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Distribution of Macroinvertebrates in the Green River Below Flaming Gorge Dam, 1963-1965

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DISTRIBUTION OF MACROINVERTEBRATES IN THE GREEN RIVER BELOW FLAMING GORGE DAM, 1963-1965

by

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of

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

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Below Flaming Gorge Dam, 1963-1965

by

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Utah State University, 1967

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This study was undertaken to determine the effects of rotenone applied during a fish control operation in September 1962 and the installation of Flaming Gorge Dam in November 1962 upon the distribution of invertebrates in the Green River. Since these two events, the river has changed from a warm, turbid stream to a cold, clear trout stream for about 45 miles below the dam. Totals of 234 bottom samples and 394 drift samples were collected between the dam and Ouray, Utah (166 miles below the dam). The species composition of the fauna above Carr Ranch was much simpler during 1964-65 than the reported pre-impoundment composition. Below Carr Ranch the species composition of the invertebrate fauna has changed little. Bottom-fauna densities were highest near the dam (max. $6347/ft.^2$) and decreased with increasing distance below the dam. Population densities below Carr Ranch (42.7 miles below the dam) appeared to be similar to reported pre-impoundment densities. Drift rates of Baetis nymphs and Simuliidae larvae were highest near the dam. Illumination, population density of other organisms, and water temperature had

significant effects on drift-net catches of *Baetis* and Simuliidae. Turbidity and water-level fluctuations had important effects under certain circumstances, while date, dissolved oxygen, and depth of water had little effect on drift-net catches.

INTRODUCTION

Construction of high dams in the Western United States has often had far-reaching effects on the rivers impounded. The river environment is changed in the impounded segment and water drawn from deep in a large reservoir into the tailwaters is usually clearer and colder than before. Other changes in water quality may be associated with the chemical limnology of the reservoir. Severe fluctuations in water level may occur in both the reservoir and tailwaters.

The Colorado River Storage Project is a long-range program by the United States Bureau of Reclamation to develop the water resources of the upper Colorado River drainage of which Flaming Gorge Dam and Reservoir are a part. Flaming Gorge Dam is an arch-type concrete structure 455 feet high located on the Green River in the northeastern corner of Utah. Power production and water storage are the primary purposes of the structure. Total hydroelectric capacity of 108,000 KW is produced by three generators each of which is supplied with water by a 10-foot-diameter penstock. Water may also be passed through the lower outlets or over the spillway. Since impoundment, however, most of the water has been released through the penstocks.

Before the dam was closed in November of 1962, a large scale fish eradication program was conducted on the Green River to suppress undesirable fish populations to allow establishment of a trout sport fishery in the reservoir and tailwaters. This was a joint action by the U. S. Fish and Wildlife service and the states of Wyoming and Utah. Approximately 21,495 gallons of an emulsified rotenone formulation, Chem-Fish regular, containing 5% rotenone were applied to the Green River and its tributaries between September 4th and 8th, 1962. The section of the Green River treated extended from above Big Piney, Wyoming to 10 miles above the present site of Flaming Gorge Dam, a distance of approximately 225 miles.

To prevent destruction of fish and aquatic invertebrates in Dinosaur National Monument, 50 miles below the last rotenone application station, a detoxification station was established 12 miles above the Monument at Brown's Park Bridge. Approximately 17,160 pounds of potassium permanganate were dispensed from this station to detoxify the rotenone. Personnel monitoring the river during the project felt that the detoxification was largely successful (Binns et al., 1963). Park rangers patrolling the river in the Monument during and shortly after the fish control project, however, saw many dead and distressed fish. Whether these sightings indicated a passage of rotenone into the Monument or the drifting of disabled fish into the Monument from above was not known.

In either case it seems certain that the rotenone application resulted in a nearly complete kill of fish and bottom organisms at least as far as Brown's Park Bridge. Binns (1965) reported a severe reduction in standing crop of bottom organisms in the river above the dam site following the rotenone application. Populations of bottom organisms recovered quickly the following 2 years, and some groups, such as Chironomidae, recovered before others. The web-spinning caddis, *Hydropsyche*, was slow to re-establish itself throughout the river above the dam (Binns, 1965).

Before construction of the dam and initiation of the fish control project, several individuals and groups had expressed concern over the effects these two events would have on the fauna of the Green River, particularly that portion in Dinosaur National Monument. As a result of this concern and interest in sound resource management, several investigations of the fauna and flora of the Green River were conducted prior to the rotenone treatment. Bosley (1960), McDonald and Dotson (1960), and Dibble ed. (1960), studied fish and invertebrates in the portion of the river now impounded by the dam. Pre-impoundment studies of the river fauna below the dam and in Dinosaur National Monument were conducted by Hagen and Banks (1963) and Woodbury et al. (1963). A study of bottom fauna conducted by Binns (1965) above Flaming Gorge Dam began before impoundment and continued through 1964.

Following the controversy arising over the fish control project, the Utah Cooperative Fishery Unit was directed by the Department of the Interior to investigate the distribution and ecology of the fishes and fish-food organisms below the dam. The present study is concerned with the latter group, the macroinvertebrates, which form an important part of the food chain for fish. The objectives of this study were to:

1. Determine the species composition of macroinvertebrates in the Green River below Flaming Gorge Dam.
2. Determine the distribution and abundance of macroinvertebrates in the Green River below Flaming Gorge Dam in 1964 and 1965.
3. Compare the composition of the invertebrate fauna below Flaming Gorge Dam with the fauna reported from the area prior to fish eradication and impoundment.

4. Determine the effects of several environmental factors upon drift rates of selected organisms in the Green River.

STUDY AREA

The study was conducted on the Green River from Flaming Gorge Dam, U.S.G.S. river mile 290 (miles above Green River, Utah) to a point just below Ouray, Utah, U.S.G.S. river mile 124. Rock formations in this area are largely sandstone, quartzite, and shale. Soils are loose, sandy, and slightly saline. The first 9 miles of the Green River below the dam (elevation 5609 feet) are in the lower end of Red Canyon. Just above the Taylor Flats Bridge, 16.1 MBD (MBD=river miles below Flaming Gorge Dam) the river runs out upon the upper end of Brown's Park, a long relatively flat basin extending across the Utah-Colorado boundry. At the lower end of Brown's Park the river enters the spectacular Canyon of Lodore, where quartzite and sandstone walls tower over 2,000 feet above the water. At the end of Lodore Canyon (65.6 MBD) the Green is joined by the Yampa River, its largest tributary in the study area. The Green then immediately enters Whirlpool Canyon to exit a short distance below at the head of Island Park (75.7 MBD). After a short winding journey (8 miles) across the narrow flats of Island, Rainbow, and Little Parks, the river plunges through Split Mountain Canyon and flows out upon the flat floor of the Uintah Basin.

Vegetation and Climate

The low-lying flats and rolling hills in Brown's Park, Island Park, and the Uintah Basin are sparsely covered with low desert shrubs and herbs. Big sagebrush, *Artemisia tridentata*, rabbitbrushes, *Chrysothamnus*, and greasewood, *Sarcobatus vermiculatus* are common shrubs on the flats.

Higher up on the foothills are found Utah Juniper, Juniperus osteosperma and pinyon pine, Pinus edulis. High in the protecting cliffs of Red, Lodore, and Whirlpool Canyons are stands of Douglas fir, Pseudotsuga menziesii.

Plants along the stream bank include rushes, Juncus; spike rushes, Eleocharis; common reed, Phragmites communis; cheat grass, Bromus tectorum; bee flowers, Cleome spp.; willows, Salix spp.; tamarisk, Tamarix pentadra; chokecherry, Prunus spp.; Fremont poplar, Populus fremontii; narrowleaf cottonwood, Populus angustifolia; and box elder, Acer negundo. The vegetation of the area has been described by Holmgren (1962a, 1962b) and Dibble, ed. (1960).

Mean annual precipitation in the area varies from about 8 inches at Jensen, Utah, to 10 inches at Flaming Gorge. Summer showers are usually of short duration but of high local intensity. These intense showers falling on loose soils with relatively sparse covers of vegetation often cause flash floods through normally dry washes. When this happens, the turbidity of the Green River increases rapidly and dramatic color changes often occur.

The average annual air temperatures at Flaming Gorge and Jensen respectively are 44.3°F. and 45.5°F. Summer daytime temperatures often reach 105°F., and nighttime air temperatures may drop to 40-50°F. Winter temperatures occasionally fall to -30°F with -10° to -15°F. reached during most winters.

Sampling Stations

In 1964 four stations (42.7 MBD, 65.8 MBD, 78.0 MBD, and 166.0 MBD) were sampled intensively (Table 1, Figure 1). Preliminary analysis of

Table 1. Location of sampling stations and distance below Flaming Gorge Dam.

Station number	Name	Miles below Flaming Gorge Dam (MBD)
1	Little Hole	7.3
2	Taylor Flats Bridge	16.1
3	Allen Ranch	26.5
4	Hoy Bottom	36.6
5	Upper Carr Ranch	42.7
6	Lower Carr Ranch	44.4
7	Mouth of Lodore Canyon	49.6
8	Echo Park (above mouth of Yampa)	64.6
9	Echo Park (below mouth of Yampa)	65.8
10	Island Park	78.0
11	Split Mountain	90.0
12	Jensen Pumping Station	118.0
13	Upper Ouray	155.0
14	Lower Ouray	166.0

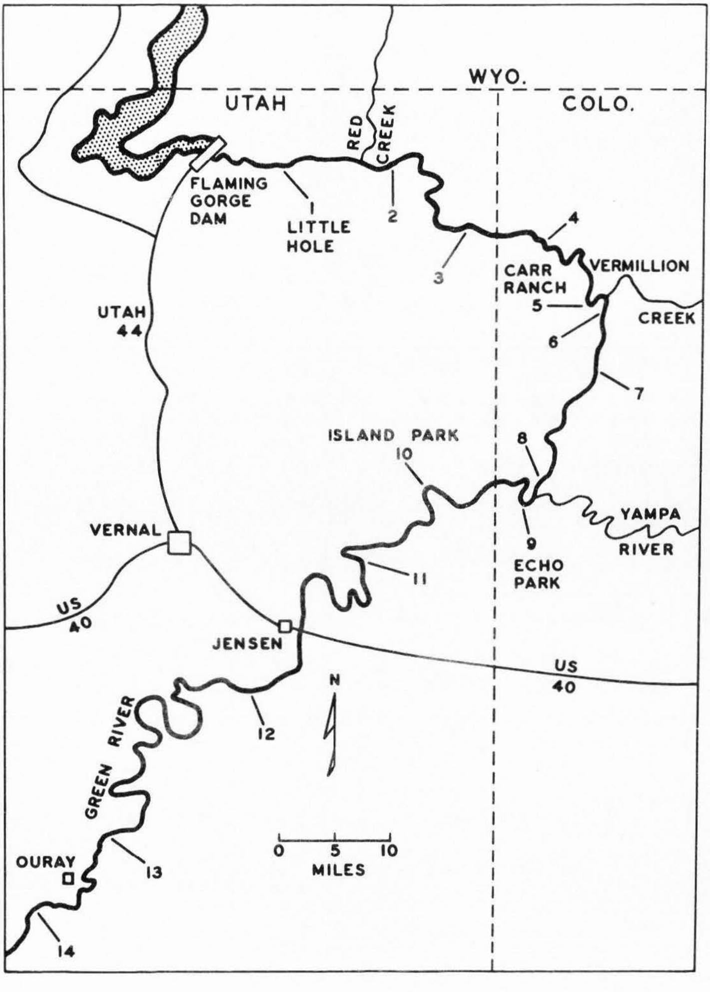

Figure 1. Location of sampling stations on the Green River, Utah - Colorado.

the 1964 data indicated that the river environment between Split Mountain campground (89.5 MBD) and Ouray (166.0 MBD) was so different from other parts of the study area (largely due to differences in gradient) that comparisons between it and upstream areas would be meaningless. Consequently, in 1965 the stations below Split Mountain campground were discontinued and sampling effort was increased in areas closer to the dam. The major stations in 1965 were Little Hole (7.2 MBD), Carr Ranch (42.7 MBD), Echo Park (65.8 MBD), and Island Park (78.0 MBD).

Eleven supplementary stations were sampled at irregular intervals to establish species distribution with greater accuracy. All samples were collected between June 1, 1964 and September 20, 1965. During the summer of 1964 Echo and Island Parks were visited once every 2 weeks. Carr Ranch and Ouray were sampled every 3-1/2 weeks. Weekend sampling trips to Island Park were made in October and November, 1964, and in January, February, March, and April, 1965. Samples were taken every 3 weeks at Little Hole, Carr Ranch, Echo Park, and Island Park during the 1965 field season (May 16 to September 20).

MATERIALS AND METHODS

Permanent staff gages were installed at the four major stations for water level observations. Records from recording water level gages maintained by the U. S. Geological Survey at Greendale (0.5 MBD) and near Jensen (93.4 MBD) were also utilized. Water temperature was measured with a 12-inch mercury-glass thermometer at all stations and with 30-day Ryan recording thermometers at Echo Park and Island Park. Additional temperature records at Greendale (0.5 MBD), Allen Ranch (26.0 MBD), Jensen (93.4 MBD), and Ouray (166.0 MBD) were obtained from the U. S. Geological Survey and the Utah Department of Fish and Game. Turbidities were determined with a Jackson candle turbidimeter. Dissolved oxygen content of the water was determined by the Thierault modification of the Winkler method. Total and phenolphthalein alkalinities were determined by procedures outlined in Standard Methods (1960). Hydrogen-ion concentration was determined with a Wallace and Tiernan comparator. A Gurley pygmy current meter was used to measure water velocities 1-inch above the bottom at each sample site. The physical nature of the substrate at each sample site was recorded according to a classification scheme similar to one suggested by Lagler (1956). All above environmental observations accompanied each quantitative sample taken of invertebrates.

Benthic invertebrates on hard substrates were sampled with a wire-mesh device similar to those described by Hess (1941) and Waters and Knapp (1961). Ninety-five and 87 samples were collected in 1964 and 1965 respectively. Organisms on soft bottoms were sampled with a 6-inch Ekman dredge mounted on a 6-foot-long, 3/4-inch-diameter metal rod. Sixteen and 36 samples were collected with the dredge in 1964 and 1965 respectively. Several small dippers and a hand screen of 1/16-inch-mesh copper screen were used for qualitative collections (5 in 1964 and 53 in 1965) at supplementary stations and in tributary streams. Drift organisms were sampled with a conical nylon-mesh net (Nitex # 423 material) mounted on a hoop 11-1/2 inches in diameter. Seventy-three and 321 drift samples were collected in 1964 and 1965, respectively. Drift sampling in the Yampa River was carried out on the Echo Park schedule during the summer of 1965. Location and year of all samples taken are given in Appendix A. Twenty-eight bottom samples collected by the late Dr. Donald R. Franklin in June-July 1963, were also analyzed and included in this study. Invertebrate identifications were made with keys in Edmunds (1952), Musser (1962), Pennak (1953), and Usinger (1956).

