3 (T)		0.5 (T)		6.7 (T)		9.8 (T)		18.5 (0.1)		18.0 (0.1)
Deuterophlebia sp.		1.0 (T)		2.1 (T)		0.3 (T)		0.3 (T)						
Atherix spp.			0.5 (T)	6.0 (0.1)	0.5 (T)	3.3 (T)	0.2 (T)	4.6 (0.2)		5.3 (0.3)		4.5 (0.1)	1.0 (T)	9.0 (0.3)
TOTALS	634.0 (3.3)	271.3 (4.3)	535.3 (2.9)	231.7 (2.3)	763.2 (3.8)	789.5 (2.9)	618.0 (2.5)	1255.1 (5.0)	732.1 (3.8)	1149.3 (4.1)	825.5 (3.2)	1009.5 (2.9)	546.0 (2.1)	880.5 (4.4)

	1965 Jan. U	Jan. L	Feb. U	Feb. L	Apr. U	Apr. L	July U	July L	Aug. U	Aug. L	Sept. U	Sept. L
COLEOPTERA Elmidae	98.5 (0.1)	51.0 (0.1)	40.5 (0.1)	30.5 (0.1)	44.8 (0.1)	52.3 (0.1)	33.5 (0.1)	23.2 (T)	53.3 (0.1)	24.3 (T)	49.0 (0.1)	128.5 (0.1)
TRICHOPTERA	133.5 (0.8)	772.0 (2.1)	150.5 (0.9)	432.5 (1.2)	105.6 (0.9)	576.8 (1.8)	33.6 (0.4)	115.1 (0.6)	178.6 (1.1)	417.1 (0.6)	265.5 (2.2)	275.2 (1.5)
Rhyacophila acropedes	15.0 (0.3)	6.5 (T)	8.0 (0.1)	3.0 (T)	12.8 (0.3)	4.3 (0.1)	0.8 (T)	0.8 (T)	5.5 (0.1)	0.3 (T)	14.5 (0.1)	0.5 (T)
Rhyacophila spp.	27.5 (0.2)	0.5 (T)	14.5 (0.2)	1.0 (T)	20.8 (0.2)	1.3 (T)	13.0 (0.4)	0.5 (T)	3.0 (0.1)		6.0 (T)	0.5 (T)
Glossoma sp.	70.5 (0.1)	428.0 (0.2)	98.5 (0.2)	217.0 (0.2)	60.5 (0.2)	364.3 (0.3)	15.0 (T)	66.8 (0.2)	122.0 (0.3)	350.0 (0.1)	131.5 (0.3)	114.5 (0.1)
Dolophilodes sp.	1.0 (T)								6.0 (0.1)	1.0 (T)	9.0 (0.3)	
Arctopsyche grandis	10.5 (0.1)	2.0 (0.1)	20.5 (0.3)	2.0 (0.1)	5.0 (0.2)	1.3 (0.1)	0.8 (T)	1.7 (T)	32.3 (0.4)	5.5 (0.2)	91.0 (1.3)	4.0 (0.4)
Hydropsyche sp.		304.5 (1.6)		166.5 (0.7)	0.5 (T)	164.5 (1.2)		24.7 (0.3)	0.3 (T)	49.0 (0.3)		125.5 (0.9)
Leptostoma sp.	0.5 (T)	2.0 (T)		16.0 (T)		3.3 (T)		0.3 (T)			0.5 (T)	2.7 (T)
Brachycentrus occidentalis	4.5 (0.1)	19.0 (0.2)	6.5 (0.1)	19.5 (0.2)	4.0 (T)	11.0 (0.1)	2.3 (T)	17.0 (0.1)	7.8 (0.1)	10.5 (T)	12.5 (0.2)	20.0 (0.1)
Micrasema sp.	4.0 (T)	9.5 (T)	2.5 (T)	7.5 (T)	2.0 (T)	26.8 (T)	1.7 (T)	3.3 (T)	1.7 (T)	0.8 (T)	0.5 (T)	7.5 (T)
DIPTERA	19.0 (0.1)	126.5 (1.3)	20.0 (0.1)	124.5 (1.7)	17.0 (0.3)	122.4 (2.0)	5.9 (0.1)	23.7 (0.2)	17.4 (0.1)	28.9 (0.4)	8.5 (0.5)	17.8 (0.3)
Antocha spp.	1.0 (T)	32.0 (0.1)		23.5 (0.1)		26.0 (0.1)	0.3 (T)	7.5 (0.1)		2.5 (T)		3.5 (T)
Cryptolabis spp.		7.0 (0.1)		8.0 (0.1)		8.3 (0.1)		0.5 (T)				0.3 (T)
Hexatoma spp.	2.5 (0.1)	4.5 (0.2)	2.0 (0.1)	5.0 (0.5)	2.0 (0.2)	2.3 (0.4)	1.3 (0.1)	1.1 (0.1)	1.3 (0.1)	2.5 (0.2)	2.0 (0.5)	1.0 (0.2)
Tendipedidae	5.0 (T)	11.5 (T)	2.0 (T)	5.5 (T)	4.5 (T)	18.0 (T)	0.5 (T)	4.4 (T)	5.8 (T)	11.5 (T)	4.0 (T)	7.5 (T)
Simulium spp.	1.5 (T)	36.5 (0.1)	2.0 (T)	53.0 (0.2)	2.0 (T)	41.8 (0.2)	3.8 (T)	2.5 (T)	10.3 (T)	3.3 (T)	2.0 (T)	1.5 (T)
Blephariceridae	8.5 (T)	17.5 (0.1)	14.0 (T)	19.0 (0.3)	7.5 (0.1)	11.5 (0.3)		0.3 (T)		1.5 (T)		1.0 (T)
Deuterophlebia sp.							0.3 (T)	5.2 (T)		0.8 (T)		1.5 (T)
Atherix spp.	0.5 (T)	17.5 (0.7)		10.5 (0.5)	1.0 (T)	14.5 (0.9)		2.2 (T)		6.8 (0.2)	0.5 (T)	1.5 (0.1)
TOTALS	701.0 (4.6)	1047.5 (5.6)	656.5 (3.3)	864.0 (4.9)	660.3 (4.7)	1035.1 (6.3)	258.3 (2.0)	206.8 (1.9)	435.4 (2.6)	499.7 (2.1)	741.3 (4.7)	479.0 (3.5)

