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Locomotive Springs Validation Study

J. Anne Holman

I. Walkiw

F. Post

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LOCOMOTIVE SPRINGS VALIDATION STUDY

J. Anne Holman, I. Walkiw
F. Post
Utah State University

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Ecology Center, Utah State University, Logan, Utah 84322

INTRODUCTION

Locomotive Springs, located at 41° 44' N latitude and 112° 57' W longitude are an important part of the ecology of Curlew Valley, Utah. The area contains six major springs: West Locomotive, Baker, Bar M, Teal, Off, and Sparks (Figure 1). Hydrologically the springs are of interest as the exit for the water of the Curlew Valley drainage system. Streams, such as Deep Creek in Idaho, are fed by melt from winter snows and rains on surrounding mountains. All the water is used up for irrigation or disappears underground before reaching the end of the valley. This water reappears to feed the six springs at the southern end of the valley. A series of channels drains the pools and flows into two diked lakes which enter via marshes into the north arm of the Great Salt Lake. The water in these pools is slightly saline.

Biologically the springs are essential for the fauna of the southern end of the valley. The pools, channels and marshy lakes provide an important haven for migratory waterbirds and are used by muskrats as well as other mammals of the area (rabbits, coyotes, etc.). During the winter they are heavily used by grazing cattle.

Off Spring, the smallest of the group (19x35 m) was chosen as an IBP Desert Biome aquatic validation site. It has three permanent spring cones, with a depth over the cones of 1.5 to 2.7 m. The rest of the oval pool is less than 0.9 m deep. The banks are 0.3 to 1.0 m high and, except in a small area of the east bank, are steep and restrict cattle use of the pool. A low dam, with USGS stage recorder and depth gauge, separates the pool from its channel, which empties into East Lake (Fig. 1). Outflow from the pool is about 0.07 m^3/sec. Table 1

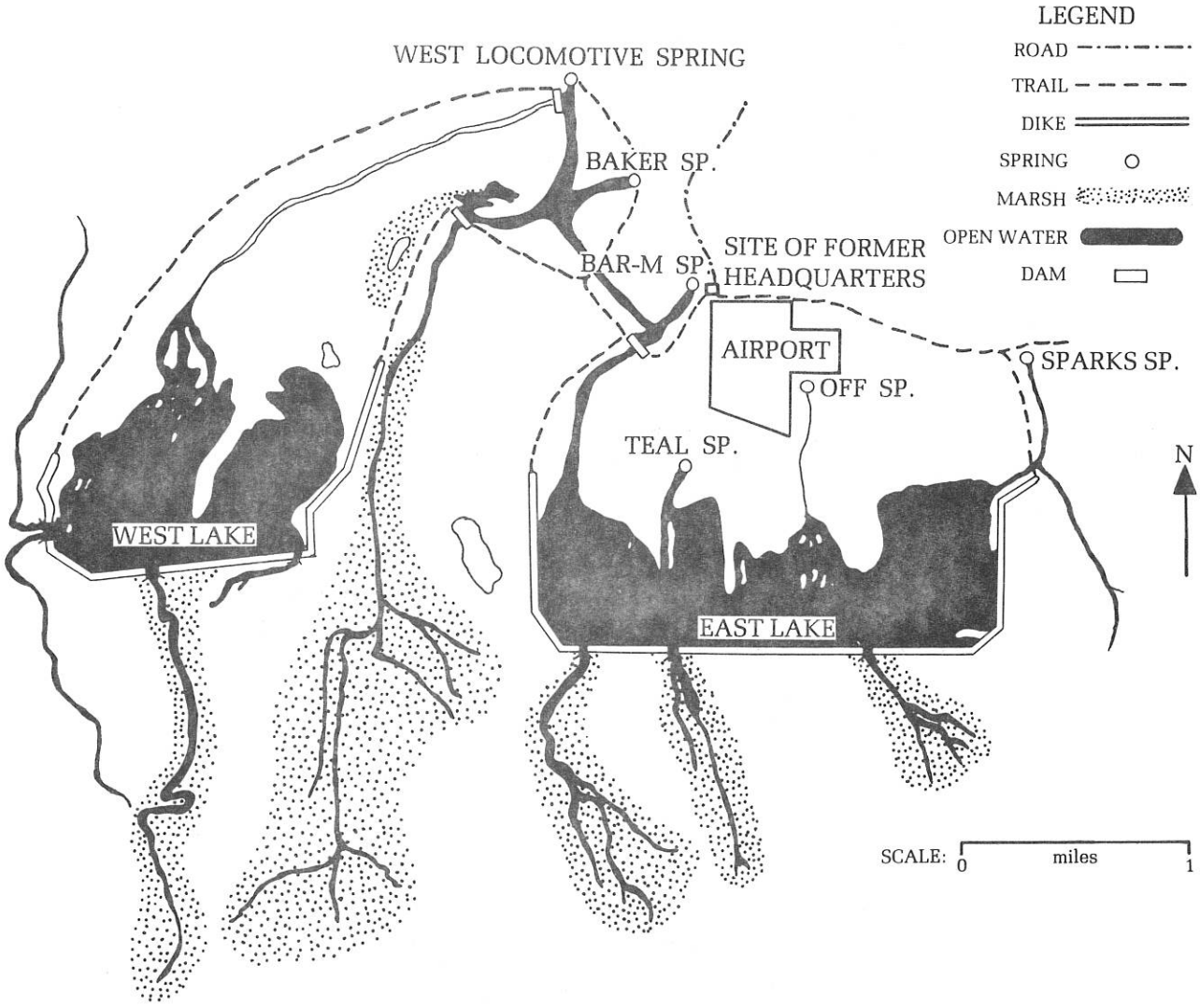

Figure 1. Map of Locomotive Springs area; Curlew Valley, Utah.

summarizes the physical and chemical characteristics of Off Spring. Sampling in the pool began in March, 1970, and continued on a biweekly to monthly basis until December, 1971. The channel also was sampled during 1971.

OBJECTIVES

1. To compile a complete taxonomic list of the flora and fauna of Off Spring.
2. To measure all physical and chemical parameters of Off Spring over a two-year period.
3. To measure the biomass of the components of the biological community in terms of grams of dry weight and calories.

METHODS

Sampling was started in March, 1970 on a biweekly basis and then reduced to monthly collections in October, 1970 because of the relative stability of the system.

Gauge Data -- Off Spring

Depth and flow data were obtained from the United States Geological Survey, which maintains a depth gauge and Stevens A-35 stage recorder in the weir at the outflow of Off Spring pool (DSCODE A3UNB01).

Air and Water Temperature -- Off Spring

A Science Associates 3-lead thermograph recording drum was installed (buried in a steel box near the spring). One lead was located in the air, one at the water surface and one near the bottom of the spring. At each sampling period the graph paper was changed, the pens filled with ink and the clock wound (A3UHQ08).

Physical and Chemical Data -- Off Spring

The pH was measured with a Beckman pH meter. Samples were brought from the field on ice and readings taken in the laboratory at room temperature. Dissolved O_2 was determined by an azide modification of the iodometric method (APHA, 1965). Samples were fixed in the field and brought on ice to the laboratory for titration. The methods used for other compounds were: nitrate, the brucine method (APHA, 1965); nitrite, the sulfanilic acid method (APHA, 1965); orthophosphate, the stannous chloride method (APHA, 1965).

The experimental design utilized random sampling. Initially, a minimum of three samples from transects of fixed grid were collected each time. However, as these were found to be quite similar, the number of samples was reduced to one sample with an occasional check of a second sample (A3UHQ04).

Table 1. Physical and chemical characteristics of Off Spring, Utah

A. Physical		
Altitude		1285 m
Longitude		112° 57' W
Latitude		41° 44' N
Volume of flow		0.07 m^3/sec
Surface area		665 m^2
Depth: mean		0.91 m
maximum		2.7 m
Air temperature:	summer mean (June - August)	22 C
	summer maximum (June - August)	50 C
	winter mean (November - March)	7 C
	winter minimum (November - March)	-8 C
Amplitude of annual temperature at mean depth (0.91 m)		4-20 C
Climate characteristics:	winter - cold, snow, October - April ground frozen; only edges of pool freeze.	
	spring - rains and runoff.	
	summer - hot, dry, windy, June - Sept.	
	fall - some rain.	
Pool sediments	mud, sand at outflow, gravel at average depths, small boulders in cones.	
B. Chemical		
Conductivity		3,390 - 7,980 mhos/cm at 25 C
pH		7.6
Dissolved oxygen		January mean 15.2 mg/l at 10 C
		July mean 5.56 mg/l at 16 C
Total alkalinity		198-234 mg/l
Total CO_2 (inorganic)		38.9 mg/l
Cl^-		960 mg/l
$SO_4^=$		87 mg/l
Ca^{++}		107 mg/l
Mg^{++}		49 mg/l
K^+		27 mg/l
Na^+		483 mg/l
PO_4-P		0.0 - 0.3 mg/l
SiO_2-Si		29 mg/l
NO_2-N		0.0 - 0.05 mg/l
NO_3-N		0.40 - 1.17 mg/l

Organic Carbon Mineralization by Bacteria (Dr. Frederick Post)

Three techniques were used: total plate count, uptake of glucose-C^{14} and kinetics of glucose uptake.