PHYSICAL AND CHEMICAL ENVIRONMENT

Many changes in the river environment have occurred since the construction of Flaming Gorge Dam. A knowledge of these changes and of those characteristics of the river which have not changed (such as gradient) is necessary to interpret the findings related to distribution and abundance of benthic invertebrates.

Gradient

Differences in gradient divide the river into several ecologically distinct reaches (Table 2). Where the gradient is low the substrate is composed of fine sediments, and where high, rubble and gravel prevail. Little Hole (7.2 MBD) and Echo Park (64.4 MBD) represent areas of high gradient (9.9 and 15.9 ft./mi. respectively), Carr Ranch (42.7 MBD) is in an area of low gradient (2.5 ft./mi.), and Island Park (78.0 MBD) represents an area of intermediate gradient (5.1 ft./mi.).

Discharge

Seasonal variations in flow have been greatly reduced by Flaming Gorge Dam with its relatively stable power output. Mean monthly flows fluctuated from 603 to 7306 cfs at Greendale before the dam was constructed and from 864 to 1947 cfs after (Table 3). In general, summer, fall, and winter flows have increased and spring flow has decreased since closure of the dam. Power demands on Flaming Gorge Dam often cause a diurnal fluctuation in flow. A frequent pattern of operation at the dam is for maximum power production during daylight hours with a

Table 2. Average gradient between selected points on the Green River below Flaming Gorge Dam (data from U.S.G.S. maps).

Location	Miles below dam	Average gradient between locations (feet per mile)
Flaming Gorge Dam	0	
		9.9
Bridgeport Ranch	19.5	
		2.5
Mouth of Lodore Canyon	48.0	
		15.9
End of Lodore Canyon	65.8	
		10.1
Upper Island Park	75.7	
		5.1
Lower Island Park	83.5	
		20.0
Split Mt. Canyon	89.5	
		7.5
Overflow Campground	96.2	
		1.6
Ouray	166.0	

Table 3. Mean monthly discharges of the Green River at Greendale (0.5 MBD) and near Jensen (93.4 MBD) before and after the construction of Flaming Gorge Dam, 1950-1965 -- expressed in cubic feet per second.

Station and Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Greendale												
Pre-impoundment												
(1950-1960)	603	751	1349	2546	4585	7306	3476	1714	930	921	794	638
Post-impoundment												
1963	367	467	106	134	130	125	104	102	113	128	312	743
1964	949	966	599	587	1477	1446	2441	1992	2200	2583	2343	3151
1965	3506	3838	3782	3420	1078	1439	474	497	734			
Jensen												
Pre-impoundment												
(1950-1960)	968	1211	2477	6018	1231	14555	5340	2353	1272	1388	1295	1016
Post-impoundment												
1963	747	1137	949	2029	5507	3428	498	453	505	346	632	1036
1964	1199	1314	1023	2464	8755	8172	4149	2390	2395	2737	2657	3484
1965	4206	4448	4421	6936	9718	11680	3860	1686	1829			

sharp drop in output late in the afternoon. A reduction in flow from 2500 to 400 cfs within an hour or less is not uncommon. Because Flaming Gorge Dam is one unit in the Colorado River Storage Project, power needs are variable and operations at the dam are unpredictable. The discharge record at the Greendale station is so variable within any single day that the U. S. Geological Survey uses integration techniques to calculate mean daily flow. This is not necessary for most other discharge records in the state.

Daily fluctuations in flow were most pronounced near the dam and sudden changes in flow were dampened progressively downstream. Maximum water level fluctuations observed for any given 24-hour period in 1965 were 2.14 feet at Little Hole, 1.47 feet at Carr Ranch, and 0.33 feet at Island Park. Near Jensen (93.4 MBD) only major changes in flow lasting 24 hours or more were detected.

The seasonal flow stability imposed on the river above Taylor Flats Bridge (16.1 MBD) has stabilized the bottom materials. At Little Hole (7.2 MBD) very little change in the physical nature of the substrate was observed among seasons or between years. Farther downstream, however, the bottom remained unstable, and at Island Park several rubble-bottomed areas were washed clean of sediments during the spring floods but were smothered by thin layers of silt as the waters receded in summer and fall. Erosion of the river bank continued throughout the year at Island Park and, to a lesser extent, at Echo Park.

Temperature

The general effect of the dam has been an increase in river temperature during the winter and a decrease in the summer. Mean monthly pre-impoundment temperatures ranged from 33°F. to 70°F. at Greendale (0.5 MBD; Figure 2) while post-impoundment monthly means ranged from 35°F. to 54°F. Effects of the dam upon river temperature were less pronounced downstream. Near Jensen (93.4 MBD) seasonal changes in water temperatures were affected little by the dam in 1963, but summer temperatures in 1964 and 1965 were 5° to 6°F. lower than the pre-impoundment average.

The summers of 1964 and 1965 were cooler than the summer of 1963 (annual mean air temperatures were 44.9, 43.9, and 48.4 respectively) which may explain the observed departure from the average. During 1963, however, discharge through the turbines at Flaming Gorge was minimized to allow the reservoir to fill (Table 3). In 1964 and 1965, much larger releases of water were made which probably influenced temperatures farther downstream than did the small releases of 1963. Summer water temperatures at Allen Ranch (26.5 MBD) were lowest in 1964 (the year of maximum summer discharge) and highest in 1963 (the year of minimum summer discharge) even though water released in 1963 was colder than that in 1964 and 1965 (Figure 3). Lower water temperatures accompanied high discharges downstream from Flaming Gorge at Carr Ranch (42.7 MBD) and Echo Park (64.4 MBD). Below the confluence of the Green and Yampa Rivers little relationship between temperature and flow was observed since the mean annual discharge of the Yampa exceeded that of the Green during 1963-1965 (1753 cfs and 1341 cfs respectively).

Turbidity

Water drawn from the reservoir was nearly sediment-free during 1963-65, but three major tributaries below the dam discharged turbid

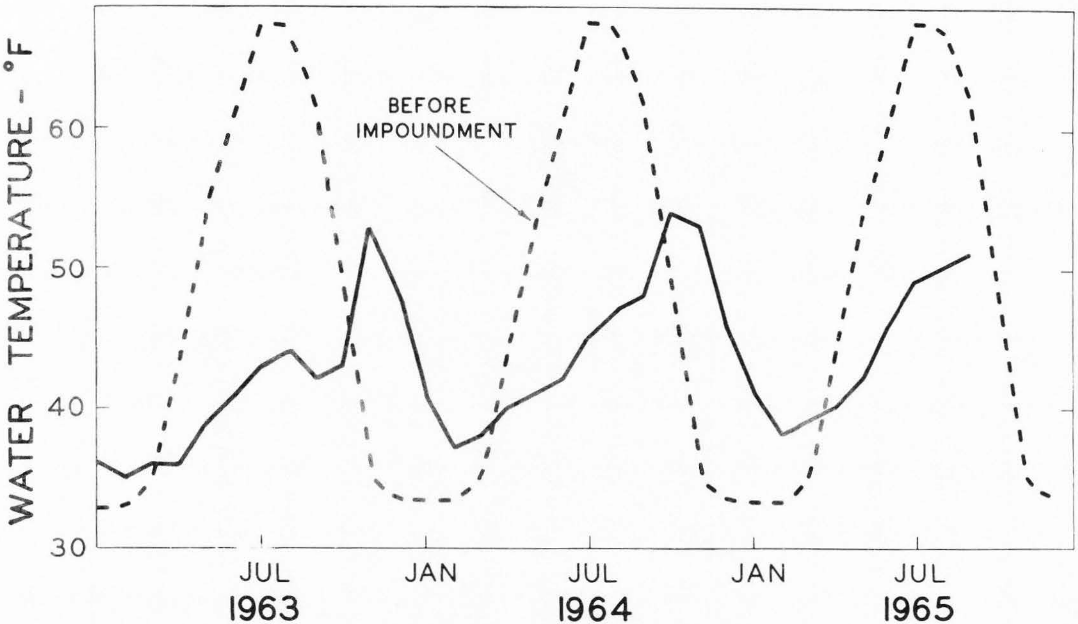

Figure 2. Mean monthly water temperatures at Greendale, Utah (0.5 MBD) during the pre-impoundment years (1957-1959, 1962) and during the post-impoundment years (1963-1965), data from U. S. Geological Survey.

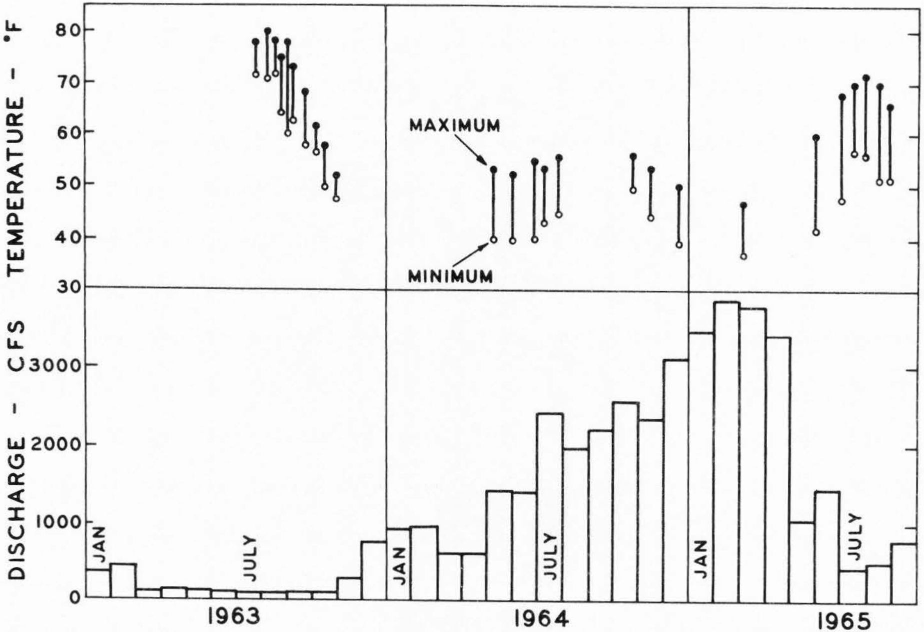

Figure 3. Mean monthly discharge of Flaming Gorge Dam and range of water temperature recorded on maximum-minimum thermometers for unequal time intervals, Allen Ranch (26.0 MBD), unpublished data from Utah Department of Fish and Game and U. S. Geological Survey - January, 1963 through September, 1965.

waters into the Green River. These were Red Creek (11.2 MBD), Vermillion Creek (43.6 MBD), and the Yampa River (65.8 MBD). Turbidity readings at Little Hole were less than 25 JTU (Jackson Turbidity Units) with the exception of the morning of June 11, 1965 when a sudden increase in flow caused temporary scouring of the riverbed and turbidity increased to 62 JTU. Turbidity at Carr Ranch did not exceed 700 JTU during the study, but the maximum observed at Echo Park and Island Park was 5000 JTU (Table 4). Mean concentration of suspended sediments at Jensen was 1529 ppm before impoundment and 925 ppm after (Table 5).

Dissolved Oxygen

Dissolved oxygen concentrations were always 6.0 ppm or above (Table 6). They were highest at Little Hole and decreased sharply between Little Hole and Carr Ranch. Dissolved oxygen concentrations at Echo and Island Parks were similar during the summer months. The few measurements made during the winter months did not contradict the above generalizations. Dissolved oxygen concentrations at Little Hole fluctuated as much as 3-4 ppm over a 24-hour period. Saturation (100 percent) was often reached after noon. Daily fluctuations decreased with increasing distance from the dam, and this was probably a reflection of of reduced algal growths downstream. At Island Park the maximum fluctuation observed in a 24-hour period was 0.8 ppm.

Before construction of the dam some concern was expressed that water drawn from the hypolimnion during summer months might be devoid of oxygen. This situation occurred in August, 1964, when water containing less than 1.0 ppm dissolved oxygen was released. Oxygen content

Table 4. Frequency of turbidity readings at the four major stations, Green River, 1964-1965.

Turbidity (JTU)[1/]	Number of samples			
	Little Hole	Carr Ranch	Echo Park	Island Park
0 - 25	115	61		
25 - 50	2	14	1	1
50 - 75	1	7	10	6
75 - 100		7	9	6
100 - 125		9	4	9
125 - 150		2	6	33
150 - 175		1	4	26
175 - 200			6	29
200 - 250			8	27
250 - 300		2	8	11
300 - 350			9	10
350 - 400			8	10
400 - 450			2	4
450 - 500			3	3
500 - 550		1	3	5
550 - 600				10
600 - 650				1
650 - 700		2	1	1
700 - 750				1
800 - 850			1	
850 - 900			1	
900 - 950			1	
950 - 1000			1	
1000 - 2000			9	2
2000 - 3000			2	1
3000 - 4000			2	1
4000 - 5000			1	3

1/ Jackson turbidity units.

Table 5. Mean concentration of suspended sediments in the Green River near Jensen before and after construction of Flaming Gorge Dam (data from U. S. Geological Survey).

Water year (Oct. - Sept.)	Mean concentration (PPM)
Pre-impoundment	
1949	1930
1950	1950
1951	1220
1952	2430
1953	1130
1954	984
1955	1400
1956	1930
1957	1280
1960	1722
1961	753
1962	1620
Mean	1529
Post-impoundment	
1963	756
1964	828
1965	1190
Mean	925

Table 6. Dissolved oxygen concentration at five stations, Green River 1964-1965.

Concentration (PPM)	Number of determinations				
	Little Hole	Carr Ranch	Echo Park	Island Park	Ouray
0.0 - 6.0	2			3	1
6.0 - 6.2	1			1	1
6.2 - 6.4				1	2
6.4 - 6.6			2	3	4
6.6 - 6.8		1	2	1	2
6.8 - 7.0	1	3	4	9	3
7.0 - 7.2	5	5	2	32	2
7.2 - 7.4	1	10	9	20	6
7.4 - 7.6	3	5	4	14	2
7.6 - 7.8	1	14	3	13	
7.8 - 8.0	1	16	16	24	1
8.0 - 8.2	4	8	14	29	1
8.2 - 8.4	7	12	16	23	
8.4 - 8.6	6	4	14	14	
8.6 - 8.8	12	11	17	6	
8.8 - 9.0	1	4	5	5	
9.0 - 9.2	1		4	1	
9.2 - 9.4	8			1	
9.4 - 9.6	1			2	
9.6 - 9.8	7			1	
9.8 -10.0	1				
10.0 -10.2	3				
10.2 -10.4	4				
10.4 -10.6	3				
10.6 -10.8	6				
10.8 -11.0	3				
11.0 +	8				

had increased to 5.0 ppm 0.2 miles below the dam, and to 9.0 ppm at Little Hole, 7.2 miles below (data from unpublished records of the Utah State Department of Fish and Game). Pfitzer (1963) reported a much slower reaeration of waters low in oxygen released from reservoirs in Tennessee (2-4 ppm in 3 miles). The tailwaters he studied had dense growths of algae on the substrate, but the temperature of the water (70-72°F.) was higher than the Green and the gradient was probably less. Nighttime reaeration rates were not significantly lower than daytime rates in his reported data. To what extent oxygenation or deoxygenation of the water took place in the Green River during winter months or at night is not known.

