RESEARCH TECHNICAL COMPLETION REPORT
PROJECT A-039-IDA

WATER for IDAHO

A Pilot Program to Determine the Effect of Selected Nutrients (Dissolved Organics, Phosphorus, and Nitrogen) on Nuisance Algal Growth in American Falls Reservoir

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Water Resources Research Institute
University of Idaho
Moscow, Idaho
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PERIOD OF INVESTIGATION March 1, 1971 to March 31, 1972

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Water Resources Research Institute

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INTRODUCTION

Accelerated eutrophication has become a problem of major dimension in Idaho and other parts of the United States during the past two decades. Associated with an accelerated rate, eutrophication has come an increased emphasis on understanding those factors which contribute to increased productivity in aquatic habitats. A very important part of this emphasis has involved numerous attempts to elucidate the specific nutrient requirements of a variety of algal forms. These studies have involved, for the most part, one of two general approaches. First, a large number of laboratory investigations have been conducted for the purpose of determining specific nutrient requirements of a particular algal species with the determination based upon maintaining that species under strictly controlled laboratory conditions. Secondly, investigation has involved field studies with the objective being to determine changes in ambient concentrations of a variety of growth promoting substances in relation to changes in algal populations especially during the summer months. In addition there have been other studies more limited in number in which a combination of these two broad types of investigation have been attempted. This project which is an example of the combined approach was undertaken in the attempt to ascertain the relative contribution or stimulatory effect of selected nutrients which might promote the growth of indigenous algal species in American Falls Reservoir.

In this study polyethylene tubes were employed to follow changes in abundance of naturally occuring algal species exposed to different concentrations of organic carbon and phosphorus. The experimental apparatus was positioned in a small bay on the north shore of American Falls Reservoir approximately 5 miles north of the town of American Falls, Idaho (Figure 1). Field studies were conducted during the summer, 1971, in an attempt to learn the relative contributions of these nutrients in the stimulation of algal growth in the polyethylene tubes, as well as to follow ambient concentrations of similar nutrients and physical factors in several bays of the reservoir. Originally, the specific objectives included: 1) developing a series of techniques for field analysis of the relative importance of dissolved organics, phosphorus and nitrogen, in the stimulation of algal growth in the reservoir; and 2) testing the design and feasibility of large suspended polyethylene tubes as culture chambers for in situ nutrient studies in reservoirs or lakes. Ancillary objectives included: 1) field testing a technique (Fitzgerald 1968) for extractive and enzymatic analysis for detection of surplus phosphorus in algae; 2) estimation of primary production (due to phytoplankton activity) both before and during conditions of an algal bloom using a combination of dissolved oxygen and pH techniques (Verduin 1956 a.b., 1957); and 3) a measurement of nitrate nitrogen was to be attempted using a specific ion probe.

In general, the primary objectives were accomplished satisfactorily within the limitations of time and funding allotted to the project. However, ancillary objectives were not accomplished, primarily as a result of the inavailability of proper equipment at a time when