Total Plate Count

Solidified Plate Count agar plates were surface-plated with 0.1 ml of serial dilutions, spread with a sterile bent glass rod

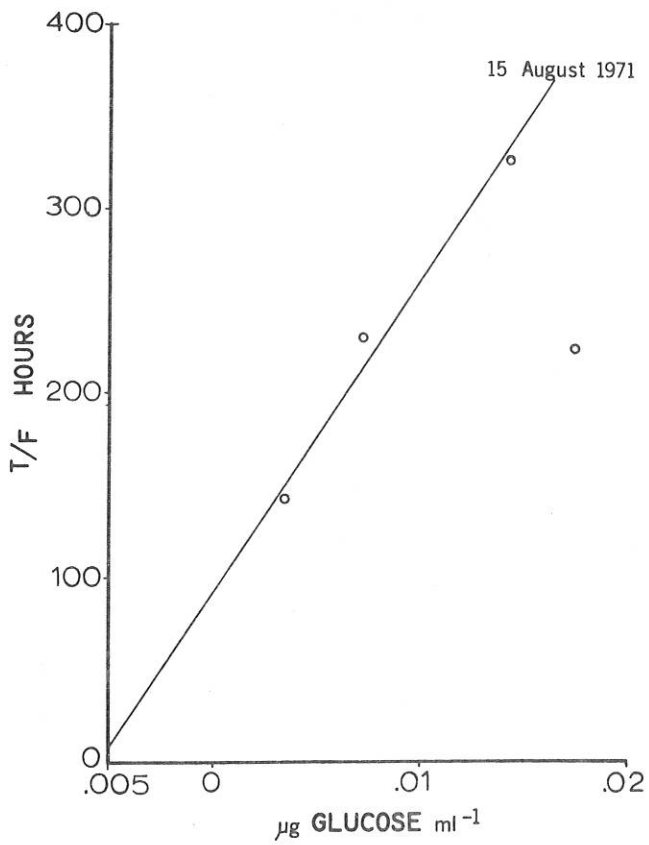

Figure 2. Glucose uptake velocity plot -- Off Spring.

and incubated at 20 C for one week. This measurement was intended to give an indication of viable heterotrophic bacteria of wide nutritional faculties. Coliform organisms were measured by the standard membrane filter technique at 35 C on m-Endo medium. Nitrate reducers were determined by the 3-tube, serial dilution technique in nitrate broth at 20 C for one week. Counts were averaged using logarithms. Counts were also converted into an estimated biomass by assuming a typical bacterial cell to weigh 10^{-12} g.

Uptake of Glucose-C^{14}

An attempt was made to estimate bacterial count by the rate of uptake of a standardized amount of glucose-C^{14}. To samples of 100 ml, 1 µg of glucose-C^{14} was added and the mixtures incubated at 20 C. Ten-ml samples were removed at various intervals and passed through a 25-cm diameter membrane filter of 0.45 µm pore size. Bacteria were retained on the filter, which was then cemented to a planchet, and after drying were counted in a Nuclear Chicago gas flow counter. Counts per minute were plotted and the linear portion of the curve converted to a rate and compared to total count. Results were highly variable and did not seem to be related to that count. Representative types of bacteria were isolated in pure culture and, with known numbers of cells, were subjected to this same procedure.

Kinetics of Glucose Uptake

If a range of concentrations of uniformly-labeled C^{14} is used as a substrate, uptake follows Michaelis-Menten kinetics (Hobbie, 1969). The adapted Lineweaver-Burk equation is then employed to give glucose turnover time and maximal velocity of uptake (or mineralization).

This equation is $t/f = (K + S)/Vmax + A/Vmax$, where t is incubation time in hours, f is the fraction of available substrate mineralized, K is the uptake constant, Vmax is the maximal mineralization velocity, S is the natural substrate concentration (unknown) and A is the added substrate concentration. When t/f is plotted against A, a straight line results. Extrapolating to A = O the y-axis intercept gives the turnover time for mineralization at the natural substrate concentration. The inverse of the slope gives Vmax. The intercept of the line with the x-axis provides a maximum for the natural substrate concentration (in practice it must be less than this value).

Samples were shaken and split into three equal volumes. Three different concentrations of uniformly-labeled glucose-C^{14} were then added to the bottles, which were then incubated for 1 hr at 20 C. The samples were processed and counted as previously described. Plots were then made (Figure 2) and the various kinetic values determined.

Primary Productivity -- Off Spring

Data are supplied on gross primary productivity, net productivity and community respiration (A3UHQ06).

The method is based on that of Kemmerer and Neuhold (1969, 1970). Three polyethylene tubes of 0.6-m diameter were placed in the spring to depths of 0.46 m, 0.62 m and 1.85 m. Samples were collected for dissolved oxygen determinations (by modified Winkler method, APHA, 1965) from the confined water at sunset of the first day and sunrise and sunset of the second day. Community respiration was determined by expanding the oxygen consumption at night over a 24-hr period. Respiration was added to net production (the second sunset oxygen concentration minus the sunrise concentration) to determine gross productivity.

The experimental design consisted of tubes placed randomly at the three depths (0.46, 0.62 and 1.85 m).

Phytoplankton and Zooplankton

A Clarke-Bumpus sample was used at first but found to be useless because of thick algal mats over most of the Off Spring pool. After May, 1970, water was collected with a hand pump and a measured quantity (5 l) poured through a plankton net. Concentrated samples were preserved in 5% formalin. Organisms were identified and counted in a Sedgewick-Rafter cell with a stereoscope and Whipple reticule (APHA, 1965). Concentration of plankton was

calculated. Beginning September 12, 1971, only cladocerans, copepods and total rotifers were counted in the plankton samples. After more than a year of sampling these were determined to be the most important planktonic organisms (A3UHQ05).

Aquatic Macrophyte Biomass, Dry Weights and Calories -- Off Spring

A core sampler (Macan, 1964) was used to collect a column of water with 45.3 cm^2 of bottom area. Samples were put into large plastic bags for transport to the laboratory. Water volume was measured, and the sample washed through a 30-mesh screen. Live plant matter was picked out and dried at 60 C for 24 hr and weighed. Caloric measurements were made on selected samples, using a Philips microbomb calorimeter (A3UHQ07).

The experimental design utilized was random selection from a fixed grid pattern of three sites that are in an area of 1-m depth or less.

Aquatic Macroinvertebrates -- Off Spring

A core sampler (Macan, 1964) was used to collect a column of water with 45.3 cm^2 area of bottom mud. Samples were put into large plastic bags for transport to the laboratory. Water volume was measured and the sample washed through a 30-mesh screen. Residue was preserved in 5% formalin and dyed with phloxin B. After 48 hr, invertebrates were picked, identified, sorted by size, measured, and counted. Numbers were recorded per unit volume or per unit bottom surface area according to the habitat of the organism (A3UHQ02).

The experimental design consisted of random selection from a fixed grid pattern of three sites that are in an area of 1-m depth or less.

Dry Weights of Macroinvertebrates -- Off Spring

Collections were made with a dip net or core sampler. Organisms were picked from the fresh sample in the laboratory, identified, measured, sorted according to size, and counted. Organisms of the same type and size were placed in a pre-weighed crucible and dried at 60 C for 24 hr. Crucible and contents were weighed on an analytical balance, heated to 600 C for 15 min, and then placed in a desiccator until cooled to room temperature. The crucible and ash were weighed and the dry-weight and ash-free weight were calculated (A3UHQ03). Samples were collected at arbitrary locations.

Growth Rate and Population Size of Utah Chub (*Gila atraria*) -- Off Spring

Fish were sampled monthly, first using electro-fishing (found to be useless because of a thick algal mat) and then using traps constructed from hardware cloth which were set overnight in the cone area. All fish captured were weighed, measured and marked before being returned to the spring. All fish over 70 mm were cold-branded on the left side with an individual number; fish less than 70 mm in length were marked by fin clipping. Total numbers were determined by mark-recapture methods. Supplemental sampling with electro-fishing gear and seines was done when the submergent vegetation allowed (A3UKE01-3) Population estimates were according to procedures found in Ricker (1968).

Abiotic Measurements -- Off Spring Channel

The parameters measured were temperature, pH, dissolved oxygen, orthophosphate, nitrate, and nitrite (A3UHQ24).

Air and Water Temperature -- Off Spring Channel

A Science Associates 3-lead thermograph drum was installed in a metal box by the channel. One lead was placed in the air and two in the water, approximately 8 m apart. At each sampling period the graph paper was changed, the pens filled with ink and the clock wound (A3UHQ28).

Phytoplankton and Zooplankton -- Off Spring Channel

Water was collected with a hand pump and a measured quantity (5 l) poured through a plankton net. Concentrated samples were preserved in 5% formalin. Organisms were identified and counted in a Sedgewick-Rafter cell with a stereoscope and Whipple reticule (APHA, 1965). Concentration of plankton was calculated. Random sampling was utilized (A3UHQ25).

Aquatic Macrophyte Biomass Dry Weight -- Off Spring Channel

A core sampler (Macan, 1964) was used to collect a column of water with 45.3 cm^2 of bottom area. Samples were put into large plastic bags for transport to the laboratory where water volume was measured and the sample washed through a 30-mesh screen. Live plant matter was picked out and dried at 60 C for 24 hr and then weighed. Two samples were collected at random (A3UHQ27).

Aquatic Macroinvertebrates -- Off Spring Channel

A core sampler (Macan, 1964) was used to collect a column of water with 45.3 cm^2 area of bottom mud. Samples were put in large plastic bags for transport to the laboratory. Water volume was measured and the sample washed through a 30-mesh screen. Residue was preserved in 5% formalin and dyed with phloxin B. After 48 hr, invertebrates were picked, identified, sorted by size, measured, and counted. Two random samples were collected (A3UHQ22).

FINDINGS

A taxonomic list was made for Off Spring in which all groups found are included. The taxa of most importance numerically in the system are starred (Table 2).

Average water temperatures ranged from 3.2 to 18.9 C in the pool and 11.2 to 16.6 C in the channel. Mixing in the channel apparently kept the temperature more uniform (Figures 3 and 4).

The water chemistry values for both pool and channel showed little variation (Tables 3 and 4).