Dissolved Solids

Concentration of total dissolved solids in the Green River increased noticeably after impoundment. Most of the increase was in sulfates, calcium, sodium, and bicarbonates (Table 7). Bicarbonate determinations made by the U. S. Geological Survey at Greendale were consistently around 192 ppm during 1964-65 whereas determinations made in the present study were consistently around 140 ppm at Little Hole, only 6.7 miles below the Greendale station. This discrepency may be due partly to a different treatment of water samples (U.S.G.S. samples were stored prior to analysis, present study samples were analyzed immediately).

Total alkalinity between the dam and Echo Park was in the 125-180 ppm range during 1964-5. Alkalinity of the Yampa River was lower than the Green during both years (52-155 ppm), particularly during the spring runoff season. Consequently, alkalinity at Island Park was low-

Table 7. Analyses of water at Greendale (0.5 MBD), Green River, before and after impoundment (data from U.S. Geological Survey) -- expressed in parts per million.

Water Year (Oct.-Sept.)	Ca	Na	HCO_3	SO_4	Total dissolved solids	Hardness (carbonate)	Hardness (non-carbonate)	pH
1957			197		359			7.5
1958	53	40	173	127	356	203	60	7.9
1959	23	47	170	155	396	215	76	7.9
1960	61	58	187	184	457	242	90	7.9
1961	69	69	191	227	540	261	114	8.0
1962	58	57	192	175	447	245	88	7.7
Mean	53	54	185	174	426	228	86	7.8
1963	80	84	215	293	653	335	158	7.8
1964	71	60	194	202	551	269	110	7.8
1965	72	68	191	243	568	298	142	7.8
Mean	74	71	200	264	591	301	137	7.8

er (65-155 ppm) than observed above Echo Park.

Hydrogen-ion Concentration

Mean hydrogen-ion concentrations recorded by the U. S. G. S. at Greendale were identical (pH=7.8) in pre- and post-impoundment years (Table 7).

Ranges in pH recorded at Little Hole, Carr Ranch, Echo Park, and Island Park were 7.7-8.8, 8.0-8.7, 8.0-8.5, and 7.7-8.9 respectively. The average pH value for all stations was 8.2. No seasonal trends were apparent. In the present study pH fluctuated as much as 0.8 units within a 24-hour period at Little Hole and 0.4 units or less at Island Park.

DISTRIBUTION AND ABUNDANCE OF BENTHIC INVERTEBRATES

Stream invertebrates usually exhibit an extremely contagious, or clumped, distribution. Many forms are restricted in their choice of "a place to live" by their own narrow environmental requirements. Temperature, turbidity, dissolved oxygen, pH, and alkalinity are environmental factors influencing large areas. Water velocity, size of substrate particles, and degree of compaction of the substrate are microenvironmental factors of great importance. Stream-dwelling organisms live in a constantly changing environment where water currents continuously sort and grade the substrate particles. Changes in water level, wind speed, and wind direction, in turn, alter the pattern of water currents. It is not unusual, therefore, to find many reports in the literature describing the extreme variability involved in sampling bottom organisms. The amount of substrate sampled in most studies is usually small in comparison to the total area of streambed and seasonal changes in abundance so pronounced in many insect and other invertebrate groups also contribute to the variability.

Needham and Usinger (1956) concluded that the number of Surber samples necessary to obtain statistical significance at the .05 level was too large for practical field investigations. Gaufin, Harris and Walker (1955) conducted a similar experiment with essentially the same results, but suggested that careful selection of sampling sites with respect to type of substrate, current speed, and depth, might reduce the variability encountered in random sampling. Waters and Knapp (1961) suggested that some of the errors (unaccounted variability) inherent in the Surber sampler might be avoided by using a sampler like the one suggested by Hess (1941). A sampler of the Hess-Waters type, constructed of wire-mesh (36 meshes per inch), prevents the escape of bottom organisms and prevents entry of drift organisms from the upstream side. In practice the sampler was turned securely into the streambed with the sampling net on the downstream side. The substrate was then thoroughly stirred and washed in such a manner that the organisms were carried into the collecting net. The entire contents of the collecting net were preserved in 10% formalin and transported to the laboratory. Bottom organisms were floated from preserved debris in a sugar solution of 1.20 specific gravity as suggested by Anderson (1959). Checks on recovery rates by hand sorting indicated that between 83% and 95% of all organisms except oligochaetes were recovered. The outer covering of oligochaetes is permeable and body fluids are readily lost to the sugar solution. Consequently, many individuals failed to float long enough to be recovered so samples containing oligochaetes were sorted by both floatation and hand-picking.

A 6-inch Ekman dredge was used to collect organisms on soft bottoms. Samples were washed in a 36-mesh seive, preserved, and handled in the same manner as Hess-Waters samples.

Little Hole

The substrate at Little Hole was composed primarily of compacted rubble with sand and gravel in the interstices. Because seasonal flooding was eliminated and the input of sand and silt from upstream reduced, the substrate in this area was relatively stable during the study period. The few pools in the area had soft sand-silt bottoms. Very little organic debris (of terrestrial origin) was present at this station but a luxurious growth of green algae (Cladophora) covered most rocks.

Twenty-six groups of organisms were collected at Little Hole but the bottom fauna community was dominated by four groups: Oligochaeta, Chironomidae, Simuliidae, and Baetis sp. I. Numbers of each of these four groups sometimes exceeded 1500 individuals per square foot of substrate (Tables 8 and 9). Population density of other groups of organisms collected at Little Hole did not exceed four individuals per square foot. Eight groups of organisms (Heptagenia elegantula, Baetis sp. IV, Paraleptophlebia pallipes, Ophiogomphus, Gerridae, Notonectidae, Chrysomelidae, and Stratiomyiidae) were not taken with quantitative samplers but were collected with hand screens and dipnets.

Baetis sp. I, one of the most abundant organisms at Little Hole, had at least two generations per year. In 1965 emergences were observed in the middle of July and the middle of September. Emergence of adults appeared to extend over a 1- to 2-week period. As a result of this synchronized emergence, nymphs were nearly absent from the river for 1 to 2 weeks after emergence and egg-laying. The eggs apparently hatched within 2 weeks after being laid and the winter was passed in the nymphal stage.

Nymphal populations of Baetis sp. I during 1964-5 fluctuated from 9 to 3729 individuals per square foot on rubble. These nymphs were rarely found on silt-sand substrates.

Oligochaete and chironomid populations increased in density as the study progressed, particularly on silt-sand substrates (Table 9).

Table 8. Abundance of benthic invertebrates on rubble or gravel substrates, Little Hole, Green River, 1964-1965 -- expressed as mean number per square foot.

Item	1964		1965							
	Aug. 30	Oct. 24	Feb. 6	Apr. 12	June 14	July 9	Aug. 7	Aug. 26	Sept. 19	Nov. 4
Nematoda									1	
Oligochaeta	41	12	3	1	298	11	221	77	299	20
Hydracarina						1	2	3	1	4
Plecoptera										
Isoperla										1
Arcynopteryx									1	1
Ephemeroptera										
Baetis sp. I	243	9	91	311	78	67	3729	1809	163	633
Baetis sp. V									1	2
Paraleptophlebia pallipes									1	1
Trichoptera										
Agraylea									1	
Diptera										
Tipulidae						1	1			
Simuliidae	2	14	18	52		304	1883	1158	95	1520
Chironomidae	599	204	135	83	408	679	485	837	662	743
Ceratopogonidae				1	1	2			1	
Rhagionidae										4
Anthomyiidae								4	1	
Pupae (all families)	107	50	3	53	21	57	26	53	77	38
Gastropoda	1									3
Number of Samples	1	1	1	1	2	2	2	2	2	2

Table 9. Abundance of benthic invertebrates on sand or silt substrates, Little Hole, Green River, 1964-1965 -- expressed as mean number per square foot.

Item	1964	1965				
	Aug. 30	June 14	July 9	Aug. 7	Aug. 26	Sept. 19
Oligochaeta	45	884	628	2904	3316	3024
Ephemeroptera						
Baetis sp. I	3					4
Diptera						
Simuliidae				4		4
Chironomidae	62	236	68	1376	2572	1650
Ceratopogonidae			4			
Pupae (all families)	5		5	13	17	208
Pelecypoda					1	
Number of Samples	2	1	2	2	2	2

Emergence of chironomids occurred throughout the year but larvae were abundant in the river at all times. Larval populations varied from 83 to 837 per square foot on rubble and from 62 to 2572 per square foot on silt-sand substrates. Numbers were lowest in April each year. No seasonal fluctuation in numbers was apparent in the oligochaete population which varied from 45 to 3316 per square foot on silt-sand substrates.

Simuliidae appeared to have one major emergence period in the spring, and were found throughout the year. Larval populations varied from 0 to 1883 per square foot on rubble substrates. Simuliidae larvae were rarely found on silt-sand substrates.

Carr Ranch

The river at Carr Ranch (42.7 MBD) was characterized by a low gradient and shifting sand substrate with few silt-free patches of gravel or rubble. There was an abundance of submerged woody and nonwoody plant debris, however, and the clinging and sprawling forms of benthic invertebrates used it for support. Very little algae was attached to the unstable substrate. Large strands of *Cladophora* drifted down, caught on the plant debris, and provided habitat for many invertebrates.

Thirty-six invertebrate forms were collected at Carr Ranch (Appendix B). The only forms found in appreciable numbers on silt-sand substrates were Oligochaeta and Chironomidae (Table 10), and both were restricted to quiter waters near shore and behind bars and snags. Only a few scattered chironomid larvae were found in channels where the sands were continuously sorted and graded by the current. Population

Table 10. Abundance of benthic invertebrates on silt or sand substrates, Carr Ranch, Green River, 1964-1965 -- expressed as mean number per square foot.

Item	1964		1965				
	June 30	July 22	June 7	July 4	Aug. 1	Aug. 22	Sept. 7
Oligochaeta	2	4	6	126	15	8	16
Ephemeroptera							
Baetis sp. I		1	4	1	1	17	4
Baetis sp. IV		1			5		19
Brachycercus sp.						1	
Tricorythodes minutus							2
Ondonata							
Gomphus							1
Hemiptera							
Corixidae					1	7	8
Diptera							
Tipulidae	1	2			1		
Simuliidae				1	2		
Chironomidae	10	0	12	7		144	524
Ceratopogonidae	2	1			2	8	1
Pupae (all families)	3	6		1	1	6	13
Number of Samples	4	4	3	2	2	3	4

densities of Oligochaeta and Chironomidae on silt-sand substrates ranged from 2 to 126 and from 0 to 524 per square foot respectively (Table 10).

The four most abundant organisms on debris substrates at Carr Ranch were Chironomidae, Oligochaeta, Baetis sp. IV and Baetis sp. I with observed density ranges of 6 to 276, 0 to 234, 0 to 106, and 0 to 58 per square foot, respectively (Table 11). Density of Hyalella, Baetis sp. VIII, Baetis sp. XIV, and Ceratopogonidae exceeded 50 individuals per square foot on at least one occasion.

Of the 11 species of mayflies collected six were either burrowers (Ephoron album), trash and debris inhabitors (Tricorythodes minutes, Baetis sp. V), or were adapted to live directly on the silt bottom in quiet water (Brachycercus sp., Baetis sp. IV, Baetis sp. VIII). Three flattened forms, usually found on gravel or rubble in swift water (Heptagenia elegantula, Rhithrogena undulata, and Choroterpes albiannulata), were rare.

Echo Park

Station # 8 (64.4 MBD) was located about 1/2-mile above the confluence of the Green and Yampa Rivers at Echo Park. The substrate in this area was gravel and rubble with limited silt and sand deposits near shore and on the inside of bends in the river. Algal growths on the substrate were more abundant than at Carr Ranch, but not nearly as abundant as at Little Hole, probably because the substrate was less stable and the turbidity higher.

Thirty-seven forms of invertebrates were collected at this station. Silt and sand deposits in the area were unstable and subject to a continuous cycle of erosion and deposition. Consequently, the in-

Table 11. Abundance of benthic invertebrates on debris, Carr Ranch, Green River, 1964-1965 -- expressed as mean number per square foot.

Item	1964			1965				
	June 30	July 22	Aug. 27	Jan. 10	June 7	July 4	Aug. 22	Sept. 7
Oligochaeta				2	234	97	64	7
Amphipoda								
Hyalella					1	1	1	57
Plecoptera								
Isoperla				1				1
Ephemeroptera								
Heptagenia elegantula			4			1	3	
Rhithrogena undulata						1		
Baetis sp. I		2	57	2	58	2	18	32
Baetis sp. IV							74	106
Baetis sp. V			1					10
Baetis sp. VIII			96				4	1
Baetis sp. XIV							76	4
Brachycercus sp.							1	1
Tricorythodes minutus					1		23	18
Choroterpes albiannulata								1
Ephoron album							1	1
Hemiptera								
Corixidae						2	3	7
Trichoptera								
Cheumatopsyche							3	3
Agraylea								11
Coleoptera								
Dytiscidae						2	1	
Dryopidae							1	
Diptera								
Tipulidae		1		2			1	
Simuliidae			3	11			22	49

Table 11 (Continued). Abundance of benthic invertebrates on debris, Carr Ranch, Green River, 1964-1965 -- expressed as mean number per square foot.

Item	1964			1965				
	June 30	July 22	Aug. 27	Jan. 10	June 7	July 4	Aug. 22	Sept. 7
Chironomidae	6	54	7	36	33	10	132	276
Ceratopogonidae	53	10			9		3	4
Anthomyiidae						1		
Pupae (all families)	3	7	3	1	3	1	15	51
Number of Samples	1	1	1	2	1	2	3	2

vertebrate population on silt-sand substrates was low. Oligochaeta and Chironomidae, the two most abundant forms on this substrate, did not exceed 40 individuals per square foot (Table 12).

The four most abundant forms on rubble or debris substrates at this station were Baetis sp. I, Hydropsyche, Chironomidae, and Isoperla, with observed densities of 6 to 605, 0 to 166, 4 to 71, and 0 to 41 per square foot respectively (Tables 13 and 14). Hydropsyche and Isoperla are forms usually associated with swift water and stable substrates.

Several genera and species of aquatic insects were found at this station which were not present at Little Hole and Carr Ranch. These included: Baetis sp. VII, Tricorythodes sp., Ephemerella inermis, Traverella albertana, Acroneuria, Isogenus, Hydropsyche, Brachycentrus, and Hydroptila.

Trichopterans of the family Hydropsychidae were represented by only one specimen in the 1964 collection but were one of the most abundant forms collected in 1965.

Island Park

Island Park, the major station farthest below the dam, was least affected by the dam. Here the river was turbid in spring and summer months, a spring rise in water level was pronounced, and water temperatures followed the pre-impoundment seasonal patterns closely. Gradient was relatively steep, and the substrate was mostly gravel and rubble with many clumps and snags of plant debris. Seasonal water-level fluctuations were severe and much bank erosion was in progress. The substrate was seasonally unstable because spring floods scoured the

Table 12. Abundance of benthic invertebrates on silt or sand substrates, Echo Park, Green River, 1964-1965 -- expressed as mean number per square foot.