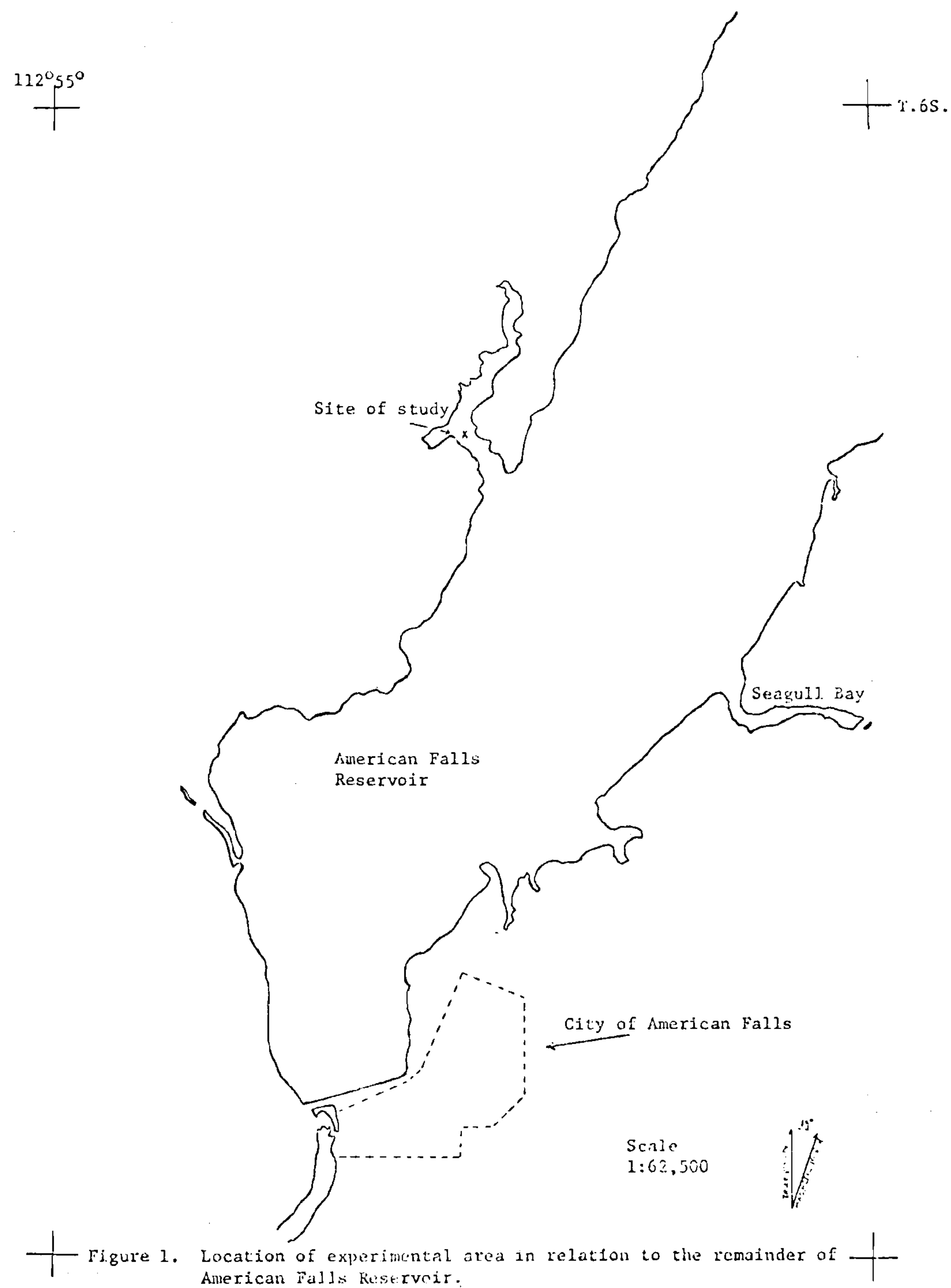

Figure 1. Location of experimental area in relation to the remainder of American Falls Reservoir.

measurements could be made. Notwithstanding, the investigators have a sense of considerable accomplishment both in terms of data collected and in terms of the experience gained. It should be noted that neither investigator received compensation for the considerable time they spent both in preparation and in the actual field work. It is our belief that this preliminary study shows additional work using polyethylene tubes is warranted and that with certain refinements the methods indeed show considerable promise for the investigation of those factors which regulate or promote algal growth in standing bodies of water. As a result of the experience gained in this study, a series of recommendations can now be made for additional work of this type.

METHODS

The polyethylene tubes which served as culture chambers for *in situ* nutrient studies employed in this study were constructed by heat sealing the margins of polyethylene sheeting. The tubes were so constructed that each tube had a diameter of 30 centimeters and a length of 4 meters. Some difficulty was encountered in the sealing procedure and was overcome after considerable experimentation. After testing for leaks the tubes were transported to the reservoir where measured amounts of the selected nutrients were introduced or enough distilled water added to achieve desired concentrations. Each column was then seeded with organisms using reservoir water. The columns were placed in position attached to flotation collars and were serviced; and samples were collected using a mobile floating platform which had been constructed using styrofoam floats and a planked metal framework.

Plankton counts were obtained by microscopic analysis using a Sedgewick Rafter cell. In some instances it was necessary to subject the raw samples to centrifugation in order that a concentration of organisms was obtained which would yield reliable counting data. In addition, water samples were collected from various bays of the American Falls Reservoir and an abundance of plankton organisms were determined in the same way. Sherri Nanninga, a student, helped in preparation of samples and in the actual counting.