Primary productivity tubes were used only in the pool. This method is useless in running water. Other methods (Odum, 1956) were tried in the channel but proved to be too erratic and difficult. The tubes supplied data of gross and net productivity and total community respiration for the pool (Table 5, Figure 5a-c) for three different depths: shallow (0.4 m), medium (0.6 m) and deep (1.4 m). The first measurements (June, 1970) were made by a different individual from the rest, which may account for the rather extreme number for the shallow tube. The sudden deviation for July, 1970, in deep tubes is due to a sampling error. Respirations at each depth compared well with each other (Figure 5). Productivity figures are difficult to compare since the amount of vegetation was so variable at the different depths.

Diatoms were the only important planktonic algae in the pool (Table 6). These attained peak numbers in late summer and fall of 1970 and January of 1971. The peak did not reappear in late summer of 1971; instead, numbers decreased to a point that the counting of zooplankton and algae was stopped.

Total plant biomass (mg dry wt/1; Figure 6, Table 7) of rooted *Potamogeton* and *Cladophora* algae in the pool peaked in summer and fall of 1970. It decreased in the winter, but without any recovery in the summer of 1971. This was clearly visible in the pool. During the summer of 1970, the pool was filled by the *Potamogeton-Cladophora* mat, which during the summer of 1971 was drastically reduced. The plant biomass in the channel showed a rather unexpected rise during the winter months, after a low in June (Figure 7, Table 8).

Caloric measurements were made on plant material for selected months during 1971. The average values remained much the same (Table 9).

Copepods were the major zooplankton in the spring. They were abundant in the summer of 1970, with a peak in August; during 1971 numbers were very low, with a small peak in September. The same holds true for rotifers. Cladocera seemed to repeat their pattern both years, with peaks during the fall (Figure 8, Table 10). In the channel, all three organisms displayed peaks in 1971 in Spetember and October (Figure 9, Table 11).

Hyalella azteca was by far the major benthic invertebrate. During the summer of 1970, numbers per liter in the pool were high, with a drop occurring during the winter months. However, there was no recovery during 1971 (Figure 10, Table 12), when numbers remained very low, with a small peak in August. During the same period in the channel the numbers were high, peaking in July and August (Figure 11, Table 13).

Utah chub, which were planted in the pool as its only fish in June, 1970 (360; 2.5-9.1 g wet wt.) were sampled from July, 1970 through December, 1971. A lack of recaptures made population estimates unreliable, as can be seen by the standard error in Table 14. From available estimates and direct observations of fish in the pool, the population must have peaked during the summer and fall of 1971. It appeared to be decreasing as of February, 1972.

The planktonic bacteria in samples taken at the outlet to the spring varied over the 2-year period from 500 to 158,000, with an average (based on $\log_{10}$ to minimize exceptional values) of 5000 per ml (Figure 12 and Table 15). Several large values possibly could be accounted for by inclusion of algae or plant debris, which dislodged fairly large numbers of bacteria. The possibility of this can be seen from Table 16, where two samples deliberately including these large forms have fairly large counts. It is well known that bacterial numbers are relatively high around and on the surface of submerged objects, especially plants and algae, since much organic matter is exuded from their surfaces.

The planktonic bacteria, based on plate counts, represent only a small biomass (Table 15); for the period of March, 1970 to December, 1971, averaging 12×10^{-9} g ml^{-1} or 1.2×10^{-5} g per liter. Using the $\log_{10}$ average as a base, this would be 5×10^{-9} g ml^{-1}, a little more than one-half the value obtained by direct averaging.

Mud samples were not collected with any frequency. Cores 2.5 cm in diameter showed a deep black color to within 1-2 mm of the surface, with a slight smell of hydrogen sulfide. The black gradually disappeared after exposure to air and after several days became a rust-brown as the black FeS was oxidized. The mud condition suggested a high biological activity, essentially anaerobic. Counts done by the semi-anaerobic MPN method showed very high counts (Table 16), with biomass values on the order of 1000 times that of the planktonic bacteria. This amounted to about 2.6×10^{-4} g g^{-1}, or 0.26 g of bacteria per kg of mud. Many of the organisms in this community are able to reduce nitrates to nitrites, but not always to N_2 gas (Table 17). On April 1, 1970, about 24 % of the viable count in the mud sample were organisms of this type.

One other observation can be made on the viable count. Pigmented colonies on the medium used were rather common, often amounting to 60-70% of all colony types. This is typical of relatively unpolluted waters and probably a normal occurrence. Yellow pigmentation was most common, with occasional red, orange and black colorations.

Glucose-C^{14} uptake experiments did not show any discernible relationship to total count. A number of cultures representing the more common types from the plankton were subjected to uptake analysis. Conclusions were as follows: (a) different strains of bacteria have different uptake rates, and (b) uptake is linearly related to bacterial numbers (with fairly large numbers of bacteria, i.e. greater than 10^4). The technique would therefore measure numbers of only the most rapidly uptaking species, even if they were present in smaller numbers than a slower species. The most important

Table 2. Taxonomic list for Off Spring, Utah. The most abundant taxa are indicated by an asterisk

PHYTOPLANKTON

- Chlorophyta
  - Chlorococcales
    - *Pediastrum*
  - Euglenales
    - *Euglena*
    - *Peniun*
  - Ulotrichales
    - *Cladophora**
    - *Microspora*
  - Zygnematales
    - *Closterium*
    - *Genicularia*
    - *Netrium*
    - *Spirogyra*
    - Other desmids (Desmidiaceae)
  - Other green algae
- Chrysophyta
  - Bacillariophyceae
    - Centrales
      - *Campylodiscus clypeus*
    - Pennales
      - *Cocconeis*
      - *Rhoicosphenia curvata*
      - *Surirella*
    - Other diatoms
- Pyrrophyta
  - Dinokontae
    - *Ceratium*

ROOTED VASCULAR PLANTS

- *Potamogeton pectinatus**
- *Ruppia maritima**

ZOOPLANKTON

- Protozoa
  - Mastigophora
  - Sarcodina
    - Rhizopoda
  - Ciliata
    - *Vorticella*
  - Other protozoans
- Aschelminthes
  - Rotifera
    - *Brachionus**
    - *Filinia longiseta**
    - *Iepodella**
    - *Monostyla**
    - *Nothalca*
    - *Trichocera**
  - Crustacea
    - Cladocera*
      - *Alona*
      - *Daphnia*
    - Copepoda*
    - Ostracoda

BENTHOS

- Annelida
  - Hirundinea
  - Oligochaeta*
- Aschelminthes
  - Nematoda
- Arthropoda
  - Crustacea
    - *Hyalella azteca**
  - Insecta
    - Collembola
    - Coleoptera
    - Diptera
      - Chironomidae*
      - Tabanidae
    - Ephemeroptera
      - *Callibaetis**
    - Hemiptera
      - Corixidae
      - Notonectidae
    - Odonata
      - Coenagrionidae
      - *Ischnura** (*Enallagma*)
    - Trichoptera
- Mollusca
  - Gastropoda
    - *Gyraulus*
    - *Lymnaea*
    - *Physa*

NEKTON

- *Gila atraria**
- *Rana pipiens* (tadpoles)*

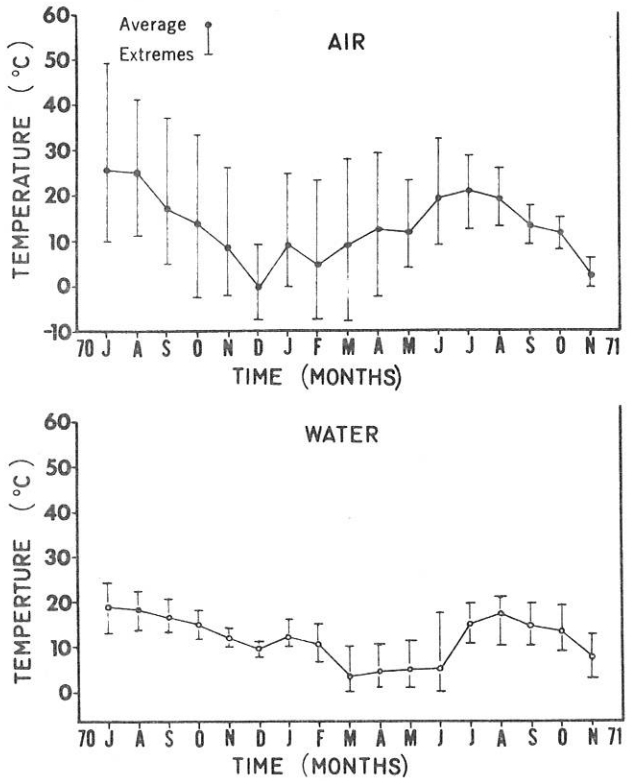

Figure 3. Air and water temperatures, Off Spring.

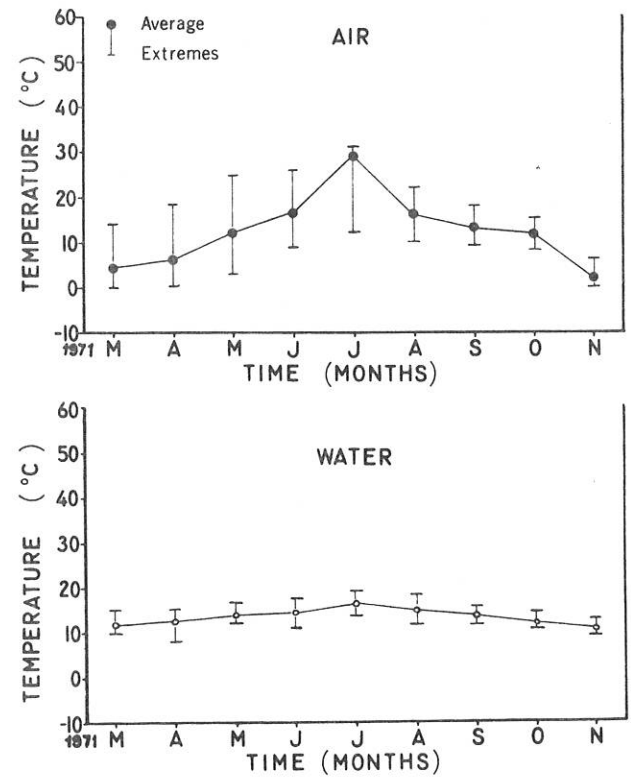

Figure 4. Air and water temperatures, Off Spring channel.

consideraton, however, was the large proportion of cultures which did not utilize glucose at all. Uniformly-labeled C^{14} acetate or proline might have provided some quantitative data, but this approach was postponed in favor of the kinetics study. Data expressed as counts per minute in 2 hr are presented in Table 18. Inspection of these data suggests little relationship with the $\log_{10}$ of total count. However, if the cpm is converted to $\log_{10}$ and averaged, there are about 350 cpm at 2 hr per 1000 cells.