Item	1964 July 16	1964 Sept. 12	1965 May 30	1965 June 28	1965 July 21
Oligochaeta	40	16			3
Ephemeroptera					
Baetis sp. I				4	
Diptera					
Simuliidae	4			3	
Chironomidae	4	3	6	31	1
Pupae (all families)				8	
Number of Samples	1	1	2	2	1

Table 13. Abundance of benthic invertebrates on rubble or debris substrates, Echo Park, Green River, 1964 -- expressed as mean number per square foot.

Item	June 25	July 16	Aug 3	Aug 25	Sept 12	Oct 31	Nov 27
Oligochaeta	1				1	1	1
Hydracarina	2						1
Plecoptera							
Isoperla	1					40	
Acroneuria	1						
Ephemeroptera							
Heptagenia elegantula	1	1	1	4	1	1	
Rhithrogena undulata				1			
Baetis sp. I	47	7	8	33	14	114	605
Baetis sp. V	1	1	2	1	1	2	1
Baetis sp. VII				1			
Baetis sp. VIII		1	1	1			
Tricorythodes minutus	7		3			1	
Tricorythodes sp.			1				
Traverella albertana			2				
Trichoptera							
Hydropsyche				1			
Hydroptila			1				
Coleoptera							
Elmidae					1		
Diptera							
Tipulidae	1						
Simuliidae				4	3		5
Chironomidae	17	10	15	8	5	21	8
Ceratopogonidae	1		2	2	2		1
Rhagionidae						1	
Pupae (all families)	2	5	2	4	4	1	
Number of Samples	2	2	2	2	2	2	2

Table 14. Abundance of benthic invertebrates on rubble or debris substrates, Echo Park, Green River, 1965 -- expressed as mean number per square foot.

Item	May 16	May 30	June 28	July 21	Aug. 14	Sept. 10
Oligochaeta		1	1		1	
Hydracarina	1	1		2	6	3
Plecoptera						
Isoperla	41	2				
Isogenus		3	1			
Ephemeroptera						
Heptagenia elegantula	4	4	7	11	6	7
Rhithrogena undulata	10	8	1	3	9	4
Baetis sp. I	90	13	6	171	36	19
Baetis sp. V				3	1	1
Baetis sp. VII					1	1
Baetis sp. VIII				1		
Tricorythodes minutus		1	3	2	8	2
Tricorythodes sp.					4	1
Ephemerella inermis	2					
Traverella albertana				17	32	18
Ephoron album				1		
Odonata						
Ophiogomphus	1					
Megaloptera						
Corydalus					1	1
Trichoptera						
Cheumatopsyche		3		29	26	11
Hydropsyche	5	5		71	166	145
Agraylea					18	11
Brachycentrus				1		2
Coleoptera						
Elmidae		1			1	1
Diptera						
Tipulidae						1
Simuliidae			1	14	8	3
Chironomidae	9	4	15	14	16	71
Pupae (all families)	6	1	5	4	2	8
Number of Samples	2	2	2	2	2	2

channels and receding waters in late summer left much macroinvertebrate habitat near the water's edge smothered under a layer of silt. Growths of green algae were scanty and little algae was observed drifting in the river.

Forty-seven forms of invertebrates were collected at this station. This increase in forms may be in part a reflection of the greater number of samples taken at this station rather than a real increase in number of forms present (Table 15). Invertebrate populations on silt-sand substrates were low, 25 organisms or less per square foot for all groups combined. Number of organisms per square foot on rubble or debris reached a maximum of 395 (Table 16). The four most abundant forms on this substrate were Chironomidae, _Baetis_ sp. I, _Ephemerella inermis_, and _Cheumatopsyche_ with observed densities of 2 to 367, 0 to 171, 0 to 77, and 0 to 27 per square foot, respectively (Tables 16 and 17).

Supplementary Stations

Supplementary stations were sampled too infrequently to estimate population densities at these locations. Results from these stations in some instances, however, made the data obtained at the major stations more understandable.

Samples taken at the Taylor Flats Bridge (16.1 MBD) indicated that the species composition of invertebrates in this area was very similar to that found at Little Hole (Appendix C), with two exceptions: one specimen each of _Tricorythodes minutus_ and _Rhithrogena undulata_ which were not found in the latter area.

In September, 1965, two Hess-Waters and several qualitative

Table 15. Abundance of benthic invertebrates on silt or sand substrates, Island Park, Green River, 1964-1965 -- expressed as mean number per square foot.

Item	1964						1965				
	June 16	July 4	July 30	Aug. 17	Sept. 9	Nov. 28	May 25	June 20	July 15	Aug. 12	Sept. 1
Oligochaeta	0					2			12	1	
Plecoptera											
Isoperla						1					
Ephemeroptera											
Baetis sp. I						1			1	3	
Tricorythodes minutus			1								
Hemiptera											
Corixidae				1							
Trichoptera											
Cheumatopsyche					1				1		
Diptera											
Tipulidae								1			
Simuliidae								1			
Chironomidae			22	6	3	14	1	2	8	5	4
Ceratopogonidae		1				1		20			3
Pupae (all families)		1						1	1		1
Number of Samples	1	2	3	2	3	1	3	4	4	3	4

Table 16. Abundance of benthic invertebrates on rubble or debris substrates, Island Park, Green River, 1964 -- expressed as mean number per square foot.

Item	June 16	July 4	July 30	Aug. 17	Sept. 9	Nov. 1	Nov. 28
Oligochaeta		1		1	1	1	
Hydracarina		6	1	1			
Plecoptera							
Isoperla	1					5	
Isogenus					2		
Ephemeroptera							
Heptagenia elegantula	2		3		1		
Rhithrogena undulata			1				
Baetis sp. I	2		7		1	2	3
Baetis sp. IV			3				
Baetis sp. V	1		3				2
Baetis sp. VI	1						
Baetis sp. VIII	1		13				
Baetis sp. XIV		1					
Tricorythodes minutus		6	31	6	4		
Tricorythodes sp.			1		1		
Ephemerella inermis		3			2		
Choroterpes albiannulata			1	1	1		1
Traverella albertana			4				
Ephoron album				1	1		
Trichoptera							
Cheumatopsyche	1	2	5	1	10		
Hydropsyche					2		
Leptocella		2					
Brachycentrus		2			1		
Coleoptera							
Dytiscidae					1		
Elmidae		1					
Diptera							
Simuliidae		13					
Chironomidae	5	22	22	89	65	53	367
Ceratopogonidae		2		1		1	
Pupae (all families)	1	1	2	34	11	12	22
Number of Samples	3	2	3	3	5	2	1

Table 17. Abundance of benthic invertebrates on rubble or debris substrates, Island Park, Green River, 1965 -- expressed as mean number per square foot.

Item	Feb. 6	Mar. 20	Apr. 11	May 25	June 20	July 15	Aug. 12	Sept. 1
Nematoda								2
Oligochaeta	1		10			1		
Hydracarina						1	4	2
Plecoptera								
Isoperla	7		1	7	7	1		1
Isogenus			2	1		4		
Acroneuria								1
Ephemeroptera								
Heptagenia elegantula			1	24	2	3	6	15
Rhithrogena undulata	2	1	4			1		
Baetis sp. I	171	44	102	16	2	27	1	5
Baetis sp. IV							1	2
Baetis sp. V						13		2
Baetis sp. VII						5	5	3
Baetis sp. VIII					1	1		
Tricorythodes minutus					2	1	6	13
Tricorythodes sp.						1	25	20
Ephemerella inermis	1	1	3	77	38	1		3
Choroterpes albiannulata							11	15
Traverella albertana						5	18	16
Ephoron album						5	2	3
Trichoptera								
Cheumatopsyche	2		7	3	7	24	11	27
Hydropsyche			1			8	4	7
Agraylea								1
Hydroptila			1				1	1
Brachycentrus					4		1	1
Diptera								
Tipulidae					1			
Simuliidae			5	1	6		1	1
Chironomidae	41	238	118	2	2	8	10	3
Pupae (all families)	1	13	10	1	1	3		
Number of Samples	2	1	3	2	3	2	3	2

samples were collected in an area of steep gradient and rubble substrate at the upper end of Lodore Canyon (49.6 MBD). The fauna in these collections (Appendix D) was similar in kind and numbers to that found at Echo Park indicating that the differences previously observed between the faunas at Carr Ranch and Echo Park were most likely due to differences in gradient and substrate type rather than to effects of the dam on water quality or to the 1962 rotenone treatment.

Population densities of invertebrates in samples taken near Split Mountain campground (90.0 MBD) were very similar to those observed at Island Park 12 miles upstream (Appendix E).

Invertebrate densities were very low (10 to 80 organisms per square foot) in samples taken near Ouray (166.0 MBD). Low gradient and shifting substrate probably account for the low numbers found at this lowermost station (Appendix F).

SPECIES COMPOSITION OF BENTHIC INVERTEBRATES BEFORE AND AFTER CONSTRUCTION OF FLAMING GORGE DAM

Data on invertebrate fauna of the study area prior to September, 1962, were taken from Dibble ed. (1960), Bosley (1960), Woodbury et al. (1963), and Binns (1965) and include only those forms collected from the Green River proper. All records from tributaries, ponds, seeps, and cutoff channels along the Green River were deleted from the list of invertebrates present prior to September, 1962. In the few cases where the literature did not clearly state whether collections were actually from the Green River, the species in question were included in the listing. Data on fauna found after September, 1962 were derived from the present study and Binns (1965), who studied the Green River above Flaming Gorge Dam.

Nine invertebrate forms reported from the area prior to September, 1962 were not collected during the present study nor by Binns (1965; Table 18). Three were mayflies (*Pentagenia*, *Pseudiron*, and *Genus et species novum*) which were apparently very rare before impoundment (Edmunds, In Dibble ed;, 1960). A fourth mayfly, *Baetis insignificans*, may have been included in the eleven unidentified forms of *Baetis* collected during the present study. *Claassenia*, a stonefly, was formerly common but was not taken in 1963-65. *Perlesta*, also a stonefly, was represented by a single specimen in the collections reported on in Dibble ed. (1960). Apparently it too was rare prior to impoundment. No damselflies of the genus *Argia* were collected during the present

Table 18. Aquatic invertebrates reported from the Green River above Ouray, Utah before and after September, 1962.

Item	Reported before Sept. 1962	Found above Flaming Gorge Dam after Sept. 1962	Found below Flaming Gorge Dam after Sept. 1962	Old groups not found by Sept. 1965	New groups not reported before Sept. 1962
Nematoda	X	X	X		
Oligochaeta	X	X	X		
Hirudinea	X	X	X		
Amphipoda					
Hyalella			X		X
Gammarus	X	X			
Hydracarina	X	X	X		
Plecoptera					
Isoperla	X		X		
Isogenus	X		X		
Arcynopteryx			X		X
Acroneuria	X		X		
Claassenia	X			X	
Perlesta	X			X	
Pteronarcidae	X	X			
Nemouridae	X	X			
Ephemeroptera					
Genus et species novum	X			X	
Isonychia	X	X			
Lachlania powelli	X		X		
Heptagenia elegantula	X	X	X		
Heptagenia sp. II	X		X		
Rhithrogena undulata	X	X	X		
Epeorus albertae	X		X		
Pseudiron sp.	X			X	
Ametropus albrighti	X		X		
Callibaetis sp.	X		X		
Baetis insignificans	X			X	

Table 18 (Continued). Aquatic invertebrates reported from the Green River above Ouray, Utah before and after September, 1962.

Item	Reported before Sept. 1962	Found above Flaming Gorge Dam after Sept. 1962	Found below Flaming Gorge Dam after Sept. 1962	Old groups not found by Sept. 1965	New groups not reported before Sept. 1962
Baetis sp. I	X	X	X		
Baetis sp. II			X		X
Baetis sp. III			X		X
Baetis sp. IV			X		X
Baetis sp. V			X		X
Baetis sp. VI			X		X
Baetis sp. VII	X		X		
Baetis sp. VIII			X		X
Baetis sp. IX			X		X
Baetis sp. XI			X		X
Baetis sp. XII			X		X
Baetis sp. XIV			X		X
Brachycercus sp.	X	X	X		
Tricorythodes minutus	X	X	X		
Tricorythodes sp.	X		X		
Ephemerella inermis	X	X	X		
Leptophlebia gravastella	X	X			
Paraleptophlebia pallipes		X	X		X
Choroterpes albiannulata	X	X	X		
Traverella albertana	X	X	X		
Ephemera sp.	X	X			
Hexagenia limbata	X		X		
Ephoron album	X	X	X		
Pentagenia	X			X	
Canis	X	X			
Iron	X	X			
Siphlonurus	X	X			
Odonata					

Table 18 (Continued). Aquatic invertebrates reported from the Green River above Ouray, Utah before and after September, 1962.

Item	Reported before Sept. 1962	Found above Flaming Gorge Dam after Sept. 1962	Found below Flaming Gorge Dam after Sept. 1962	Old groups not found by Sept. 1965	New groups not reported before Sept. 1962
Gomphus	X		X		
Ophiogomphus	X		X		
Argia	X			X	
Hemiptera					
Gerridae	X		X		
Notonectidae	X		X		
Naucoridae					
Ambrysus			X		X
Corixidae	X	X	X		
Megaloptera					
Corydalus	X		X		
Sialidae		X			X
Trichoptera					
Cheumatopsyche	X		X		
Hydropsyche	X	X	X		
Agraylea			X		X
Hydroptila	X		X		
Leptocerus	X		X		
Leptocella	X	X	X		
Brachycentrus	X	X	X		
Lepidoptera					
Pyralididae	X	X			
Coleoptera					
Haliplidae	X	X	X		
Dytiscidae	X	X	X		
Gyrinidae	X			X	
Hydrophilidae	X	X			
Hydraenidae	X	X			

Table 18 (Continued). Aquatic invertebrates reported from the Green River above Ouray, Utah before and after September, 1962.

Item	Reported before Sept. 1962	Found above Flaming Gorge Dam after Sept. 1962	Found below Flaming Gorge Dam after Sept. 1962	Old groups not found by Sept. 1965	New groups not reported before Sept. 1962
Dryopidae	X	X	X		
Elmidae	X	X	X		
Chrysomelidae	X	X	X		
Curculionidae	X	X			
Heteroceridae	X	X			
Histeridae	X	X			
Helodidae	X			X	
Diptera					
Blepharoceridae			X		X
Tipulidae	X	X	X		
Psychodidae	X	X			
Culicidae	X	X	X		
Simuliidae	X	X	X		
Chironomidae	X	X	X		
Ceratopogonidae	X	X	X		
Stratiomyiidae			X		X
Tabanidae	X		X		
Rhagionidae	X	X	X		
Anthomyiidae			X		X
Empididae	X	X			
Gastropoda					
Physidae	X	X	X		
Lymnaeidae	X	X			
Pelecypoda			X		X

study, but their absence could be explained by the lack of intensive collecting in backwaters and side pools. Most of the collecting in this study was done in moving water. Adult damselflies were frequently observed and collected at all stations. Beetles of the family Helodidae were represented by one specimen in the collection of Bosley (1960) on the upper Green River. This family has not been reported below Flaming Gorge Dam. Beetles of the family Gyrinidae were often observed in the river but were not collected with the devices used in this study.