the same general seasonal trends in total numbers and biomass. Maximum numbers occurred during September in the lower riffle and during November in the upper riffle with minimums in July. The greatest biomass was in April and the least in July. Total numbers and biomass were greater in the lower riffle for most of the sampling period (Table 2). The ratio of total numbers for the upper and lower riffles was about 1:2 in June and 2:1 in August 1963 with an average annual ratio of 5:6. The ratio of total biomass for the upper and lower riffle varied from about 3:4 in August 1963 to 2:1 in December 1964 with an average annual ratio of 3.4: 3.9.

Five orders of aquatic insects were encountered in each riffle during this study. Numbers and biomass varied within the orders in both riffles.

Ephemeroptera — Annual fluctuations in total numbers and biomass of this order were similar for both riffles. Maximum numbers and biomass occurred in April. Minimum numbers were in September for the lower riffle and December for the upper, while the minimum biomass was in September for both riffles. Total numbers varied from 17 times greater for the upper riffle in September 1963 to approximately twice in April 1965 with an annual average of four times. Biomass ranged from eight times greater for the upper riffle in January 1965 to about twice in June 1963 with a yearly average of four times. Of the 14 taxa of Ephemeroptera encountered, 13 were found in the upper and 12 in the lower. *Baetis* spp. and *Ephemerella inermis* were the most abundant organisms in the lower riffle comprising 75% of the number and 72% of the biomass. These were also abundant in the upper riffle along with *Ephemerella doddsi*, *Ephemerella hystrix*, *Iron* longimanus, Rhithrogenia hageni and Cinygmula sp. These seven organisms comprised 92% of the numbers and 91% of the biomass. All of the abundant organisms occurred in greater numbers and biomass in the upper riffle. Ephemerella flavilinea and Ephemerella grandis ingens were the only organisms found in both riffles which were more abundant in the lower riffle (Table 2).

Plecoptera — Annual fluctuations in total numbers and biomass were similar in both riffles. Maximum numbers occurred in December 1964 in the upper riffle and in February 1965 for the lower riffle, while minimums were in August 1965 for both riffles. Maximum biomass was in January 1965 for the upper riffle and in June 1963 for the lower riffle, while minimums occurred in December 1964 for both riffles. The ratio of total numbers for the upper and lower riffles varied from 5:1 in December 1964 to 1:2 in February 1965 with an annual average of 7:5. The ratio of biomass for the upper and lower riffles varied from 1.6:1.5 in October 1964 to 1:8 in June 1963 with a yearly average of 2:3. Eleven Plecoptera taxa were encountered with 10 in the upper and six in the lower riffle. In the upper riffle Nemoura spp., Leutra sp., Alloperla spp. and Acroneuria theodora were the most numerous organisms comprising 68% of the numbers. In the lower riffle Isoperla spp., Acroneuria pacifica, and Claassenia sabulosa constituted 85% of the numbers. Acroneuria theodora, Pteronarcys californica and Acroneuria pacifica make up 84% of the biomass in the upper riffle, while the latter two plus Claassenia sabulosa comprised 95% of the biomass in the lower riffle. Of the five Plecoptera found in both riffles only Acrynopteryx spp. and Alloperla spp. occurred in greater numbers and biomass in the upper riffle (Table 2).