Midway in the project the kinetic studies began using three levels of glucose. After the data were plotted as illustrated in Figure 12, the turnover time and velocity constants were calculated. A summary of these data is given in Table 19 and Figure 13. One would expect the turnover time to be long in winter and short in summer. These data are plotted in Figure 13 against time and suggest that from June to October there is fairly good agreement with this theory, but the last two samples seem out of character. The velocity constants show a similar pattern. The velocity constants seem to be in fair agreement with the work of others in relatively unpolluted water (Hobbie, 1969; Harrison et al., 1971). Although the number of points is small, the velocity constant does seem to be related to bacterial number (Figure 14). When plotted together, the velocity constant appears to be related to count. The curve cannot be accurately drawn due to the limited number and high scatter of points. This aspect should be explored more thoroughly.

Table 3. Physical and chemical data -- Off Spring

Month	Mean Temp. °C	Mean pH	Mean Oxygen mg/l	Mean NO_3 ppm	Mean NO_2 ppm	Mean PO_4 ppm
March '70	15.0	7.8	8.80	0.74	0.00	0.00
April	15.4	7.7	6.86	1.16	0.00	0.21
May	15.9	7.7	8.40	1.17	0.00	0.05
June	16.5	7.2	6.90	0.83	0.00	0.06
July	16.0	7.4	5.56	1.16	0.01	0.30
August	16.0	7.4	7.40	1.05	0.05	0.09
September	16.0	7.7	12.00	1.02	0.01	0.13
October	15.0	7.3	7.43	1.06	0.00	0.09
November	9.0	7.4	9.26	1.10	0.00	0.03
January '71	10.0	7.8	15.20	0.74	0.00	0.10
February	15.0	7.2	10.80	1.06	0.01	0.20
March	15.0	7.4	7.30	0.74	0.00	0.01
April	15.0	7.5	6.50	0.88	0.02	0.20
June	15.0	7.7	--	0.84	0.02	0.14
July	17.0	--	10.50	0.40	0.01	0.01
August	18.0	7.5	8.80	0.70	0.00	0.02
September	17.0	7.1	6.70	0.88	0.00	0.02
October	15.5	7.8	8.40	0.80	0.00	0.01
November	14.0	7.5	7.20	0.90	0.01	0.00
December	12.0	7.8	8.00	1.06	0.00	0.01

Table 4. Physical and chemical data -- Off Spring channel

Month	Mean Temp. (C°)	Mean pH	Mean Oxygen	Mean NO_3-N	Mean NO_2	Mean PO_4
			mg/l	ppm	ppm	ppm
February '71	13.0	7.4	14.50	0.90	0.00	0.19
March	13.0	8.2	8.23	0.10	0.00	0.10
June	15.0	7.7	---	.80	0.02	0.10
July	17.0	0.0	13.10	0.13	0.00	0.01
August	16.0	7.6	12.63	0.20	0.00	0.00
September	15.0	7.4	4.36	0.77	0.00	0.00
October	14.0	8.1	9.40	0.15	0.01	0.00
November	13.0	7.6	6.20	0.80	0.02	0.00
December	12.0	7.9	9.2	0.87	0.00	0.01

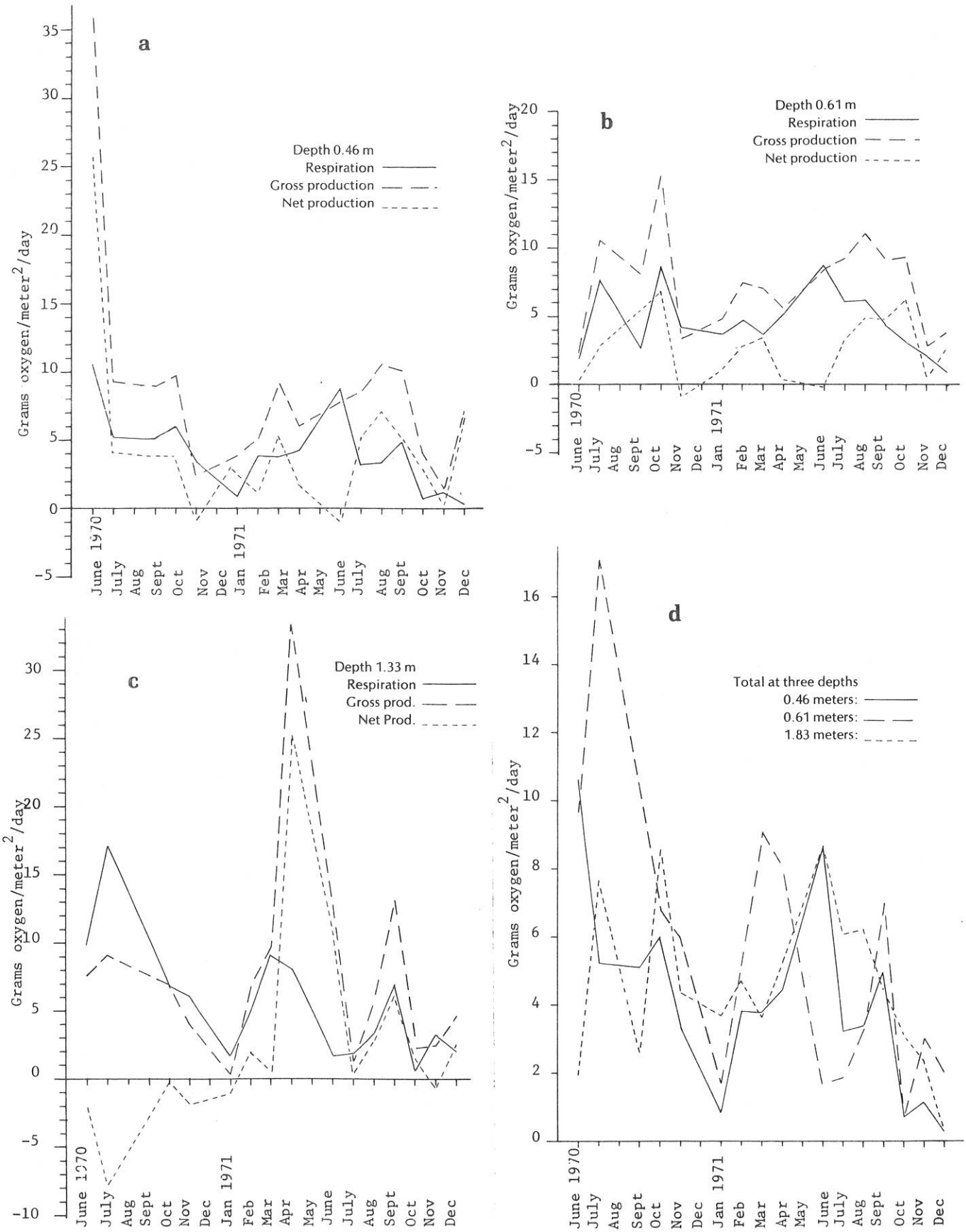

Figure 5. Primary productivity and community respiration at three depths, Off Spring. Figure 5-d shows total respiration for the three depths.

Table 5. Primary productivity tubes. Data: g $0_2/m^2$/day. Off Spring, June, 1970-December, 1971

Date	Depth (m)	Respiration	Gross Prod.	Net Prod.
June '70	.46	10.62	36.40	25.78
	.62	1.93	2.25	0.32
	1.85	9.86	7.68	-2.18
July	.46	5.23	9.29	4.06
	.61	7.71	10.50	2.79
	2.90	17.10	9.11	-7.99
Sept.	.46	5.10	9.0	3.90
	.61	2.60	8.04	5.44
	1.83	(negative)	--	--
Oct.	.46	6.00	9.72	3.72
	.61	8.60	15.36	6.76
	1.83	6.80	6.94	0.14
Nov.	.46	3.40	2.48	-0.92
	.61	4.20	3.35	-0.85
	1.83	6.00	4.18	-1.82
Jan. '71	.46	0.86	3.86	3.00
	.61	3.72	4.85	1.13
	1.83	1.73	0.32	-1.41
Feb.	.46	3.85	5.09	1.24
	.61	4.72	7.46	2.74
	1.83	5.00	6.92	1.92
March	.46	3.81	9.13	5.32
	.61	3.62	7.18	3.56
	1.83	9.10	9.62	0.52
April	.46	4.28	6.04	1.76
	.61	5.22	5.57	0.35
	1.83	8.11	33.35	25.24
June	.46	8.76	7.82	-0.94
	.61	8.76	8.64	-0.12
	1.83	1.70	12.81	11.11
July	.46	3.24	8.51	5.27
	.61	6.10	9.38	3.28
	1.83	1.90	1.28	-0.62
Aug.	.46	3.42	10.58	7.16
	.61	6.24	11.19	4.95
	1.83	3.35	6.05	2.70
Sept.	.46	4.78	10.14	5.16
	.61	4.44	9.22	4.78
	1.83	7.02	13.14	6.12
Oct.	.46	0.69	3.59	2.90
	.61	3.15	9.44	6.29
	1.83	0.69	2.26	1.57
Nov.	.46	1.20	1.55	0.35
	.61	2.20	2.76	0.56
	1.83	3.06	2.46	-0.60
Dec.	.46	0.27	7.22	6.95
	.61	0.94	3.77	2.83
	1.83	2.07	4.68	2.61