Ten groups not previously reported were collected during the present study, exclusive of 11 Baetis species. Of the ten new forms, Hyalella, Arcynopteryx and Paraleptophlebia pallipes probably represent forms which existed in cool mountain tributaries and found suitable living conditions in the Green River after the dam was closed. The remaining seven forms are not uncommon in the western fauna and their discovery may reflect a paucity of previous collecting effort rather than recent invasion. Of the 11 different types of Baetis nymphs collected little can be said. Baetis sp. V is probably an invader from cool tributaries. Perhaps the same is true for some of the other Baetis collected. Edmunds (In Dibble ed., 1960) reported five types of Baetis from the area, of which four were identifiable to species. One of these (Baetis sp. VII), a form with flattened, shovel-like claws, was frequently found during the present study. It is possible that the four remaining forms mentioned by Edmunds were also among the 11 forms of Baetis collected during the present study.

The fauna of the Yampa River was very similar in composition to the fauna of the Green River at Island Park (Appendix G). Fauna of the smaller tributaries was quite different in composition from the fauna of the Green River with the exceptions of Baetis sp. I, Chironomidae, and Simuliidae which were common to most tributaries and the Green River (Appendix G).

DRIFT RATES OF BENTHIC INVERTEBRATES

The downstream drifting of stream invertebrates is a normal continuous process. Dendy, (1944), Berner (1951), and Muller (1954) were the earliest workers to report on the enormous numbers of organisms in relation to the standing crop which may drift past a given point per unit time on a stream. Muller also postulated the "colonization cycle" for aquatic invertebrates having adult forms capable of flight. His hypothesis was that depletion of upstream areas by drift removal is offset by upstream migration of flying adults prior to egg laying. Roos (1957) presented some rather sketchy data substantiating upstream migration of adults in several orders of aquatic insects.

A quantitative study of drift fauna was included in this study because of its importance as a means of dispersal throughout the study area. Drift samples also contributed information on the species composition of upstream areas.

Invertebrate drift has been divided into three classes (Waters, 1965):

a. "Constant drift" - due to normal accidental dislodgement.

b. "Behavioral drift" - due to an active response on the part of the organism.

c. "Catastrophic drift" - due to floods and other severe conditions.

Drift Sampling

Drift samples were collected on an exploratory basis at several stations in 1964. Cursory examination of the results indicated wide differences in drift rates within and among stations. A regular schedule for drift sampling was maintained in 1965 at Little Hole, Carr Ranch, Echo Park, and Island Park. From May 16 to September 20 each station was visited for 3 days on a continuous rotation. Every fourth day was set aside for travel between stations and replenishing supplies.

The drift net was staked down with its rim resting on the substrate in water 14-26" deep. A 6-inch-diameter flow meter with attached counter was installed in the mouth of the drift net and used in 1965. Most sets were for 5 minutes and the mean number of revolutions recorded for this time period was 353 (range: 28 to 1074).

In 1965 all drift-net catches were converted to a "standard sample" which was the number of organisms which would have been taken with a flowmeter reading of 300 revolutions in 5 minutes. The formula was:

$$\text{No. of organisms at 300 revolutions} = \frac{300 \text{ X No. of organisms in the sample}}{\text{No. of revolutions recorded for the sample}}$$

The above conversion assumes that a linear relationship exists between number of meter revolutions and current velocity. The actual relationship was slightly curvilinear and the above formula embodies a slight error (4% or less). Average velocity of water through the 11-1/2-inch diameter drift net was estimated (from a calibration curve) to be .75 ft./sec. at 300 revolutions in 5 minutes. The volume of water filtered for the "standard sample", therefore, was 162.2 cubic feet.

Drift samples from 1964 were preserved in 10% formalin and organisms were later separated from debris by flotation in a sugar solution (specific gravity 1.200). All drift samples taken in 1965 were sorted in the field while organisms were alive. Samples were emptied into a white-enameled pan and organisms were removed with a forceps or pipette. A 6-volt, 3-milliampere, electric-shocking device similar to that described by Bayless (1961) was employed to induce movement of the invertebrates to aid in sorting them. Organisms recovered with the shocker were preserved in 10% formalin and transported to the laboratory for identification.

Observations on water levels, adult insect emergences, weather conditions, unusual occurrences, etc. were recorded in diary form throughout the study.

Little Hole

Thirteen forms of aquatic invertebrates were taken in drift nets at Little Hole. The drift fauna was composed primarily of the same four groups predominant in the bottom samples: Baetis sp. I, Chironomidae, Simuliidae, and Oligochaeta. Other aquatics were rarely caught in the drift nets.

Numbers of drifting Chironomidae larvae collected during a 24-hour series (eight 5-minute catches 3 hours apart) were relatively constant in the summer of 1965 (24 to 250 organisms). Numbers of Oligochaeta, Baetis sp. I, and Simuliidae fluctuated from 22 to 133, 4 to 6224, and 1 to 478, respectively, during the same period (Table 19).

The highest drift rates of Baetis sp. I nymphs occurred in early August, shortly after the summer brood had hatched and nymphal popu-

Table 19. Drift rates of aquatic invertebrates, Little Hole, Green River, 1965 -- expressed as total numbers taken in a diurnal series consisting of eight 5-minute samples beginning at 0600, 0900, 1200, 1500, 1800, 2100, 2400, and 0300 hours.

Date	Oligochaeta	*Baetis* sp. I	Chironomidae	Diptera (Pupae)	Simuliidae	Others
6-11	27	33	133	22	2	3
6-14	69	25	250	22	1	0
7-08	350	72	185	17	48	0
7-10[a]	193	268	147	16	135	0
8-05	62	1626	248	90	213	2
8-07	75	6224	89	12	415	1
8-25	9	3194	194	24	478	1
8-27[a]	9	1204	119	16	222	2
9-17[a]	6	9	81	37	31	1
9-19	0	4	24	24	13	0

[a] 0300 sample missing from data.

ulations were highest. The highest drift rates of Simuliidae larvae occurred in late August.

Carr Ranch

Twenty-five groups of aquatic invertebrates were collected in drift nets at Carr Ranch. The most abundant drift forms were Baetis sp. I (54 to 1650 per 24-hour series), Simuliidae (0 to 243 per 24-hour series), and Baetis sp. IV (0 to 67 per 24-hour series) (Table 20).

Baetis sp. I catches were highest in late August. Catches of Simuliidae larvae were highest in late July, 1965. Baetis sp. IV nymphs first appeared in the catch in late July and declined in numbers throughout the rest of the season.

Echo Park

Twenty-nine groups of aquatic invertebrates were taken in drift nets at Echo Park. Drift rates for all groups were lower here than at the two upper stations (Table 21). Drift catches of Baetis sp. I were highest in late May, 1965, (563 per 24-hour series) and declined steadily throughout the season to a low of 1 per 24-hour series in September. Numbers of oligochaetes caught in the 24-hour series were 0 to 12; of Chironomidae, 0 to 20; and of Simuliidae, 1 to 51 (Table 21).

Island Park

Forty groups of aquatic invertebrates were captured in drift nets at Island Park. Drift-net catches of Oligochaeta, Baetis sp. I, Chironomidae, and Simuliidae during the 24-hour series varied from 0 to 4, 2 to 57, 0 to 4, and 0 to 10, respectively (Table 22).

Table 20. Drift rates of aquatic invertebrates, Carr Ranch, Green River, 1965 -- expressed as total numbers taken in a diurnal series consisting of eight 5-minute samples beginning at 0600, 0900, 1200, 1500, 1800, 2100, 2400, and 0300 hours.

Date	Oligochaeta	*Baetis* sp. I	*Baetis* sp. IV	*Baetis* sp. V	Chironomidae	Simuliidae	Diptera Pupae	Others
6-05	5	436	0	0	21	3	4	0
6-08	16	668	0	0	50	0	13	5
7-03	10	160	1	0	9	42	1	2
7-05	12	120	1	2	11	46	1	1
7-31	37	1260	67	10	54	243	42	28
8-02	5	908	63	6	52	156	7	25
8-21	38	1650	38	15	63	82	11	13
8-23	26	1630	21	4	33	47	7	6
9-05	6	311	37	49	37	78	4	6
9-07	8	54	8	16	8	65	4	5

Table 21. Drift rates of aquatic invertebrates, Echo Park, Green River, 1965 -- expressed as total numbers taken in a diurnal series consisting of eight 5-minute samples beginning at 0600, 0900, 1200, 1500, 1800, 2100, 2400, and 0300 hours.

Date	Oligochaeta	Hydracarina	*Baetis* sp. I	Chironomidae	Simuliidae	Diptera Pupae	*Cheumatopsyche* and *Hydropsyche*	Others
5-29	0	4	593	3	9	1	0	19
6-27	12	8	73	20	51	5	1	18
7-20	0	3	27	1	11	2	5	9
8-15	0	1	7	0	1	0	3	6
9-11	0	1	1	0	1	2	1	1

Table 22. Drift rates of aquatic invertebrates, Island Park, Green River, 1965 -- expressed as total numbers taken in a diurnal series consisting of eight 5-minute samples beginning at 0600, 0900, 1200, 1500, 1800, 2100, 2400, and 0300 hours.

Date	Baetis sp. I	Traverella albertana	Ephemerella inermis	Cheumatopsyche and Hydropsyche	Chironomidae	Simuliidae	Diptera Pupae	Others
5-23	30	0	17	4	4	8	3	13
5-25	19	0	12	2	1	4	0	9
6-18	9	0	8	2	3	5	2	14
6-21	10	0	3	5	1	10	2	23
7-14	57	7	0	10	0	4	1	66
7-16	29	7	0	14	1	7	0	30
8-10	14	35	0	11	0	3	0	15
8-12	13	22	0	9	0	4	0	28
8-31	2	6	0	10	0	0	0	7
9-02	4	2	0	12	2	0	0	11

Web-spinning Trichoptera larvae of the genera <u>Hydropsyche</u> and <u>Cheumatopsyche</u> were slightly more common in the drift here (2-14 per 24-hour series) than at Echo Park (0-5 per 24-hour series).

<u>Traverella</u> <u>albertana</u> and <u>Ephemerella</u> <u>inermis</u> nymphs were taken in drift nets for relatively short periods immediately after hatching and then disappeared from the river following annual emergences in early and late summer respectively. The "other" category contains more organisms at this station (21.6 per 24-hour series) than at Little Hole, Carr Ranch, or Echo Park (1.0, 9.1, and 10.6 per 24-hour series respectively) reflecting the increased number of invertebrate forms present at this station.

FACTORS RELATED TO CHANGES IN DRIFT RATES

"Catastrophic" and "constant" drift are results of the environment acting directly, and to some extent irresistibly, on individual organisms. "Behavioral" drift, however, seems to be the result of an active response on the part of the organism in which it releases its hold on the bottom and either swims or allows itself to be carried downstream by the current. Crowding of individuals (production per unit area in excess of carrying capacity) seems to be a primary requisite for behavioral drifting (Waters, 1961, 1962b, 1964). Secondarily, behavioral drift for most groups is not initiated until light intensity falls below a threshold. Constant and catastrophic drifting may, therefore, occur at any time of day, whereas behavioral drifting normally takes place only after sunset. Effects of flooding, population density, and time of day on drift rates of stream invertebrates have been reported by Muller (1954), Tanaka (1960), and Waters (1961).

Multiple regression analysis was used in this study to determine the unique contribution of eight environmental factors to drift rates of Baetis sp. I nymphs and Simuliidae larvae.

The eight independent variables were:

X_1 = water temperature

X_2 = dissolved oxygen

X_3 = turbidity

X_4 = water depth

X_5 = illumination

X_6 = date

X_7 = density of all other organisms upstream

X_8 = water level fluctuations

The dependent variables were:

Y_1 = $\log_{10}$ no. Baetis sp. I nymphs + 1 in the standardized drift sample

Y_2 = $\log_{10}$ no. Simuliidae larvae + 1 in the standardized drift sample

Numbers of Baetis sp. I and Simuliidae in the standardized drift sample were converted to logarithms to meet the assumption of linearity for regression analysis. In addition, simple correlation coefficients between all pairs of X and Y variables were calculated to help define interactions. Data from Little Hole and Carr Ranch were analyzed separately, but data from Echo and Island Parks were combined for analysis because numbers were low and drift catches were relatively similar at these two stations.

All analyses were carried out on the IBM 1620 Computer of the Department of Applied Statistics and Computer Science, Utah State University. The R^2 multiple correlation values obtained indicated that 76%, 81%, and 32% of the variability observed in the drift rates of Baetis sp. I nymphs was accounted for by the eight ecological factors at Little Hole, Carr Ranch, and Echo Park-Island Park, respectively (Tables 23, 25, and 27). R^2 values obtained for Simuliidae larvae were .72, .65, and .13 at the three stations, respectively (Tables 24, 26, and 28).

Table 23. Abbreviated regression analysis of factors affecting drift rates of Baetis sp. 1 nymphs, Little Hole, Green River, 1965.

Source	Degrees freedom	Mean square	Coefficient	Standard coefficient
Total	76	4.27	-5.722	
Illumination	1	31.44*	.274	.435
Density	1	49.42*	.002	.569
Temperature	1	18.89*	.190	.439
Turbidity	1	1.65	.027	.079
Water Level	1	0.01	-.003	-.003
Date	1	13.54*	-.116	-.280
Dissolved Oxygen	1	2.65	-.027	-.161
Depth	1	1.23	.050	.083
Model	8	30.68		
Error	68	1.16		

R^2 = .76

* Significant at the .05 level.

Table 24. Abbreviated regression analysis of factors affecting drift rates of Simuliidae larvae, Little Hole, Green River, 1965.

Source	Degrees freedom	Mean square	Coefficient	Standard coefficient
Total	76	2.28		
Illumination	1	4.49*	.104	.225
Density	1	10.24*	.001	.306
Temperature	1	33.11*	.224	.708
Turbidity	1	.06	-.005	-.021
Water Level	1	.18	-.023	-.035
Date	1	1.42	-.037	-.124
Dissolved Oxygen	1	5.26*	-.037	-.303
Depth	1	.39	-.028	-.063
Model	8	15.67		
Error	68	.71		

R^2 = .72

* Significant at the .05 level.

Table 25. Abbreviated regression analysis of factors affecting drift rates of Baetis sp. I nymphs, Carr Ranch, Green River, 1965.

Source	Degrees freedom	Mean square	Coefficient	Standard coefficient
Total	77	4.22	5.855	
Illumination	1	137.02*	.503	.796
Density	1	10.87*	-.008	-.369
Temperature	1	8.01*	-.088	-.228
Turbidity	1	7.80*	.003	.182
Water Level	1	.50	-.065	-.044
Date	1	3.40	.092	.212
Dissolved Oxygen	1	.11	-.012	-.029
Depth	1	.93	-.059	-.068
Model	8	32.77		
Error	69	.90		

$R^2 = .81$

* Significant at the .05 level.

Table 26. Abbreviated regression analysis of factors affecting drift rates of Simuliidae larvae, Carr Ranch, Green River, 1965.