Total and soluble phosphorus and total and soluble orthosphosphate were measured according to procedures described in the manual, "Analytical Techniques for the National Eutrophication Research Program" (Krawczyk 1969). A corrected equation: corrected absorbance x $\frac{\text{concentration of standard}}{\text{absorbance of standard}}$ x dilution factor was used in place of the published one. Results are expressed as mg/l phosphorus.

Analyses for nitrogen were carried out using reagents prepared by the Hach Chemical Company (Ammonium-N by direct Nesslerization method; Nitrite-N by diazotization method; Nitrate-N by cadmium reduction method) and a Bausch & Lomb "Spectronic 20" colorimeter. Results are expressed as mg/l nitrogen.

Particular and dissolved organic carbon were measured by quantitative dichromate oxidation (Maciolek 1962; Strickland and Parsons 1968). Oxygen consumed (mg) was converted to calories using a coefficient of 3.4. Results are reported as cal/l. Spectrophotometric determination of chlorophyll a was carried out according to the methods of Strickland and Parsons (1968) employing Lorenzen's method to correct for inactive chlorophyll degradation products. The algae were collected on glass fiber filters prior to extraction.

Total dissolved solids were estimated from specific conductance measurements (Am. Publ. Health Assoc. 1965) by multiplying the factor 0.65 (+0.1) (Rainwater and Thatcher 1960). All chemical analyses were performed by James Terch and Tom Jarmon performed the chlorophyll analyses.

The experimental portion of the study was designed to utilize two sets of tubes consisting of 6 tubes each (Figure 2). Both sets were to contain identical series of orthophosphate (K_2HPO_4) concentrations and one set was also to have 2 mg/l glucose ($C_6H_{12}O_6$) added to each tube. The planned orthosphosphate concentrations were 0.05, 0.1, 0.6, 1.2 and 2.4 plus a control of reservoir water. However, the original phosphate content of the make-up water was initially miscalculated due to an error in the published procedures. Consequently, the actual (calculated) orthophosphate concentrations were 0.005, 0.01, 0.46, 1.06 and 2.26, respectively, based on an assumed value of 0.016 mg/l for the reservoir water. Water samples from the tubes were taken at 0.5 m depths.

RESULTS

This investigation involved the documentation of water quality conditions at five selected sites throughout American Falls Reservoir