Table 6. Planktonic algae (numbers/1) -- Off Spring

Algae	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1970									
Penium						7.2			
Cocconeis (No.x 10^4)			3.9	2.1	4.9	9.6	7.7	2.1	
Other Diatoms (No.x 10^4)		0.23	15.9	468.3	4,793.6	43.3	11.8	20.5	
Suriella						10.5		42.2	
Ceratium					15,194.1				
Other Desmids			198.8	449,775.5					
Closterium								5.3	

1971	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.
Penium	9,796.8	160.8	193.6	13,304.3				
Cocconeis (NO.x 10^4)	33.5	1.3	7.4	1.7		1.7	0.7	0.4
Other Diatoms (No.x 10^4)	163.2	339.6	118.2	119.7		59.3	26.5	5.4
Suriella	1,236.0	120.9	28.0	16.3		4.3	31.1	
Ceratium								
Closterium		7.6	7.0				17.8	
Other Desmids								
Chlorophyta			3,068.6					
Euglena							8.9	

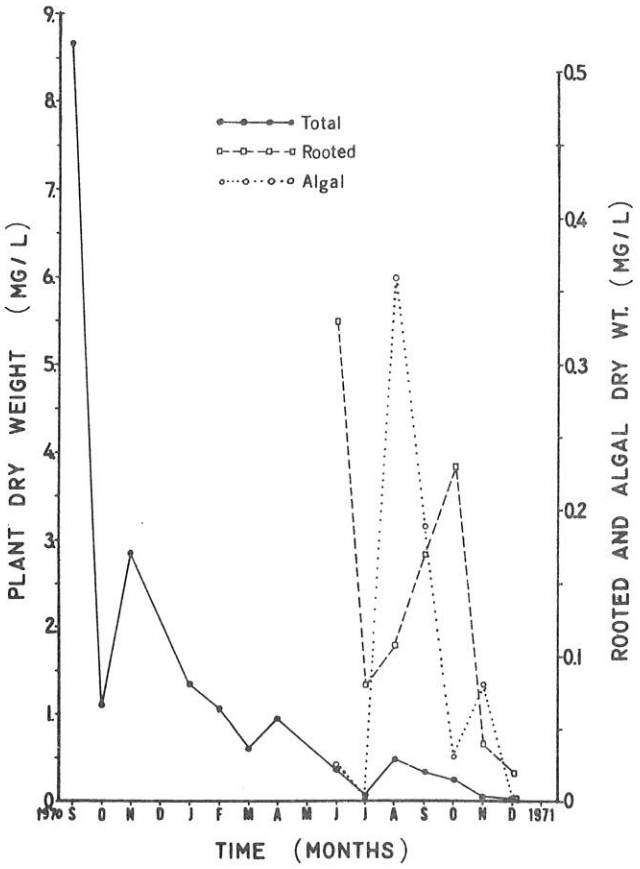

Figure 6. Plant dry weight, Off Spring.

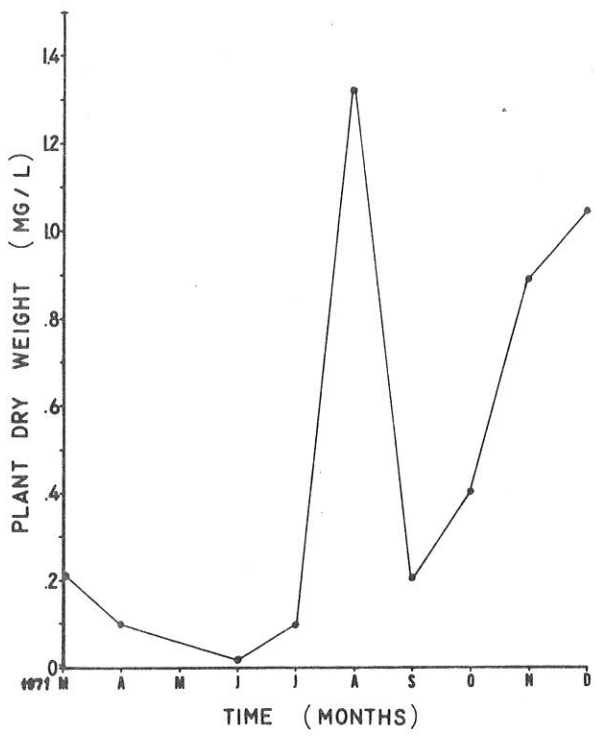

Figure 7. Plant dry weight, Off Spring channel.

Table 7. Plant dry weight (mg/1) -- Off Spring

Date	Dry Weight	Plant dry weight (Ave.) Separated	Total
September '70	0.92		8.66
	16.40		
October	1.48		1.12
	0.67		
	1.21		
November	4.15		2.88
	1.81		
January '71	2.68		1.36
	2.34		
	0.96		
February	0.79		1.05
	0.88		
	2.15		
March	0.13		0.59
	0.44		
	0.10		
April	1.23		0.99
	1.29		
	1.44		
June	0.23	Rooted .33	
	0.04	Algal .02	.35
	0.01		
	0.03		
	0.03		
July	0.95	Rooted .08	
	0.01	Algal .003	.083
	0.01		
August	0.23	Rooted .107	
	0.00	Algal .36	.47
	0.13		
	0.80		
	0.08		
	0.29		
September	0.11	Rooted .17	
	0.05	Algal .18	.35
	0.31		
	0.40		
	0.07		
October	0.22	Rooted .23	
	0.37	Algal .03	.26
	0.33		
	0.08		
November	0.00	Rooted .04	
	0.23	Algal .08	.12
December	0.10	Rooted .02	
		Algal 0	.02

Table 8. Plant dry weight (mg/1) -- Off Spring channel

Date	Dry Weight mg/1	Plant dry weight (Ave.) Separated mg/1	Total
March '71	0.30		.21
	0.13		
April	0.00		.10
	0.20		
June	0.04		.02
	0.00		
July	0.13		.10
	0.07		
August	1.70	2.08	1.32
	2.47		
	0.47	0.35	
	0.23		
	0.03	0.52	
	1.02		
September	0.02	0.32	0.21
	0.63		
	0.08	0.08	
	0.11		
	0.35	0.23	
October	0.72	0.48	0.41
	0.24		
	0.02	0.02	
	0.01		
	1.33	0.73	
	0.13		
November	3.62	1.87	0.88
	0.12		
	0.02	0.02	
	0.09	0.75	
	1.42		
December	1.90	1.82	1.05
	1.75		
	0.16	0.14	
	0.13		
	0.43		
	1.97	1.20	

Table 9. Caloric values of plant material -- Off Spring

Date	Type	Samples cal/gm	Average cal/gm
January	Mixed	3518.7	
		3641.8	3604.8
		3653.8	
February	"	3695.9	
		3642.2	3678.0
		3695.9	
July	Rooted	3679.7	
		3440.7	3542.5
		3507.1	
August	Rooted	4043.1	
		3608.8	3841.4
		3872.4	
September	"	3723.5	
		3824.5	3874.1
		4074.4	
October	"	4001.3	
		3955.4	3921.3
		3807.3	
November	"	4023.6	
		3851.1	3996.3
		4114.2	

Table 10. Planktonic invertebrates (numbers/1) -- Off Spring

Taxon	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1970									
Copepods	8.55	147.53	579.32	1554.1	4946.5	3039.7	2100	749.44	
Cladocera	9.1	146.91	43.75	49.4	79.01	73.61	166.67	63.33	
Ostracods	1.81	18.52	0.77	11.7	29.63			36.94	
Rotifers		17.16	1.54	11.95	1568.8	343.61	100.0	263.89	

Taxon	Jan	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971												
Copepods	600	207.78		32.59		39.17	120.00	11.85	410.67	16.42		1.16
Cladocera	12	49.11	3.50	36.67		78.33	53.33	8.89	579.33	73.89	3.28	
Ostracods									29.33			
Rotifers	1260.00	162.44	73.50	260.74		30.46	26.66	2.96	33.00			2.32

Table 11. Planktonic invertebrates (numbers/1) -- Off Spring Channel

Taxon	Mar	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1971										
Copepods				32.41	43.52	698.52	85.76	208.33	1.53	250.67
Cladocera		17.78			17.41	526.42	27.08	317.71		24.00
Rotifers	92.59	48.89		18.53		212.59	18.06	57.29		16.00

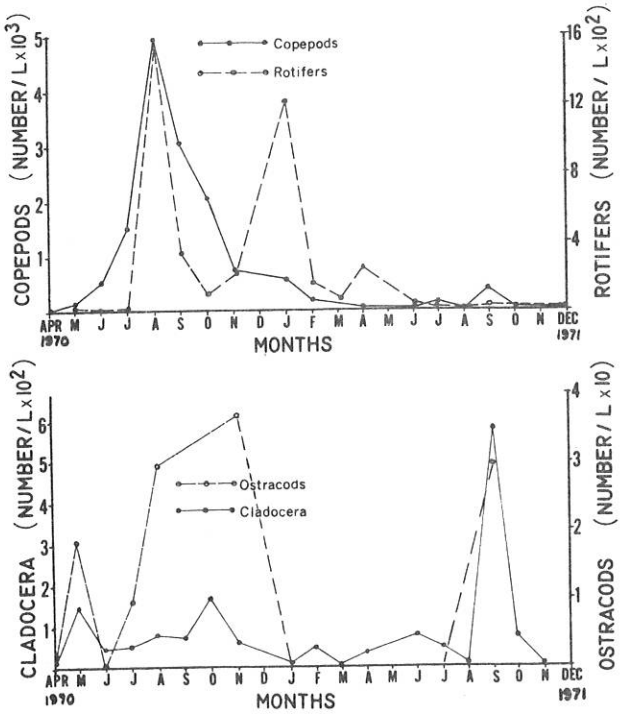

Figure 8. Planktonic invertebrates -- Off Spring.