Source	Degrees freedom	Mean square	Coefficient	Standard coefficient
Total	77	1.45	1.367	
Illumination	1	2.78*	.072	.193
Density	1	10.36*	-.007	-.606
Temperature	1	2.91*	-.053	-.235
Turbidity	1	.44	.001	.074
Water Level	1	2.25*	.138	.158
Date	1	25.78*	.249	.978
Dissolved Oxygen	1	2.75*	-.058	-.247
Depth	1	.01	.003	.005
Model	8	9.12		
Error	69	.56		

$R^2 = .65$

* Significant at the .05 level.

Table 27. Abbreviated regression analysis of factors affecting drift rates of Baetis sp. I nymphs, Island Park and Echo Park, Green River, 1965.

Source	Degrees freedom	Mean square	Coefficient	Standard coefficient
Total	157	1.08	7.778	
Illumination	1	.06	-.007	-.020
Density	1	1.36	-.004	-.103
Temperature	1	.14	-.009	-.059
Turbidity	1	.75	.001	.075
Water Level	1	.01	.011	.009
Date	1	25.45*	-.130	-.651
Dissolved Oxygen	1	.14	-.009	-.059
Depth	1	5.95*	-.084	-.279
Model	8	6.86		
Error	149	.77		

R^2 = .32

* Significant at the .05 level.

Table 28. Abbreviated regression analysis of factors affecting drift rates of Simuliidae Larvae, Island Park and Echo Park, Green River, 1965.

Source	Degrees freedom	Mean square	Coefficient	Standard coefficient
Total	157	.34	.519	
Illumination	1	1.15	-.029	-.159
Density	1	.29	.002	.083
Temperature	1	.01	.001	.007
Turbidity	1	.39	.001	.097
Water Level	1	.14	.037	.053
Date	1	2.58*	-.041	-.366
Dissolved Oxygen	1	.13	.010	.098
Depth	1	.15	-.013	-.079
Model	8	.89		
Error	149	.31		

R^2 = .13

* Significant at the .05 level.

Illumination

Diurnal periodicity of drifting Baetis nymphs has been reported by Tanaka (1960), Waters (1962a), and Muller (1963). In the present study, numbers of drifting Baetis sp. I nymphs increased dramatically after sunset at Little Hole and Carr Ranch. Post-sunset increases were less frequently observed at Echo and Island Parks apparently because the density of nymphs was seldom high enough to initiate behavioral drifting. Diurnal periodicity of drifting was also observed in Chironomidae larvae, Simuliidae larvae, Trichoptera larvae of the family Hydropsychidae, and many of the mayflies, especially Traverella albertana, Heptagenia elegantula, Baetis sp. IV, and Baetis sp. V.

A subjective classification of illumination levels from bright sunlight to moonless nights was used to estimate the amount of incident light (Table 29). In the multiple regression analysis illumination was one of the most important individual contributors to variation in numbers of drifting Baetis sp. I nymphs at Little Hole and the most important contributor at Carr Ranch (Tables 23 and 25). Illumination accounted for a significant (.05 level) amount of variability in drift rates of Simuliidae larvae at Little Hole and Carr Ranch. Again, Simuliidae densities at Echo Park and Island Park probably never reached the level necessary to induce behavioral drifting in 1965. Illumination correlated significantly (.05 level) with dissolved oxygen at both Little Hole and Carr Ranch (r = .62 and .38 respectively; Tables 30 and 31), and with water temperature and flow at Little Hole (r = .25 and .23 respectively). These interactions may have masked

Table 29. Classification system used to describe illumination.

Class	Description
1	Bright sunlight, cloudless day.
2.	Light overcast or partly cloudy day.
3.	Heavy overcast day.
4	Dusk or dawn.
5	Night, full moon.
6	Night, 1/2 - full moon.
7	Night, less than 1/2 moon.
8	Night, no moon.

Table 30. Correlation matrix of environmental factors and drift rates of Baetis sp. I and Simuliidae, Little Hole, Green River, 1965 (N=77).

	Illumination	Density	Temperature	Turbidity	Water Level	Date	Dissolved Oxygen	Depth	Baetis Drift	Simuliidae Drift
Illumination	1.00									
Density	.07	1.00								
Temperature	-.25**	.64**	1.00							
Turbidity	-.13	-.16	-.22*	1.00						
Water Level	-.10	.01	-.10	-.13	1.00					
Date	.05	.31**	.30**	-.27*	-.10	1.00				
Dissolved Oxygen	-.63**	.05	.48**	-.10	-.09	-.25*	1.00			
Depth	-.45**	-.44**	-.45**	.34**	-.15	-.50**	-.08	1.00		
Baetis Drift	.37**	.68**	.48**	-.06	.07	.03	-.12	-.13	1.00	
Simuliidae Drift	.20	.64**	.66**	-.23*	.01	.30**	-.06	-.39**		1.00

* Significant at the .05 level.
** Significant at the .01 level.

Table 31. Correlation matrix of environmental factors and drift rates of Baetis sp. I and Simuliidae, Carr Ranch, Green River, 1965 (N=78).

	Illumination	Density	Temperature	Turbidity	Water Level	Date	Dissolved Oxygen	Depth	Baetis Drift	Simuliidae Drift
Illumination	1.00									
Density	-.00	1.00								
Temperature	-.08	-.08	1.00							
Turbidity	.09	.46**	-.08	1.00						
Water Level	-.04	-.19	.22	-.03	1.00					
Date	.01	.70**	.38**	.30*	-.02	1.00				
Dissolved Oxygen	-.38**	.21	-.51**	-.06	-.02	-.19	1.00			
Depth	-.14	-.09	-.26*	.02	-.33**	-.37**	.01	1.00		
Baetis Drift	.86**	-.11	-.17	.17	-.04	-.04	-.34**	-.15	1.00	
Simuliidae Drift	.32**	.04	.33**	.13	.19	.53**	.53**	.33**		1.00

* Significant at the .05 level.

** Significant at the .01 level.

some of the effect of illumination in the regression analyses.

Bottom Fauna Density

Bottom fauna densities were expressed as the sum of the products of the number of organisms per square foot of area for each type of substrate and the estimated percentage of the substrate present immediately above the drift sampling station. Density of all organisms therefore, was estimated in terms of an "average" square foot of substrate. Numbers of *Baetis* sp. I and Simuliidae were subtracted from the calculated densities used in the analysis of drift rates of these two organisms respectively to avoid autocorrelation in the determination of interspecific effects. Oligochaetes were not included in this analsis because: 1) counts made by the flotation method were inaccurate and 2) it did not seem likely burrowing oligochaetes would compete for space with either *Baetis* sp. I or Simuliidae larvae.

Interspecific effects

Both *Baetis* sp. I and Simuliidae drift rates were correlated positively with bottom fauna densities at Little Hole (r = .68 and .65 respectively, Table 30). Bottom fauna density upstream accounted for a significant amount of the variability observed in the regression analyses as well (Tables 23 and 24).

Bottom fauna densities at Carr Ranch, however, showed non-significant correlations with drift rates of both *Baetis* sp. I and Simuliidae but the mean squares were significant and the partial regression coefficients were negative. Perhaps the density of the bottom fauna at Carr Ranch was heavily influenced by late season increases in numbers of Baetis sp. IV nymphs and Chironomidae larvae, both of which are adapted for life on silt substrates, whereas Baetis sp. I nymphs and Simuliidae larvae require rubble or debris for support. Therefore, while the bottom fauna density fluctuated widely at Carr Ranch the fluctuation occurred on areas not heavily populated by Baetis sp. I and Simuliidae and had little effect on the drift rates of these two forms.

Intraspecific effects

A high positive correlation was found between 24-hour series drift catches of both Baetis sp. I and Simuliidae and their respective population densities at Little Hole (r = .82 and .98; Figures 4 and 5). Drift rates of Baetis sp. I and Simuliidae were correlated positively with their respective densities upstream at Carr Ranch (r = .40 and .73), but drift rates were much higher relative to the standing crop than at Little Hole (Figures 6 and 7).

Temperature

Temperature was the most important factor in explaining variability in drift rates of Simuliidae, and the second most important factor in explaining variability in drift rates of Baetis sp. I at Little Hole (Tables 23 and 24). At Carr Ranch temperature again provided significant b values but the signs were negative.

Temperature was correlated significantly with dissolved oxygen and date at Little Hole, Carr Ranch, and Echo Park-Island Park and with depth and bottom fauna density at Little Hole (Tables 30, 31, and 32).

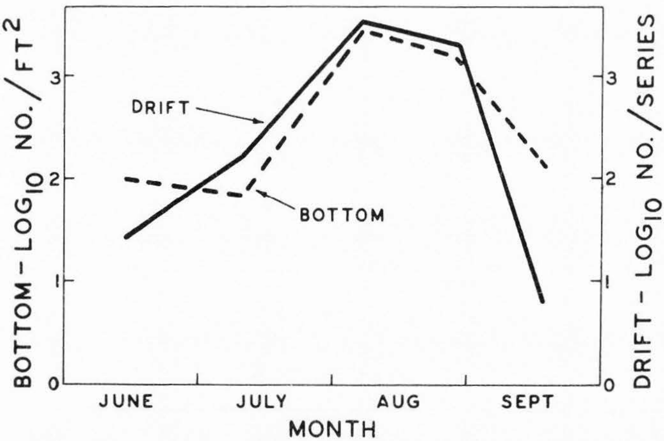

Figure 4. Density of Baetis sp. I nymphs on the bottom and in drift, Little Hole, Green River, 1965.

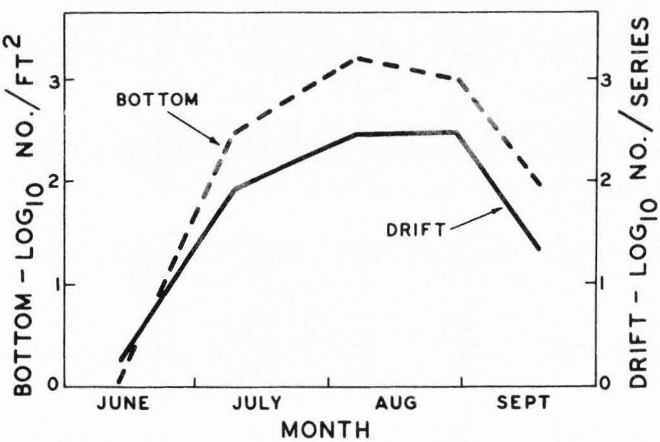

Figure 5. Density of Simuliidae larvae on the bottom and in drift, Little Hole, Green River, 1965.

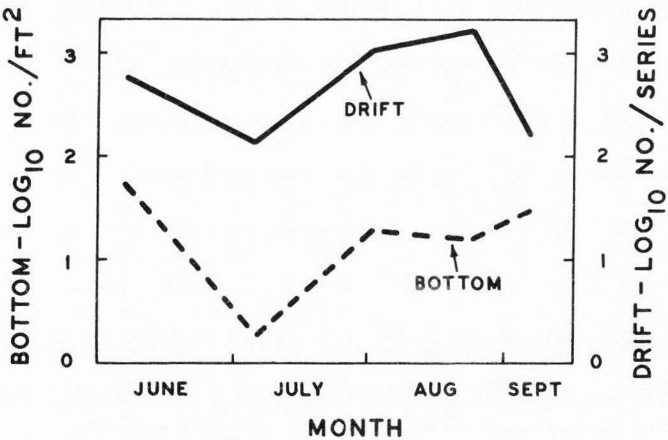

Figure 6. Density of <u>Baetis</u> sp. I nymphs on the bottom and in drift, Carr Ranch, Green River, 1965.

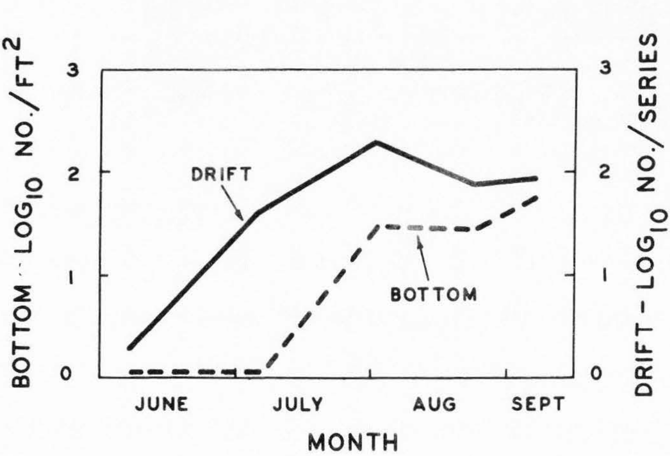

Figure 7. Density of Simuliidae larvae on the bottom and in drift, Carr Ranch, Green River, 1965.

Table 32. Correlation matrix of environmental factors and drift rates of Baetis sp. I and Simuliidae, Echo Park-Island Park, Green River, 1965 (N=158).

	Illumination	Density	Temperature	Turbidity	Water Level	Date	Dissolved Oxygen	Depth	Baetis Drift	Simuliidae Drift
Illumination	1.00									
Density	-.01	1.00								
Temperature	-.07	.31**	1.00							
Turbidity	.18*	.10	.07	1.00						
Water Level	.09	.16*	.21**	.02	1.00					
Date	-.06	.32**	.56**	-.08	.10	1.00				
Dissolved Oxygen	-.15	-.33**	-.78**	-.32**	-.18*	-.31**	1.00			
Depth	-.07	-.08	-.47**	-.08	-.07	-.69**	.35**	1.00		
Baetis Drift	.08	-.26**	-.23**	.17*	-.05	-.49**	.04	.16*	1.00	
Simuliidae Drift	-.12	-.02	-.20*	.09	.00	-.30**	.13	.20*		1.00

* Significant at the .05 level.

** Significant at the .01 level.

Turbidity

Turbidity was a significant contributor to variability in the multiple regression analysis only at Carr Ranch for Baetis sp. I. Under certain conditions, however, turbidity did affect drift rates. Early in the afternoon of September 5, 1965, local thundershowers caused a sudden increase in turbidity which was accompanied by a rise in drift rates of Baetis sp. I nymphs (Figure 8). This rise in drift rate continued after sunset. Two days later, turbidity was low during the daylight hours and Baetis drift followed the normal pattern of increased drift rate beginning shortly after sunset. On another occasion a short surge of turbid water came down the Yampa River (August 17, 1965) and initiated drifting of Traverella albertana nymphs in the late afternoon before sunset. Drift rate on this occasion continued to be high at 2100 hours even though turbidity had decreased. On June 27, 1965, turbidity increased at Echo Park but no increase in drift rate of Baetis sp. I nymphs was observed. Nymphal densities upstream were probably too low to induce behavioral drifting on this occasion since no post-sunset increase was observed either.

Water Level Fluctuations

Observations were made on permanent staff gages at half-hour intervals during all diurnal drift series. The difference between maximum and minimum readings in the 3 hours prior to sampling time was coded in 1/3-foot intervals and used as a measure of water level fluctuation for the regression analyses.