Coleoptera — Both adult and larval forms were found in each riffle. The adult and larva total numbers and biomass were combined in each riffle for each month (Table 2). Seasonal trends of this order show irregular monthly fluctuations in total numbers for both riffles, while the biomass was more constant throughout the sampling period. The ratio of the total yearly numbers and biomass for the upper and lower riffle were 2:1 and 1:1 respectively.

Trichoptera — Both study riffles had the same general seasonal trends in numbers and biomass. Maximum numbers occurred during the September-November period with minimum in July. Maximum biomass was in September and minimum in July. The ratio of total numbers for the upper and lower riffle varied from 1:7 in September 1963 to 1:1 in September 1965 with a yearly average of 1:3. The ratio of biomass for the upper and lower riffle varied from 5:3 in August 1963 to 1:4 in September 1963 with a yearly average of 5:7. Of the 14 Trichoptera taxa encountered, 13 were found in the upper riffle and 14 in the lower. The most abundant Trichoptera in the upper riffle were *Rhyacophila* spp., *Arctopsyche grandis* and *Glossoma* sp. which comprised 90% of the total numbers. These three organisms plus *Rhyacophila acropedes* constitute 90% of the biomass. In the lower riffle *Glossoma* sp. and *Hydropsyche* sp. made up 94% of the numbers and 79% of the biomass. *Rhyacophila acropedes*, *Rhyacophila* spp., *Dolophilodes* sp. and *Arctopsyche grandis* were the only Trichoptera present in both riffles which were more abundant in the upper riffle (Table 2).

Diptera — In the upper riffle maximum numbers occurred in August and minimums in October. In the lower riffle maximum numbers were in January and minimums in September. Maximum biomass was in September and minimums during mid-winter (January-February) in the upper riffle. Maximum biomass in the lower riffle occurred in January and minimums in July. Nine taxa of Diptera were encountered with eight in each riffle. The ratio of total numbers for the upper and lower riffle varied from 1:2 in August 1965 to 1:17 in October 1964 with a yearly average of 1:5. The ratio of biomass for the upper and lower riffle varied from 3:2 in June 1963 to 1:17 in February 1965 with an annual average of 3:8. In the upper riffle Hexatoma spp., Tendipedidae, Simulium spp. and Blephariceridae were the most abundant organisms comprising 94% of the total numbers. In the lower riffle Antocha spp., Tendipedidae, Simulium spp., Blephariceridae and Atherix spp. comprised 87% of the total numbers. Hexatoma spp. constituted 90% of the biomass in the upper riffle, while these plus Atherix spp. comprised 72% of the biomass in the lower riffle. All Diptera present in both riffles were more abundant in the lower (Table 2).

The seven most abundant organisms in the upper riffle in order of abundance were Glossoma sp., Elmidae, Rhithrogenia hageni, Ephemerella hystrix, Cinygmula sp., Iron longimanus and Baetis spp. In the lower riffle the two most abundant were Glossoma sp. and Hydropsyche sp. These organisms comprised 68% of the total numbers in each riffle. The seven organisms in the upper riffle which constituted most of the biomass were Acroneuria theodora, Arctopsyche grandis, Hexatoma spp., Rhyacophila spp., Rhithrogenia hageni, Ephemerella doddsi and Cinygmula sp. In the lower riffle the four organisms comprising most of the biomass were *Hydropsyche* sp., *Claassenia sabulosa*, *Acroneuria pacifica* and *Hexatoma* spp. These organisms constituted 54% of the biomass in the upper riffle and 56% in the lower.

The index of diversity (d) was derived from the linear relationship between the number of species (m) and the logrithm of total individuals (N). They were calculated by the following equation (Margalef 1951):

$$d = \frac{m - 1}{\ln N}$$

The average yearly index of diversity in the upper riffle was 11.19 and the lower was 9.67.

Comparison of Aquatic Insect Orders in the Study Riffles

In the upper riffle, Ephemeroptera was the most abundant order during most of the sampling period, except in August 1963, October and November 1964 when Trichoptera was the most abundant (Table 3). During the remainder of the sampling period Trichoptera was second and Coleoptera third. Diptera was the least abundant. Ephemeroptera had the greatest biomass with Trichoptera second and Plecoptera third. In the lower riffle Trichoptera was the most abundant order during the entire sampling period with Ephemeroptera second and Diptera third. Plecoptera was the least abundant. Trichoptera had the greatest biomass with Plecoptera second and Diptera third.