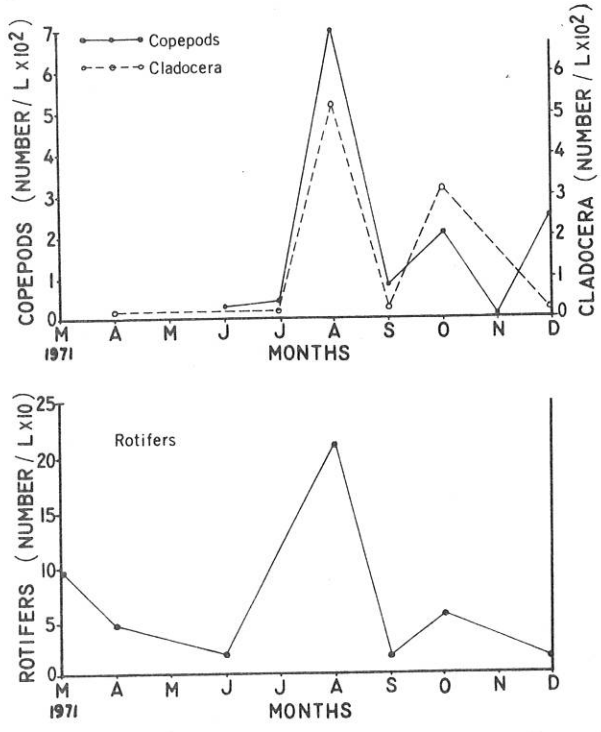

Figure 9. Planktonic invertebrates -- Off Spring channel.

Table 12. Benthic invertebrates -- Off Spring

Taxon	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
	1970						1971											
Hyalella #/liter	179.95	69.21	54.49	15.52	41.00		14.04	3.09	1.56	0.63		1.25	0	15.0	4.39		0.89	0.5
Chironomid #/cm^2	0.86	0.63	0.14	0.46	0.08		0.22	0.09	0.18	0.09		2.42	3.75	2.99	1.07		0.12	0.23
Oligocheates #/cm^2	8.74	4.25	6.16	4.78	0.23		5.08	3.05	3.85	1.39		7.49	11.8	9.17	3.26		4.89	5.89
Ischnura #/cm^2	0.19			1.29	1.6		0.93	0.42	0.44			0.83	0.11	2.0				
Callibaetis #/cm^2			1.7	1.11	7.05		0.21	0.24	0.22									
Nematode #/cm^2	.04		0.38									0.06	0.29					
Physa #/cm^2				0.67	0.6													

Table 13. Benthic invertebrates -- Off Spring channel

Taxon	Mar.	Apr.	May	June	July	1971 Aug.	Sept.	Oct.	Nov.	Dec.
Hyalella #/liter	206.66	23.33		1.43	338.33	533.12	124.78		225.39	360.61
Chironomid #/cm^2		0.86		3.44	3.85	1.39	1.31		0.23	0.37
Oligocheates #/cm^2	6.40	2.96		3.88	7.9	8.51	10.41		2.23	7.13
Nematode #/cm^2		0.06		.06	0.12	0.23	0.46			0.06
Ischnura #/cm^2						0.61			3.44	13.89
Callibaetis #/cm^2						3.33			10.66	
Hyrudinea #/cm^2										

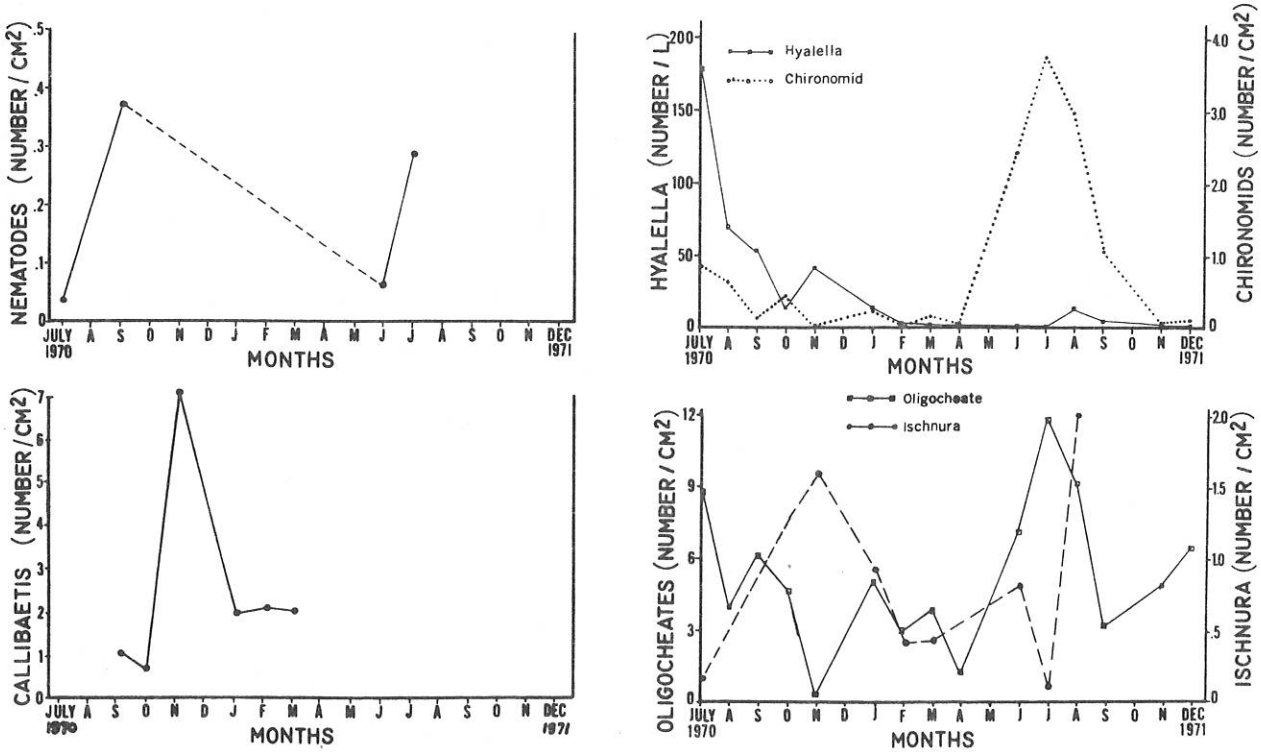

Figure 10. Benthic invertebrates -- Off Spring.

Table 14. Mean weight and estimate of fish population -- Off Spring

Date	Fish Size	Mean Wt. gm	Est. of Pop.	Standard Error
June, '71	Greater than 70 mm	7.1	no estimate	1823.09
	Less than 70 mm	2.6	10185.39	1545.23
	Combined	2.7	44332.74	5999.21
July	Greater than 70 mm	4.3	no estimate	2036.18
	Less than 70 mm	2.7	8682.50	6072.55
	Combined	2.7	10816.00	7573.39
August	Greater than 70 mm	6.5	no estimate	761.46
	Less than 70 mm	3.2	459.00	209.87
	Combined	3.2	1721.75	823.60
September	Greater than 70 mm	5.0	no estimate	171.82
	Less than 70 mm	2.0	86.00	0.0
	Combined	2.0	6552.00	3172.25
October	Greater than 70 mm	7.0	1053.00	495.23
	Less than 70 mm	1.4	17600.10	3772.33
	Combined	1.4	18806.09	3752.89
November	Greater than 70 mm	5.0	660.00	448.75
	Less than 70 mm	2.3	8058.00	3204.65
	Combined	2.3	9328.00	3432.22
December	Greater than 70 mm	4.8	2784.00	1931.51
	Less than 70 mm	2.2	756.00	414.17
	Combined	2.3	3696.75	1795.47

Table 15. Planktonic bacterial biomass without visible algae or plants

Date	No. Bacteria ml^{-1}	Log. No. ml^{-1}	Biomass* gm ml^{-1}
11 Mar., '70	1,700	3.230	1.7×10^{-9}
1 Apr.	3,600	3.556	3.6×10^{-9}
21 Apr.	29,000	4.380	2.9×10^{-8}
9 July	158,000	5.199	1.6×10^{-8}
20 Aug.	5,000	3.700	5.0×10^{-9}
4 Sept.	41,000	4.613	4.1×10^{-8}
15 Oct.	6,300	3.799	6.3×10^{-8}
13 Nov.	8,000	3.930	8.0×10^{-9}
8 Dec.	4,000	3.602	4.0×10^{-9}
24 Jan., '71	12,000	4.080	1.2×10^{-8}
28 Feb.	4,800	3.671	4.8×10^{-9}
30 Apr.	5,000	3.653	5.0×10^{-9}
19 June	4,700	3.672	4.8×10^{-9}
15 Aug.	500	2.698	5.0×10^{-10}
10 Oct.	1,600	3.204	1.6×10^{-9}
15 Nov.	1,250	3.097	1.3×10^{-9}
20 Dec.	750	2.875	7.5×10^{-10}
Average		3.700 (=5000)	12×10^{-9}

* Biomass based on 10^{-12} gm $cell^{-1}$ viable count.