Changes in water level accounted for none of the variation observed in drift rates of Baetis sp. I and Simuliidae (all b values were non-

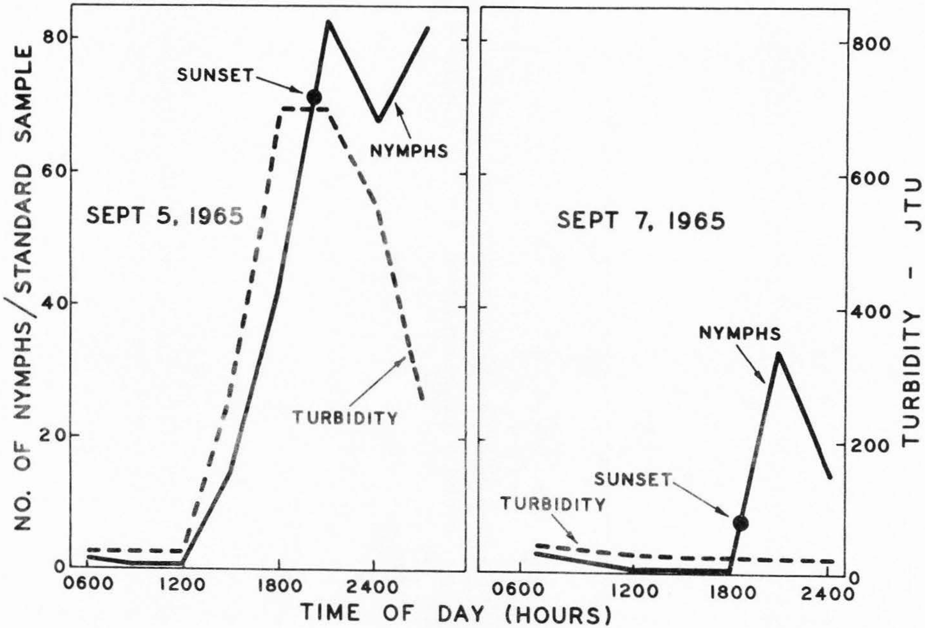

Figure 8. Turbidity and drift rates of <u>Baetis</u> sp. I nymphs, Carr Ranch, Green River, September 5 and 7, 1965.

significant). The failure to find statistical significance, however, may have been due to the choice of a short 3-hour period to record water level changes whereas changes over a longer time span may have been more important. Sudden fluctuations in water level did appear to influence drift rates, but the effect may have been more dependent upon timing in relation to hours before darkness rather than the magnitude of water level change.

In one instance, flow was drastically reduced at Island Park (September 7, 1964) by hydrological studies being conducted upstream at Little Hole. An estimated 25% of the streambed which had been submerged for at least the previous 5 months was exposed beginning on the morning of September 7th. In the afternoon drift rates were not different from those observed earlier in the summer. After sunset, however, drift rates of mayflies, caddisflies, and stoneflies reached the highest levels recorded at this station (Figure 9). Drift rates of Chironomidae increased slightly after dark. The number of taxonomic groups drifting also increased above that previously observed. The sudden reduction in flow occurred just prior to the emergence of many species of mayflies in the river and at a time when invertebrate densities on the streambed were high. The high drift rates observed may have been due to increased behavioral-drift following a reduction in available living space. Water levels returned to normal on September 9th and drift rates of all aquatic organisms decreased sharply and exhibited no after-sunset increase, with the exception of Chironomidae larvae, which increased. The high drift rates of Chironomidae larvae

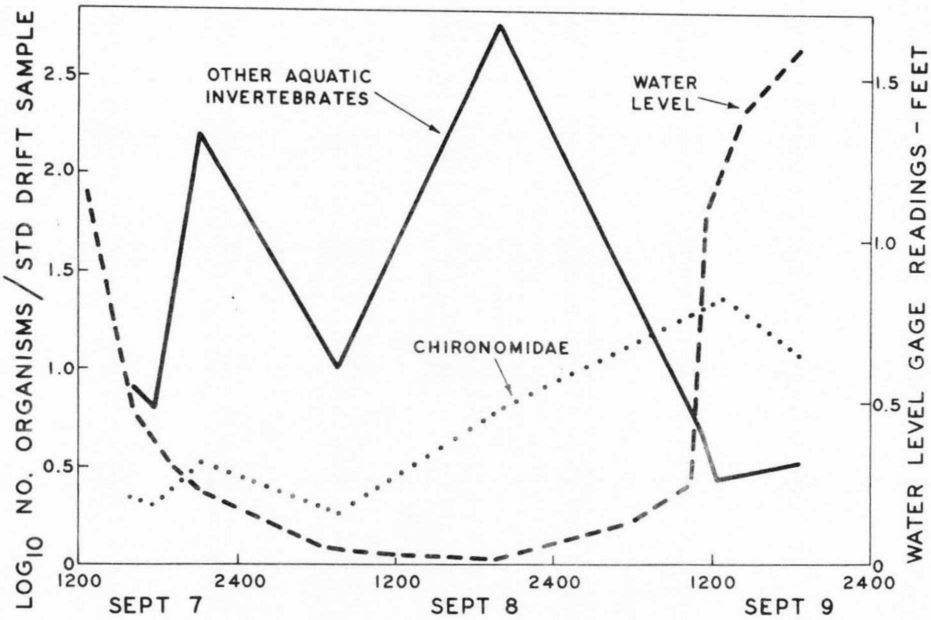

Figure 9. Drift rates of Chironomidae larvae and other aquatic invertebrates during a 1-1/2 ft. drop and rise in water level, Island Park, Green River, September 7-9, 1964.

accompanying the rise in water level may have resulted from erosion of larvae-containing silt deposits laid down shortly before by the receding water.

At Little Hole, Chironomidae larvae and Oligochaeta survived for at least 24 hours in damp Cladophora mats exposed during reductions in flow. On June 14, 1965, the water level dropped 1.02 feet at 0800 hours and remained low until 0620 hours on June 15, when it rose to its previous level. At 1100 hours (June 15th) two samples were taken with the Hess-Waters sampler, one in the previously-exposed zone and one in the permanently-wetted zone. Both samples were taken on rubble substrates where current speeds were comparable. Oligochaeta and Chironomidae densities were higher in the exposed area while the density of Baetis sp. I was lower (Table 33). Simuliidae larvae were absent following a recent emergence.

Table 33. Numbers of organisms in permanently-wetted and previously-exposed zones, Little Hole, June 15, 1965 -- expressed as number per square foot.

Item	Stream Zone	
	Permanently-Wetted	Previously-Exposed
Baetis sp. I	153	2
Oligochaeta	35	561
Chironomidae	273	542

Sudden increases in flow at Little Hole occasionally dislodged organisms forcibly and drift increased (catostrophic drift). Drift rates usually increased only for 1/2- to 1-hour after a rise, and increases were most pronounced for Chironomidae and Simuliidae (Figure 10). The substrate at Little Hole was very stable and sudden increases in water level of the magnitudes observed (0-2.5 feet/24 hours) probably

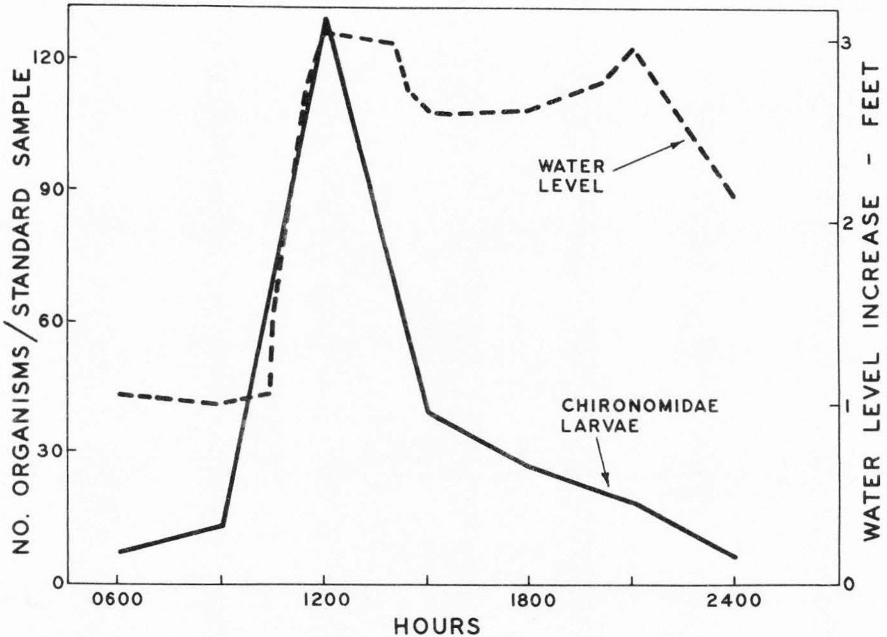

Figure 10. Increased drift rates of Chironomidae larvae following a sudden increase in flow, Little Hole, Green River, June 11, 1965.

had little effect on invertebrate populations.

Invertebrates were observed at the water's edge at all stations while water levels were fluctuating. Little or no crawling activity of benthic invertebrates occurred during increases in flow. As levels fell, mayfly nymphs moved toward deeper water usually by crawling, but occasionally by swimming. Chironomidae and Simuliidae larvae attempted to move toward deeper water as levels fell, usually by swimming. Few mayfly nymphs were stranded as levels receded but stranded Chironomidae and Simuliidae larvae (dead and alive) were commonly found under rocks and debris.

Date

Calendar date was expressed as day number (1-365) and accounted for more variability in drift rates of Simuliidae at Carr Ranch than any of the other seven factors tested (Table 26). Date also accounted for significant amounts of variability in drift rates of *Baetis* sp. I at Little Hole, and Echo Park-Island Park. Significance in these cases probably reflects seasonal changes in abundance of these organisms.

Dissolved Oxygen

Dissolved oxygen concentration accounted for significant amounts of variability in drift rates of Simuliidae larvae at Little Hole and Carr Ranch, but inversely (Table 24 and 26). Simuliidae larvae are known to require running waters of high oxygen concentrations and reduced oxygen levels may induce behavioral drift.

Depth

Waters (1965) reported that drifting organisms were nearly evenly distributed vertically in a small stream, but that *Baetis* nymphs showed a slight tendency to concentrate in the upper strata of water. Depth of water over the drift net ranged from 0 to 15 inches at all stations in the present study and was significant only in the combined analyses for *Baetis* sp. I at Echo and Island Parks (Table 27).

DISCUSSION

Discussion of population densities before and after September 1962 is somewhat speculative since no prior quantitative data are available. Numerical densities of invertebrates (and probably volumetric and gravimetric densities as well) during the present study were by far the highest at Little Hole on both rubble-debris and silt-sand substrates. Overall invertebrate densities were low at Carr Ranch. Invertebrate densities on silt-sand substrates, however, were higher at Carr Ranch than on silt-sand at Echo Park or Island Park. This may indicate that invertebrate densities at Carr Ranch were higher in 1964 and 1965 than in the pre-impoundment years. Invertebrate populations at Echo Park, Island Park, and Split Mountain were generally similar in numbers.

Observations made during a float trip through Desolation Canyon (approximately 230 miles below the dam) in October, 1965, indicated that invertebrate populations on rubble substrates in this region were similar to those observed at Island Park. If it is assumed that: 1) environments and invertebrate populations at Little Hole and Echo Park-Island Park were relatively similar before September, 1962, and that, 2) invertebrate populations have changed little at Echo Park-Island Park, then the observed numbers of macroinvertebrates at Little Hole indicate a substantial increase over pre-impoundment densities. Higher concentrations of dissolved solids in the water, reduced turbidity, increased algae growth, seasonally stable water flow, and stability of bottom materials may have been factors causing the population increase.

The bottom-fauna community at Little Hole was a very simple one in terms of number of forms present. It is, of course, difficult to say whether this was due to the fish eradication project or to construction of the dam. In light of the rather complete recovery of the bottom fauna (Binns, 1965) in the river above Flaming Gorge Reservoir, where the river environment has not been greatly altered, however, it seems likely that changes wrought on the river below by Flaming Gorge Dam account for the simplified invertebrate community existing between the dam and Allen Ranch (26.5 MBD). A comparison of pre- and post-impoundment data indicates that species composition of the invertebrate community of the Green River has not been noticably altered below Echo Park, and perhaps not below the mouth of Lodore Canyon.

Six of the nine forms previously reported from the Green River, but not found during the present study, were collected above the present site of Flaming Gorge Dam. Of the nine missing forms, it appears that *Perlesta*, *Genus et species novum*, *Pseudiron*, *Pentagenia* and Helodidae were all rather rare before September, 1962, since each of them was represented by fewer than five specimens in the published reports. Failure to find these forms below Flaming Gorge Dam certainly does not exclude their presence in the area during 1964-65, since the sampling effort expended during this study was so small in comparison to the size of the river. *Baetis insignificans*, as was explained before, was probably represented in the 11 unidentified species of *Baetis* collected during this study. The sampling techniques used in this study were such that both *Argia* and Gyrinidae were not collected, even though Gyrinidae adults were frequently seen on the river. Claassenia, a stonefly, was reported common in the study area prior to September, 1962. The collecting techniques used in this study should have taken nymphs of this genus at the reported levels of abundance. Apparently this genus has actually been reduced in numbers since impoundment.

The rather abrupt appearance of Trichoptera larvae of the family Hydropsychidae at Echo Park in 1965 (only one specimen was collected in 1964 at this station) considered with the fact that these larvae were common in both years at Island Park indicates that some species succession in the post-impoundment years may have occurred as far down as Echo Park. No such signs of succession were noticed at Island Park.

Total catches of invertebrates in 24-hour drift series declined steadily with increasing distance from the dam. If behavioral drift (which made up the bulk of the total drift) is related to production rate (as suggested by Muller, 1954; and Waters, 1961), production of invertebrates was highest at Little Hole and lowest at Island Park.

Although illumination and population density were the most important factors related to drift rate, temperature accounted for significant amounts of variability in the drift rates observed at Little Hole and Carr Ranch. The "b" values, however, were positive and negative, respectively, at these two stations. Muller (1966) presented data in which water temperature was correlated positively with drift rates of Baetis. It seems reasonable that invertebrate activity (and the chance of being swept away) would increase as temperature increased.

At Carr Ranch, drift catches were higher than might have been expected from an area supporting a relatively small bottom fauna population. Water released from the dam reached Carr Ranch only 12 hours later and drift organisms observed at Carr Ranch may well have originated in the Little Hole area where population densities were higher. If this were the case, it would also help explain why calendar date accounted for so much of the variability observed in drift rates of Simuliidae larvae at Carr Ranch. Simuliidae larvae were rarely found in the bottom samples at Carr Ranch but were abundant in drift-net catches. These larvae may have originated at Little Hole and drifted through the Carr Ranch area because of the lack of suitable attachment points. So, drift rates of Simuliidae at Carr Ranch would have been dependent on factors, such as population density, operating at Little Hole. Since calendar date and population density were highly correlated at Little Hole, perhaps the variability attributed to date at Carr Ranch should have been assigned to population density at Little Hole.

CONCLUSIONS

The macroinvertebrate fauna of the Green River between Flaming Gorge Dam and Ouray, Utah in 1963-1965 consisted of at least 69 different forms, including 28 species of mayflies, 4 genera of stoneflies, 7 genera of caddisflies, 10 families of Diptera, and 5 families of Coleoptera. Macroinvertebrate densities were highest at Little Hole (7.2 MBD) and lowest at Island Park (78.0 MBD). In general, the invertebrate community at Little Hole was a very simple one, comprised almost entirely of four groups of organisms (*Baetis* sp. I, Chironomidae, Simuliidae, and Oligochaeta). With increasing distance below the dam, density of bottom fauna on any given type of substrate decreased and the number of taxonomic groups increased.