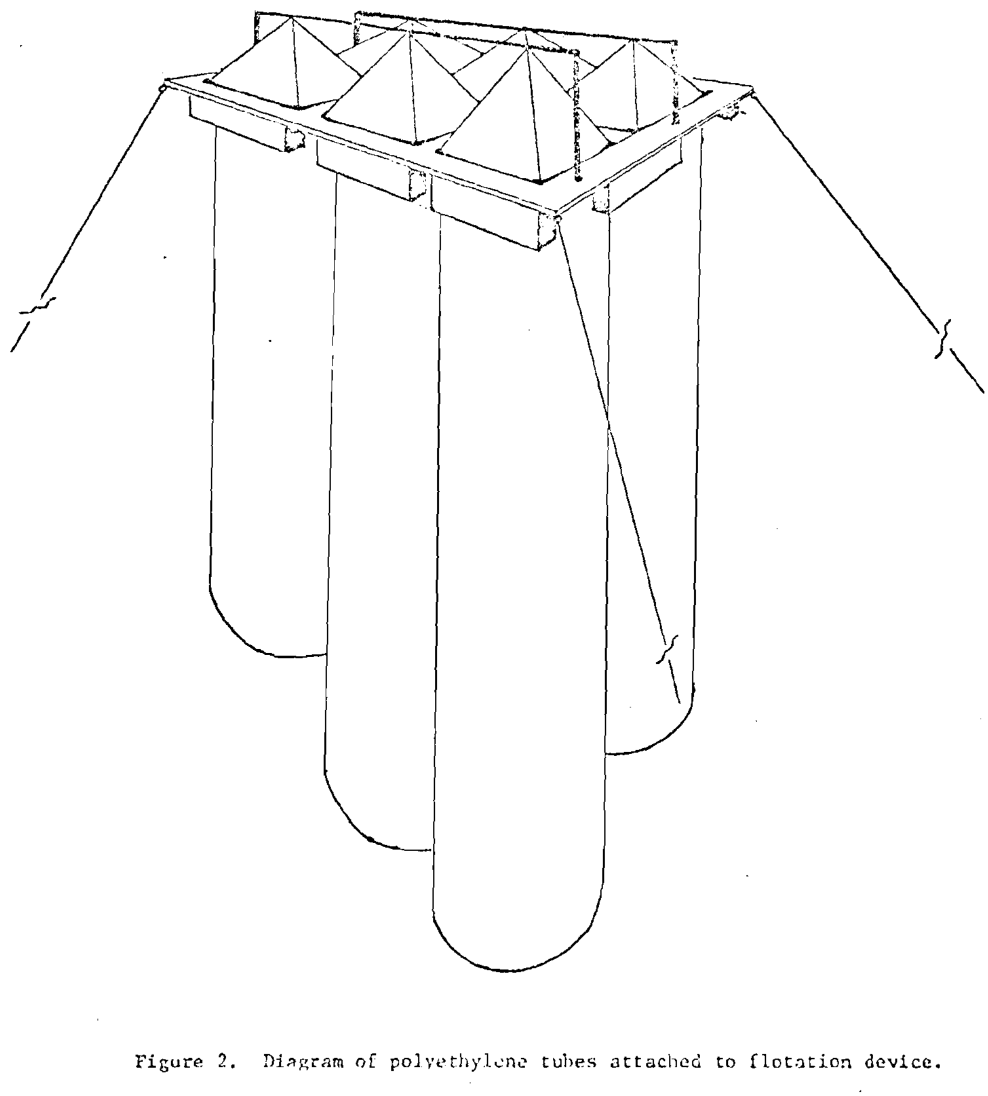

Figure 2. Diagram of polyethylene tubes attached to flotation device.

and the manipulation of potential algal nutrients in experimental tubes located in an unnamed bay on the northwest side of the reservoir.

Conditions in American Falls Reservoir

Measurements of total dissolved solids, nitrogen (nitrate, nitrite, ammonia) and phosphorus, were made at five stations in the reservoir during the period of 26 May through 27 July 1971. Organic carbon, chlorophyll a and total number of cells were determined on 3 or 4 occasions beginning the end of June. In addition, a single complete set of determinations was made for samples taken at the mouth of the Portneuf River on 27 July.

There was a general decrease in total dissolved solids during the study period (Table 1). Values were consistently lowest at Big Hole and generally higher at Bannock Creek, Unnamed Bay and Little Hole. Nitrate values were highest in May (the first sampling date) at Bannock Creek, Big Hole and Little Hole and on 30 June in Unnamed Bay and Sea Gull Bay; lowest values were recorded on 13 July at all stations except Sea Gull Bay. High ammonium-nitrogen values were recorded at the outset (26 May) at all stations except Big Hole; lowest concentrations were measured in June for all except Bannock Creek. Most of the orthophosphate was in the soluble form, but a fair proportion of the total phosphate frequently was in the particulate form. A discrepancy is evident in the values for 30 June when the total soluble phosphate values exceeded the total phosphate levels at all stations except Bannock Creek. Phosphate concentrations gradually declined during the study period with soluble orthophosphate reaching

Table 1. Phosphorus, nitrogen, and total dissolved solids concentrations at selected locations in American Falls Reservoir, Idaho during summer 1971. All values expressed as mg/l.