Table 3. Relative abundance (upper row) and relative biomass (lower row) for each aquatic insect order expressed as percent of total number and biomass.

Aquatic Insect Orders	Upper Range	Upper Average	Lower Range	Lower Average
Ephemeroptera	32.5-69.5	49.2	1.4-28.4	9.8
	16.0-61.7	35.3	0.5-15.9	7.7
Plecoptera	2.1-13.4	4.5	1.6- 6.1	2.6
	6.1-41.3	23.5	15.9-58.6	33.3
Coleoptera	6.2-27.5	16.1	2.0-16.8	6.3
	2.1- 9.1	2.9	0.5- 3.4	2.6
Trichoptera	8.6-51.2	26.9	38.0-87.5	72.2
	17.4-46.8	29.4	20.7-68.0	35.9
Diptera	0.4- 3.9	2.1	3.7-24.0	8.9
	2.2-28.0	8.8	4.5-34.1	20.5

DISCUSSION

A comparison of taxa and biomass between the two study riffles showed that the upper riffle had the largest number of taxa, while the lower riffle had the largest number of individuals and biomass. Ephemeroptera was the dominant order in total numbers and biomass in the upper riffle, while Trichoptera dominated the lower riffle. Most of the taxa present in the upper riffle were present in the lower riffle, however the number of organisms in each taxa was less. Water temperature and water chemistry probably account for most of the differences in the taxa present, number of individuals and total biomass for the two riffles.

Temperature is important in determining the distribution of aquatic insects. Some prefer cold water, some warm water and others have little temperature preference. As the mean and maximum temperatures increase from the upper to the lower riffle, some of the cold water forms are probably eliminated or reduced in abundance, while warmer water forms appear. Dodds and Hisaw (1925) found a definite altitudinal zonation of 100 species of aquatic insects due mainly to temperature changes. The range in temperature also influences the number of taxa present, as the range increases the number of taxa should increase. The lower riffle had a wider range in temperature and fewer taxa than the upper. The number of Ephemeroptera and Plecoptera taxa decreased from the upper to the lower riffle, while the number of Trichoptera increased. In contrast Ide (1935) found an increase in the number of Ephemeroptera species downstream from its source where the greater temperature fluctuations occurred. Sprules (1947) stated that as average summer temperature increased, the number of Ephemeroptera and Trichoptera species increased, while Plecoptera decreased. The formation of anchor ice in the upper riffle may have eliminated or limited certain taxa. Armitage (1961) listed certain aquatic insects as cold water forms, warm water forms and no temperature preference forms. Three of the cold water and three of the no temperature preference were more abundant in the lower study riffle. This suggests that other factors may influence their distribution. The high concentrations of K, Na, Cl, PO_4 and SO_4 in the lower riffle may have eliminated or limited certain organisms. These concentrations may have been favorable to other organisms.

Differences observed in the standing crop for the upper and lower riffles probably were the result of water temperature and chemistry differences. As mean and maximum temperature increase from the upper to the lower riffle, the standing crop should increase. Warm water is usually more productive than cold water, other factors being favorable. No appreciable amount of surface ice formed on either riffle, but anchor ice appeared in the upper riffle during December 1964. No anchor ice was observed in the lower riffle. A noticeable decline in total numbers and biomass, especially of Arctopsyche grandis, occurred at this time in the upper riffle, but not in the lower riffle. Another net building Trichoptera (Hydropsyche), which comprised about 22% of the total biomass in the lower riffle, was rare in the upper riffle. Benson (1955) collected species of Ephemerella, Glossoma, Hydropsyche, Simulium and Elmis from floating anchor ice. Brown et al. (1953) found no appreciable change in the quantity of organisms where anchor ice had occurred, but do state that bottom organisms could be dislodged and carried away. The greater ion concentration and alkalinity in the lower riffle probably accounted for the larger numbers and biomass there. Armitage (1958) concluded that bicarbonates appeared to be the main factor determining the total quantity or organisms, but other factors such as temperature and bottom type modify the influence of bicarbonates.

The index of diversity is used to relate total numbers of individuals with the number of taxa present. The thermal and chemical effluents entering the Gibbon River between the two study riffles from surrounding geyser basins may have reduced the index of diversity in the lower riffle. The higher water temperatures and dissolved solids in the lower riffle are apparently more favorable for production of Trichoptera than Ephemeroptera.

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