Species composition of the fauna below Echo Park (64.4 MBD) did not differ significantly in 1964 and 1965 from that before impoundment. Species composition of the fauna between the dam and the mouth of Lodore Canyon (49.6 MBD), however, differed significantly in 1964 and 1965 from the composition reported prior to September of 1962. It is difficult to determine whether these changes were effected by the rotenone treatment or by changes in the environment caused by the dam probably both had some effect.

Illumination, population density, and temperature had significant influences on drift rates of both *Baetis* sp. I and Simuliidae. Turbidity and water level fluctuations were related to changes in drift rates indirectly through influence upon illumination and population density, respectively. Dissolved oxygen content, calendar date, and depth of water did not affect drift rates of Baetis sp. I nymphs and Simuliidae larvae.

SUMMARY

1. The installation of Flaming Gorge Dam on the Green River in northeastern Utah has greatly affected the river environment. This study attempted to determine what changes had occurred in the distribution and abundance of macroinvertebrate fauna on a 166-mile section of the Green River between Flaming Gorge Dam and Ouray, Utah, from September, 1962 to September, 1965.

2. Sampling effort was concentrated in the summers of 1964 and 1965. Four major stations and 11 supplementary stations were employed. Samples of the invertebrate fauna were collected with a Hess-Waters bottom sampler (194 samples), a 6-inch Ekman dredge (68 samples), an 11-1/2-inch diameter drift net (394 samples), and several handscreens and dipnets (58 samples). Environmental measurements included illumination, water temperature, turbidity, water level, dissolved oxygen, depth, pH, alkalinity, current speed, and substrate type.

3. The installation of Flaming Gorge Dam has effected the following changes in the Green River below the dam:

a. Reduced seasonal fluctuations in discharge.

b. Increased daily fluctuations in discharge.

c. Reduced summer water temperatures and increased winter water temperatures.

d. Reduced turbidity.

e. Increased daily fluctuation in dissolved oxygen.

f. Increased concentration of most dissolved solids.

g. Increased daily fluctuation in hydrogen-ion concentration.

4. Bottom fauna densities were highest (6347 per square foot) near the dam and decreased with increasing distance below the dam. Population densities near the dam were probably higher in 1964 and 1965 than in pre-impoundment years. Densities below Carr Ranch were probably similar in 1964 and 1965 to pre-impoundment densities.

5. Nine forms of invertebrates reported from the area prior to September of 1962 were not collected during this study while ten groups not previously reported were collected. The species composition of the invertebrate fauna between the dam and Carr Ranch in 1964 and 1965 was considerably different from that reported prior to September, 1962. Below Carr Ranch the invertebrate fauna was very similar to that reported prior to September, 1962.

6. Drift rates of *Baetis* sp. I and Simuliidae were highest near the dam and decreased with increasing distance below the dam.

7. Illumination, population density of other organisms, and water temperature had significant effects on drift-net catches of *Baetis* sp. I and Simuliidae. Turbidity and water-level fluctuations had important effects on drift-net catches under certain circumstances. Date, dissolved oxygen content of the water, and depth over the net had little effect on drift-net catches.

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APPENDIX

Appendix A. Number of samples collected, Green River and tributaries, 1963-1965.

Location	1963 H-W	1963 Ekman	1964 H-W	1964 Ekman	1964 Drift	1964 Qualitative	1965 H-W	1965 Ekman	1965 Drift	1965 Qualitative	Totals
Station 1			4	1	3		14	9	81	8	120
2	1	1	3				2			1	8
3		2	3								5
4		2									2
5		2	8		7	2	9	2	79		109
6			3				5	6		1	15
7							2			4	6
8	4		15	1	18	1	14	3	40	1	97
9	2	1	16	1			16	1		1	38
10	3	2	25	6	29	1	21	15	80	2	184
11	2	1	7	1	5	1	4		1	3	25
12		2	2		3						7
13		3	6	3	1						13
14			3	3	3						9
Yampa River					4				40	8	52
Small Tributary Streams										24	24
Totals	12	16	95	16	73	5	87	36	321	53	714

Appendix B. Occurrence of macroinvertebrates at all stations, Green River, 1964 and 1965.

Item	Station Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Nematoda	X									X				
Oligochaeta	X	X	X	X	X	X		X	X	X	X	X	X	X
Hirudinea							X							
Amphipoda														
Hyalella					X	X			X					
Hydracarina	X	X			X		X	X	X	X	X		X	
Plecoptera														
Isoperla	X	X			X	X	X	X	X	X	X		X	X
Isogenus							X	X	X	X	X	X		
Acroneuria	X						X	X	X	X	X	X		
Arcynopteryx	X	X												
Ephemeroptera														
Lachlania powelli							X		X	X	X			
Heptagenia elegantula	X	X		X	X	X	X	X	X	X	X	X		
Heptagenia sp. II										X	X			
Rhithrogena undulata		X			X		X	X	X	X	X	X		
Epeorus albertae										X				
Ametropus albrighti												X		
Callibaetis sp.					X									
Baetis sp. I	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Baetis sp. II										X				
Baetis sp. III									X	X				
Baetis sp. IV	X			X	X	X		X	X	X	X	X	X	X
Baetis sp. V	X				X	X	X	X	X	X	X	X		
Baetis sp. VI										X			X	
Baetis sp. VII					X			X	X	X	X			
Baetis sp. VIII					X	X		X	X	X	X	X	X	
Baetis sp. XI								X		X				
Baetis sp. XII										X				
Baetis sp. XIV					X	X	X		X	X				
Brachycercus sp.					X								X	

Appendix B (Continued). Occurrence of macroinvertebrates at all stations, Green River, 1964 and 1965.

	Station Number													
Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14
<u>Tricorythodes minutus</u>		X			X	X	X	X	X	X	X	X	X	X
<u>Tricorythodes</u> sp.							X	X	X	X	X	X	X	
<u>Ephemerella inermis</u>	X							X	X	X	X	X		X
<u>Paraleptophlebia pallipes</u>	X							X	X	X				
<u>Choroterpes albiannulata</u>						X	X	X	X	X	X	X	X	X
<u>Traverella albertana</u>					X		X	X	X	X	X	X	X	X
<u>Hexagenia limbata</u>														X
<u>Ephoron album</u>					X	X		X	X	X	X	X	X	
Odonata														
<u>Gomphus</u>													X	X
<u>Ophiogomphus</u>	X							X						
Hemiptera														
Gerridae	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Notonectidae	X													
Naucoridae								X				X		X
Corixidae				X	X	X				X		X	X	
Megaloptera														
<u>Corydalus</u>				X			X	X	X	X	X			
Trichoptera														
<u>Cheumatopsyche</u>					X	X	X	X	X	X	X	X	X	X
<u>Hydropsyche</u>		X					X	X	X	X	X	X		
<u>Agraylea</u>	X					X		X		X				
<u>Hydroptila</u>		X				X	X	X	X	X	X	X		
<u>Leptocerus</u>										X				
<u>Leptocella</u>					X			X	X	X		X		
<u>Brachycentrus</u>					X			X	X	X	X			
Coleoptera														
Haliplidae					X									
Dytiscidae				X	X	X		X	X	X	X		X	
Dryopidae		X			X	X			X					
Elmidae					X	X	X	X		X	X			X

Appendix B (Continued). Occurrence of macroinvertebrates at all stations, Green River, 1964 and 1965.

Item	Station Number													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Chrysomelidae	X				X									
Diptera														
Blepharoceridae										X				
Tipulidae	X	X			X	X		X	X	X			X	
Culicidae										X				
Simuliidae	X	X			X	X	X	X	X	X	X	X	X	X
Chironomidae	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Ceratopogonidae	X	X			X	X		X	X	X	X		X	X
Stratiomyiidae	X													
Tabanidae					X				X					
Rhagionidae	X							X	X		X			
Anthomyiidae	X					X								
Gastropoda	X													
Pelecypoda	X													

Appendix C. Abundance of benthic invertebrates, Taylor Flats Bridge and Allen Ranch, Green River, 1964-1965 -- expressed as mean number per square foot.

Item	Allen Ranch	Taylor Flats Bridge	
	Sept. 18, 1964	Sept. 7, 1964	Sept. 16, 1965
Oligochaeta	314	44	69
Hydracarina			5
Plecoptera			
Isoperla			1
Arcynopteryx			3
Ephemeroptera			
Rhithrogena undulata			1
Baetis sp. I	3	44	189
Tricorythodes minutus			1
Trichoptera			
Hydropsyche			1
Hydroptila			1
Diptera			
Tipulidae		2	1
Simuliidae		5	1566
Chironomidae	95	582	293
Ceratopogonidae			1
Pupae (all families)	6	137	99
Substrate type	Sand-Gravel	Rubble	Rubble
Number of samples	3	3	3

Appendix D. Abundance of benthic invertebrates on rubble or debris substrates, north end of Lodore Canyon, Green River, September 6, 1965 -- expressed as mean number per square foot.

Item	Sample Number		
	HW-330	HW-331	Mean
Hydracarina	2	7	4.5
Plecoptera			
Acroneuria	2	1	1.5
Ephemeroptera			
Lachlania powelli	1	0	.5
Heptagenia elegantula	9	3	6.0
Baetis sp. I	15	17	16.0
Baetis sp. V	78	53	65.5
Tricorythodes minutus	6	3	4.5
Tricorythodes sp.	9	21	15.0
Traverella albertana	109	4	56.5
Trichoptera			
Cheumatopsyche	0	24	12.0
Hydropsyche	240	96	168.0
Hydroptila	0	6	3.0
Diptera			
Simuliidae	66	10	38.0
Chironomidae	50	13	31.5
Pupae (all families)	8	7	7.5

Appendix E. Abundance of benthic invertebrates on rubble or debris substrates, Split Mountain Campground, Green River, 1964-1965 -- expressed as mean number per square foot.

Item	1964			1965	
	Aug. 9	Sept. 4	Oct. 25	Mar. 19	Aug. 29
Oligochaeta		27	1	1	1
Hydracarina	1				2
Plecoptera					
Isoperla	1		30	1	2
Isogenus	1	1			1
Ephemeroptera					
Heptagenia elegantula	2	1	1		7
Rhithrogena undulata	7		3	3	15
Baetis sp. I	1	1	10	59	5
Baetis sp. IV	1				
Baetis sp. V	2		1		1
Baetis sp. VII			1		
Baetis sp. VIII			1		
Tricorythodes minutus	3	1	6		1
Tricorythodes sp.	3	8			15
Ephemerella inermis	1	1	2	2	1
Choroterpes albiannulata		3	1		1
Traverella albertana	52	3			48
Ephoron album	1	4			1
Magaloptera					
Corydalus					2
Trichoptera					
Cheumatopsyche	5	27	1		30
Hydropsyche		3			81
Hydroptila					1
Brachycentrus					5
Coleoptera					
Dytiscidae		1			
Elmidae	1	1		1	
Diptera					
Simuliidae			2	9	
Chironomidae	4	45	80	17	9
Ceratopogonidae		1			
Rhagionidae					1
Pupae (all families)	1	9	2	1	2
Number of samples	2	4	2	2	2

Appendix F. Abundance of benthic invertebrates, Ouray, Green River, 1964 -- expressed as mean number per square foot.

	Station 11			Station 12		
Item	June 10	July 14	Aug. 6	June 8	July 13	Aug. 7
Oligochaeta			3	1		4
Plecoptera						
Isoperla	1			1		
Ephemeroptera						
Baetis sp. IV			4		5	
Baetis sp. VI	1					
Baetis sp. VIII		1				
Brachycercus sp.		1				
Tricorythodes minutus		1	42			6
Ephemerella inermis						1
Choroterpes albiannulata			2			4
Traverella albertana		1				3
Ephoron album		1				
Odonata						
Gomphus			1		5	1
Hemiptera						
Naucoridae						1
Corixidae			3			
Trichoptera						
Cheumatopsyche	1					1
Coleoptera						
Dytiscidae			1			
Elmidae						2
Diptera						
Tipulidae			1			
Simuliidae						1
Chironomidae	2	12	18	7	25	21
Ceratopogonidae	9		2	1		1
Pupae (all families)			3		4	3
Substrate type	Debris	Sand	Debris	Debris	Silt	Debris
Number of samples	4	3	2	2	2	2

Appendix G. Aquatic invertebrates collected from tributaries to the Green River, 1964 and 1965.

Item	Stream													
	Gorge	Goslin	Little Davenport	Unnamed	Jackson	Red	Sears	Willow	Crouse	Beaver	Matt	Vermillion	Cottonwood	Yampa
Oligochaeta				X					X				X	
Amphipoda														
Hyalella								X			X			
Gammarus											X			
Plecoptera														
Isoperla			X						X					X
Isogenus									X					X
Acroneuria	X													
Claassenia	X													
Arcynopteryx	X	X					X		X					
Ephemeroptera														
Lachlania powelli														X
Heptagenia elegantula														X
Heptagenia sp. II														X
Rhithrogena undulata														X
Epeorus albertae	X													
Baetis sp. I	X	X	X	X	X		X	X	X	X				X
Baetis sp. IV													X	
Baetis sp. V														X
Baetis sp. VII														X
Baetis sp. VIII														X
Baetis sp. XIV												X		
Tricorythodes minutus														X
Tricorythodes sp.														X
Ephemerella inermis														X
Ephemerella coloradensis	X													

Appendix G (Continued). Aquatic invertebrates collected from tributaries to the Green River, 1964 and 1965.

Item	Stream													
	Gorge	Goslin	Little Davenport	Unnamed	Jackson	Red	Sears	Willow	Crouse	Beaver	Matt	Vermillion	Cottonwood	Yampa
Paraleptophlebia pallipes		X							X					
Choroterpes albiannulata														X
Traverella albertana														X
Ephoron album														X
Odonata														
Ophiogomphus														X
Hemiptera														
Gerridae	X													
Naucoridae														X
Megaloptera														
Corydalus														X
Trichoptera														
Cheumatopsyche	X													X
Hydropsyche	X						X		X	X		X		X
Rhyacophila	X								X					
Brachycentrus									X	X				X
Coleoptera														
Haliplidae														X
Dytiscidae		X					X	X			X		X	
Dryopidae								X	X			X		
Elmidae	X								X					X
Chrysomelidae							X							
Diptera														
Blepharoceridae														X
Tipulidae	X									X				

Appendix G (Continued). Aquatic invertebrates collected from tributaries to the Green River, 1964 and 1965.

Item	Stream													
	Gorge	Goslin	Little Davenport	Unnamed	Jackson	Red	Sears	Willow	Crouse	Beaver	Matt	Vermillion	Cottonwood	Yampa
Psychodidae		X					X							
Simuliidae	X	X		X	X	X	X	X	X	X			X	X
Chironomidae	X	X		X	X					X	X	X		X
Ceratopogonidae				X										
Tabanidae				X		X			X	X				
Gastropoda		X	X											
Pelecypoda				X			X		X					