	Soluble Ortho-P	Total Ortho-P	Total Soluble-P	Total-P	Nitrite-N	Nitrate-N	Ammonia-N	TDS
Bannock Creek								
5-26	-	-	-	-	.006	.174	0.72	261
6-12	.06	-	.09	.20	.008	.122	0.59	265
6-30	.06	-	.08	.16	.005	.155	0.64	232
7-13	.02	.03	.02	.06	.005	.075	0.37	203
7-27	.01	.02	.04	.05	.001	.139	0.50	190
Big Hole								
5-26	-	-	-	-	.006	.204	0.50	209
6-12	.01	-	.00	.10	.005	.075	0.47	187
6-30	.03	-	.11	.06	.005	.165	0.48	198
7-13	.01	.02	.01	.03	.001	.059	0.44	188
7-27	.00	.02	.02	.06	.001	.119	0.65	179
Unnamed Bay								
5-26	-	-	-	-	.001	.129	1.03	267
6-12	.10	-	.37	.54	.005	.065	0.37	223
6-30	.04	-	.07	.06	.008	.162	0.53	205
7-13	.02	.02	.02	.06	.003	.047	0.43	196
7-27	.00	.02	.01	.05	.001	.129	0.66	187
Little Hole								
5-26	-	-	-	-	.006	.174	0.56	241
6-12	.01	-	.02	.10	.001	.059	0.35	228
6-30	.02	-	.04	.03	.005	.155	0.50	214
7-13	.02	.02	.01	.06	.001	.049	0.45	216
7-27	.00	.03	.02	.06	.001	.129	0.43	190
Sea Gull Bay								
5-26	-	-	-	-	.005	.145	0.58	256
6-12	.02	-	.00	.02	.002	.048	0.30	195
6-30	.02	-	.10	.09	.007	.173	0.56	201
7-13	.02	.03	.01	.06	.002	.058	0.48	195
7-27	-	.02	.01	.05	-	-	-	-

a negligible level by 27 July. The trend in reduction of phosphorus generally was more consistant than that for nitrogen and is more likely to have reached limiting levels by 27 July.

Highest dissolved organic carbon levels (Table 2) were registered at Big Hole and Little Hole. High particulate organic carbon and chlorophyll a values in excess of 1 mg/l were recorded at least once at all stations. In general, values for these parameters as well as for total cell counts were greatest on the last date collections were made (14 August).

Temperature data was collected at five locations in several bays around American Falls Reservoir. These data are summarized in the five figures included in Appendix I. Generally there was an increase in surface temperatures from approximately 15° or $25^{\circ}C$. during the period 26 May to 12 August 1971. Temperatures at the 3 meter and 5 meter depths were routinely 2 to 7 degrees cooler than at the surface but exhibited the same overall increase with time.

Cell counts of planktonic organisms were made from samples collected in three bays of American Falls Reservoir. These data are summarized in Figure 3 and indicate that an overall increase in planktonic organisms occurred from the period 26 May to 12 August 1971. At the time of the late June sampling there was a slight decrease in the total cell count at all stations. This change corresponds with a decline in surface water temperatures associated with mixing of surface waters after a period of windy weather. At the time of the last sampling total cell counts in all bays exceeded 1,000 cells/ml.

Table 2. Organic carbon, chlorophyll a, and total number of algae at selected locations in American Falls Reservoir, Idaho during summer 1971.

	Bannock Creek	Big Hole	Unnamed Bay	Little Hole	Sea Gull Bay	Portneuf River
Organic Carbon (cal/l)						
Dissolved						
30 June	4.26	9.00	0.94	0.00	1.42	
13 July	0.42	0.00	1.28	0.00	0.42	
27 July	5.74	11.48	2.88	29.68	0.00	16.28
Particulate						
30 June	9.94	2.36	4.26	1.42	9.00	
13 July	2.14	1.28	2.14	9.88	8.16	
27 July	14.84	14.36	9.10	4.78	14.36	15.80
Chlorophyll a (mg/m^3)						
30 June	0.21	0.43	0.37	0.53	0.27	
13 July	1.12	0.32	0.21	0.27	0.16	
27 July	0.37	0.59	1.39	0.00	0.11	0.59
14 August	0.00	1.17	2.14	1.07	1.07	
Total Cells ($x10^3/ml$)[1.]						
29 June		0.43	0.41	1.5		
13 July		0.39	1.05	3.7		
29 July		7.6	M	3.7		
12 August		11.5	21.0	9.9		

[1.] Expressed as totals of individuals of <u>Melosira</u> and <u>Fragillaria</u> and colonies of <u>Aphanizomenon</u>.