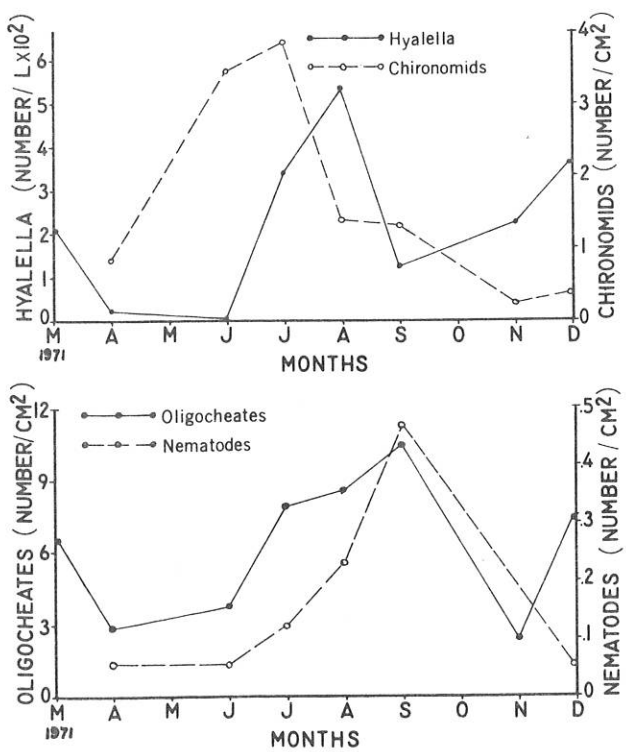

Figure 11. Benthic invertebrates, Off Spring channel.

Table 16. Benthic and plant-attached bacterial biomass

Date		No. Bacteria ml^{-1} or gm^{-1}	Log No. ml^{-1} or gm^{-1}	Biomass* gm ml^{-1} or gm^{-1}
Mud	1 Apr., '70	1.5×10^6	6.176	1.5×10^{-6}
	9 July, '70	2.5×10^8	8.398	2.5×10^{-4}
	20 Aug., '70	6.5×10^6	6.812	6.5×10^{-6}
	Average		7.129(=1.4×10^7)	2.6×10^{-4}
Algae	11 Mar., '70	9×10^4	4.954	9.0×10^{-8}
Plants	20 Aug., '70	6×10^4	4.778	6.0×10^{-8}

* Biomass based on 10^{-12} gm $cell^{-1}$ viable count.

Table 17. Miscellaneous bacterial groups

Date	Sample type	Bacterial Group	No. Bacteria ml^{-1} or gm^{-1}
1 Apr., '70	Mud	MPN Nitrate Reducers	3.6×10^5
4 Sept., '70	Water	MF Coliforms	3.5

Table 18. Glucose-C^{14} uptake and total count

Date	Log_{10} Count ml^{-1}	Cpm 1000^{-1} Cells 2 hr^{-1}	Log_{10} Cpm
9 July, '70	5.199	14	1.146
4 Sept.	4.613	38	1.580
15 Oct.	3.799	603	2.780
13 Nov.	3.930	154	2.188
8 Dec.	3.602	375	2.574
24 Jan., '71	4.080	623	2.794
28 Feb.	3.671	354	2.549
30 Apr.	3.653	212	2.326
19 Jan.	3.672	256	2.408
15 Aug.	2.698	5330	3.727
10 Oct.	3.204	413	2.615
15 Nov.	3.097	1535	3.186
20 Dec., '71	2.875	1545	3.189
Average	3.700(=5000 cells)		2.543(=350 cpm 1000^{-1} cells

Table 19. Glucose-C^{14} uptake kinetics

Date	Total Count ml^{-1}	Hrs. Turnover time	Velocity µg glucose l^{-1} $hr.^{-1}$
19 June 71	4700	375	1.6
11 July	--	110	1.2
15 Aug.	500	98	0.7
10 Oct.	1600	210	1.4
15 Nov.	1250	98	0.43
20 Dec.	750	290	0.32

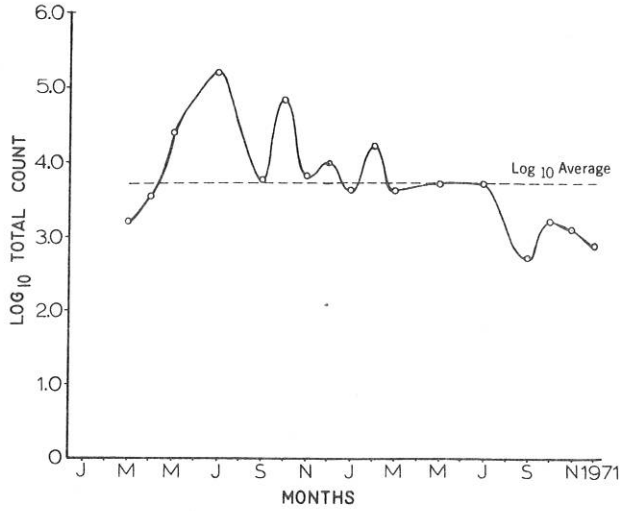

Figure 12. Bacteria total count -- Off Spring.

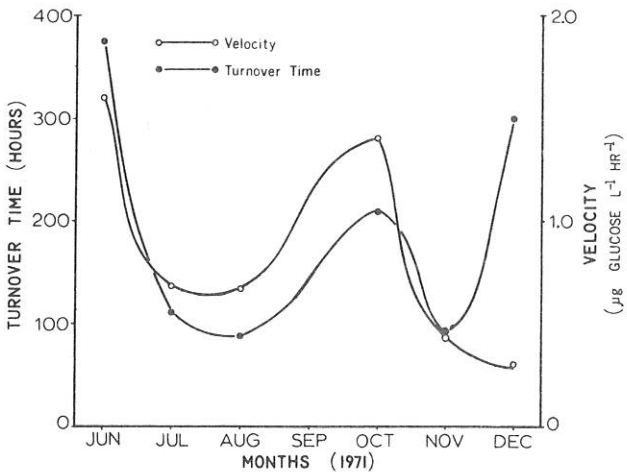

Figure 13. Glucose C^{14} uptake -- Off Spring.

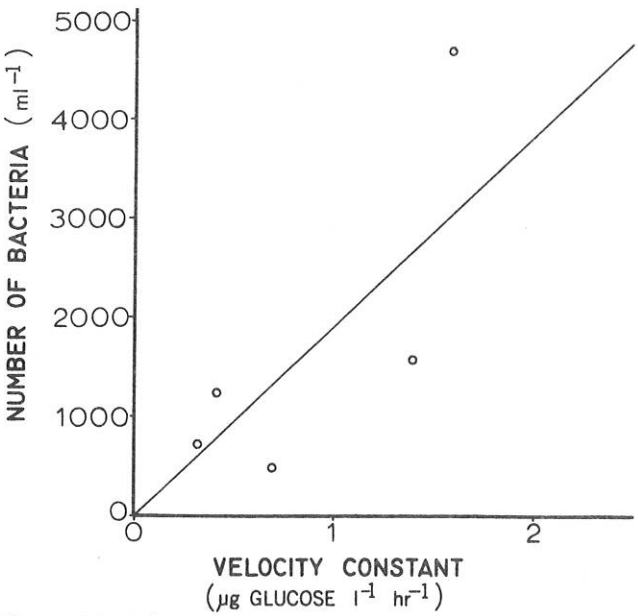

Figure 14. Relationship of velocity constant to bacterial number in Off Spring.

DISCUSSION

Though this study was designed primarily to supply values for the testing of the aquatic model, interesting observations were made on the differences between the two years of data collection. Inadvertently, Off Spring was poisoned with rotenone in the fall of 1969, thus eliminating all the fish from the pool. In order to have a complete system, 360 *Gila atraria* (Utah chub) of known weight and length were placed in the pool in June of 1970. During the 1970 growth season the pool was choked with vegetation mats of *Potomogeton* and *Cladophora* from bottom to the surface, so much so that our collection methods had to be modified to deal with it. Figure 6 shows the large amount of plant material still in the pool by September, 1970. From November, 1970, on there was a steady drop in plant standing crop without any recovery in the summer of 1971, except for a slight rise in August. Numbers of *Hyalella azteca* also were higher during the summer and fall of 1970 (Figure 10) and fell to almost negligible values through 1971, with a slight recovery in August of that year. This seems to be a logical interaction, since *Hyalella* is found in the vegetation mat feeding on it and using it for protection from predation.

Estimating the fish population during the summer of 1970, after the introduction of the *Gila*, proved to be very difficult because of the vegetation mat. Electro-fishing had to be abandoned and baited traps were used. Therefore, population estimates are not available until June of 1971. However, visual observations and photographs of the clear spring cone areas indicated that reproduction of the *Gila* was excellent during the summer of 1970. By June, 1971, the population was estimated at approximately 44,300. *Gila* are omnivorous and must have been feeding on both the vegetation mats and the invertebrates. This may account for the depletion of both plants and *Hyalella*. Numbers of other invertebrates in the pool (e.g., Chironomids) appeared to reach peaks in the summer of both years (Figure 10) in spite of the huge fish population. From this it appears that *Hyalella* numbers are more closely tied to vegetation amounts. When *Hyalella* numbers and plant dry weight per liter are plotted on the same graph for several months, a possible correlation is evident (Figure 15). As 1971 progressed the fish population declined, possibly from emigration, reduced reproduction, lack of food or cover, or predation on the fry by the adults and on adults by mergasers and herons. Physical and chemical factors were similar for both years, the changes being evident only in the biotic community of the pool.

This desert spring pool is a very simple biological community with a delicate balance which is easily disturbed. Removal of the fish released the controls on the plant growth, which then supplied an abundance of food for the few fish added in 1970. Figure 16 gives a simple energy-flow diagram for Off Spring.

The amounts of dissolved nutrients in the water are very low and rather stable (Tables 3 and 4). Yet where does the

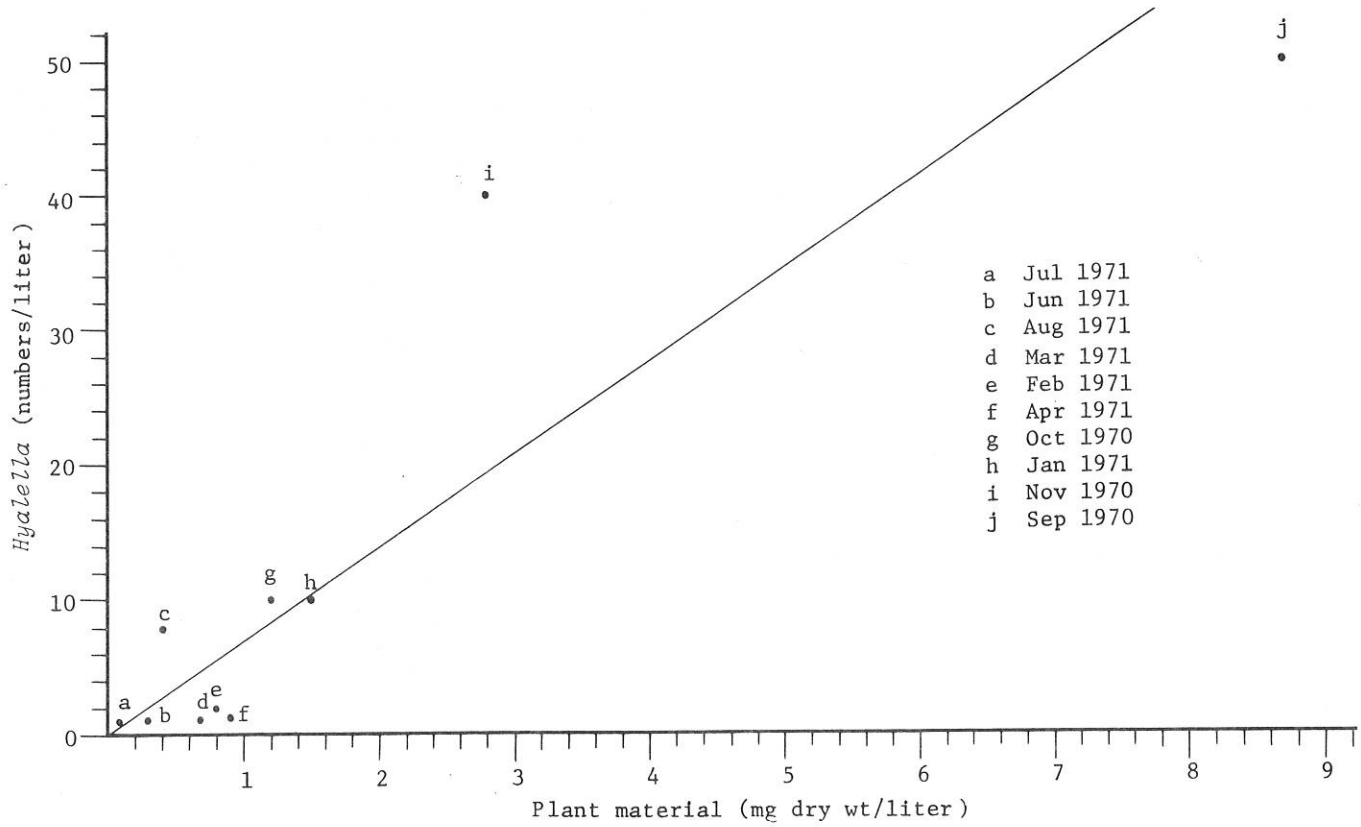

Figure 15. *Hyallella azteca* numbers related to dry weight of plant material in Off Spring.

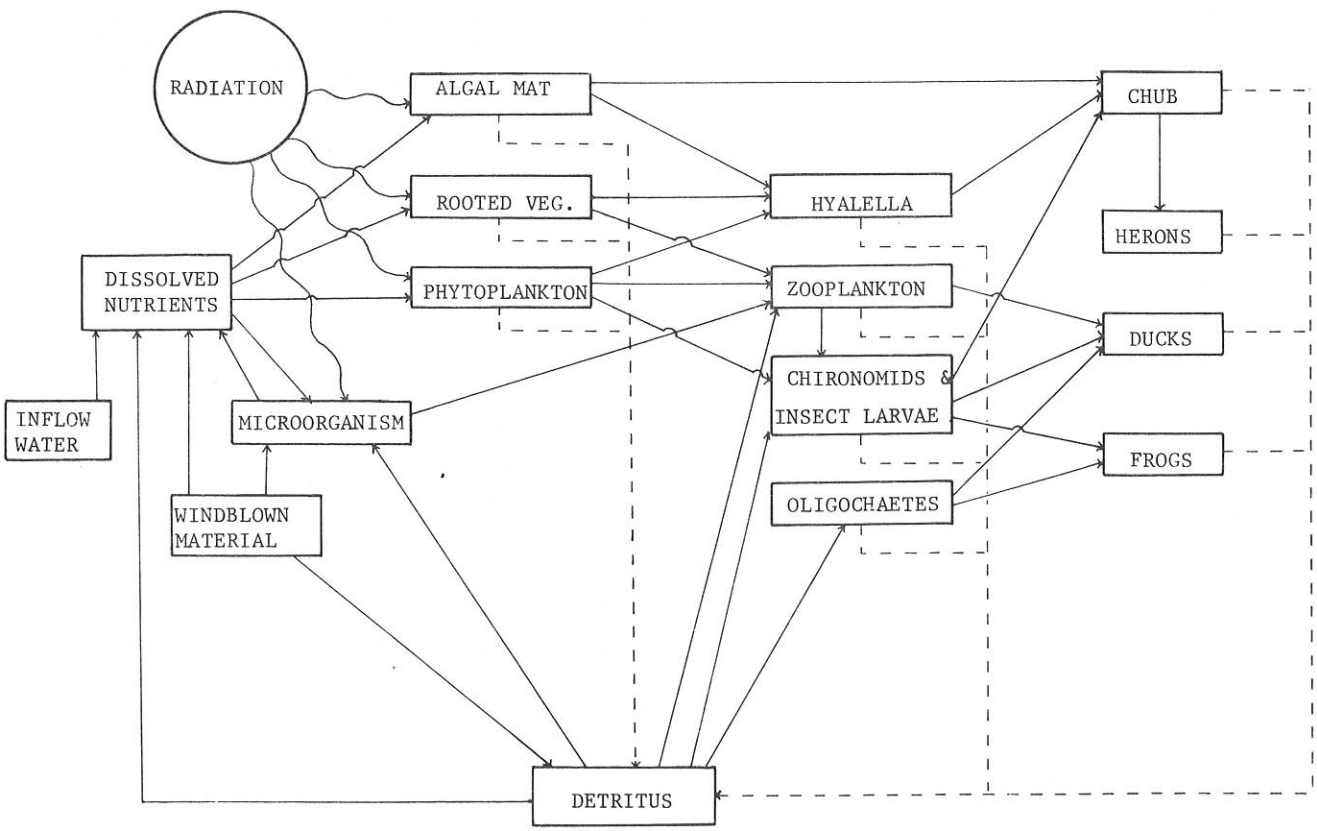

Figure 16. A simple energy flow diagram for Off Spring. Interrupted lines indicate contributors to the detritus pool.

vegetation obtain these nutrients? It has been hypothesized that the vegetation mats may be constantly releasing nutrients into the water. These are then immediately taken up by the plants again. Certainly the results in Tables 15 and 16 indicate far greater numbers of bacteria attached to the plants and associated with the bottom than found free in the water.

The kinetics of uptake of uniformly-labeled glucose-C^{14} appears to be a useful tool for determining microbial activity and mineralization of carbon. Based on rather limited sampling, uptake velocity seems to be related to numbers of bacteria. Effort centered on planktonic bacteria due to limited funding. Some samples of vegetation and mud suggest that in the future these habitats should be studied much more extensively since the heterotrophic biomass represented here (and especially on the mud surface; Harrison et al., 1971) is significantly greater than in the plankton. Glucose velocity constants for the planktonic bacteria in Off Spring agree reasonably well with similar environments as reported in the literature, about 1.0 to 1.6 μg glucose per liter per hour. The mud surface would be expected to mineralize carbon at a rate of about 25 times that of the plankton (Harrison et al., 1971). Carbon substrates other than glucose (acetate, proline) should be studied also since a significant proportion of the bacteria present does not utilize glucose.

ACKNOWLEDGEMENTS

Irene Walkiw served as chief research assistant on the project. Mike Brooks and Richard Howard assisted with the field work. Dr. Clair Stalnaker was in charge of the fish population estimates.

LITERATURE CITED

American Public Health Assoc. 1965. Standard methods for the examination of water and wastewater, 12th ed. Amer. Publ. Health Assoc. Inc., N.Y. 769 pp.

Harrison, M. J., R. T. Wright, and R. Y. Morita. 1971. Methods for measuring mineralization in lake sediments. Applied Microbiol. 21:698-702.

Hobbie, J. E. 1969. A method for studying heterotrophic bacteria. *In* R. A. Vollenweider (ed.), A manual on methods for measuring primary production in aquatic environments. IBP Handbook No. 12. Blackwell Scientific Publications, Oxford, England. 213 pp.

Kemmerer, A. J., and J. M. Neuhold. 1969. A method for gross primary productivity measurements. Limnol. Oceanogr. 14:607-610.

Kemmerer, A. J. 1970. Primary productivity and fish production in a tertiary oxidation pond. Unpubl. Ph.D. Diss. Utah State Univ. Logan. 152 pp.

Macan, T. T. 1964. The Odonata of a moorland fishpond. Int. Rev. Ges. Hydrobiol. 49:325-360.

Odum, H. T. 1956. Primary production in flowing waters. Limnol. Oceanogr. 1:102-117.

Ricker, W. E. 1968. Methods for assessment of fish production of freshwaters. IBP Handbook No. 3. Blackwell Scientific Publications, Oxford, England.

Seki, H. 1970. Microbial biomass on particulate organic matter in seawater of the euphotic zone. Appl. Microbiol. 19:960-962.