M = missing

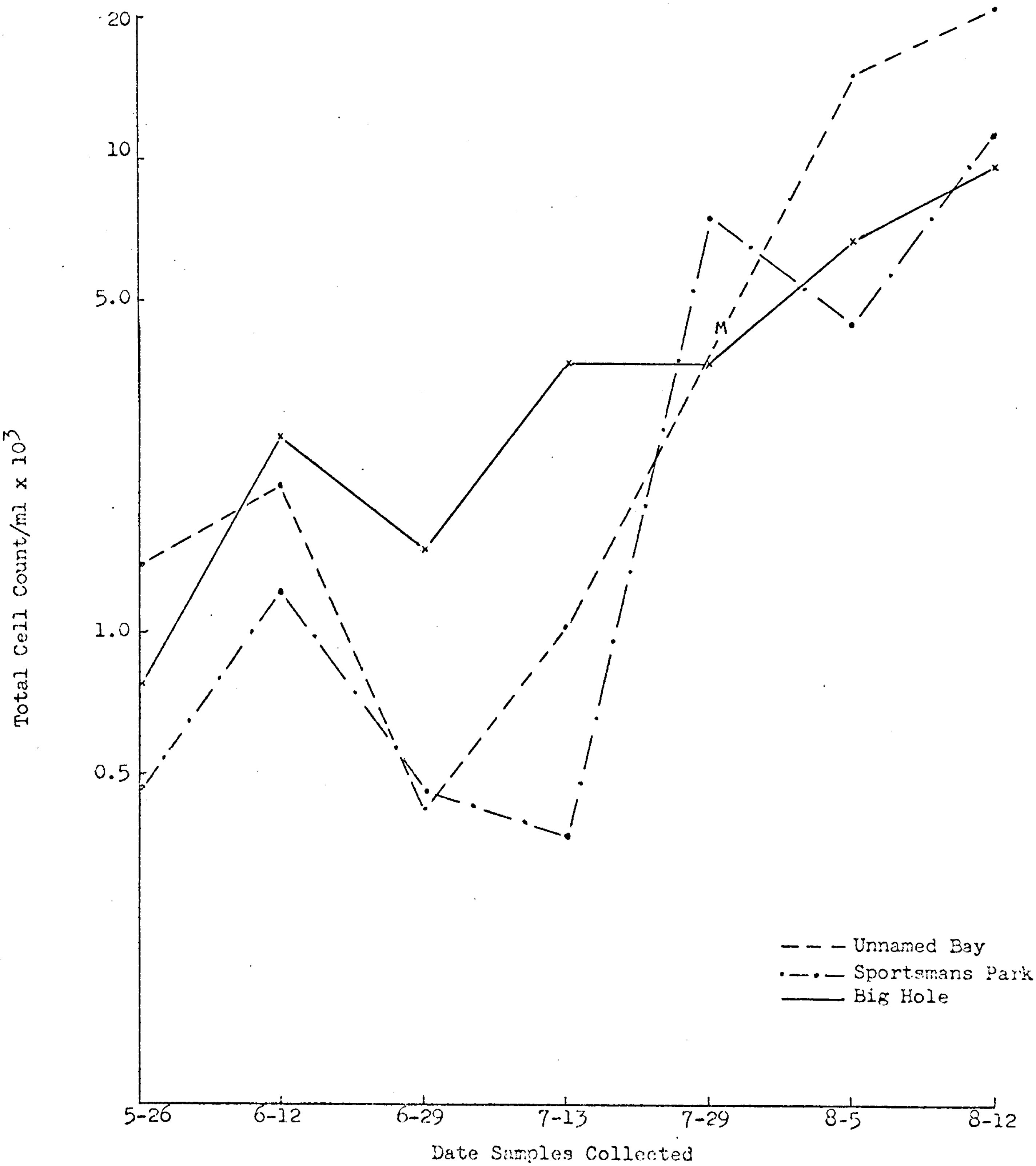

Figure 3. Total cell counts for phytoplankton organisms in three bays of American Falls Reservoir.
M = missing

Experimental Tubes

Essentially all of the orthophosphate present was in the soluble form (Table 3). Therefore, only this data is illustrated (Figure 4) even though total orthophosphate was also measured. The amounts present in the control tubes and those in the two lowest concentrations were too small to be detected by the procedures used. The measured orthophosphate values for both sets of tubes are in the correct sequence expected from the calculated concentrations. However, they are not identical between sets for any given concentration, nor are they precisely the values calculated. These discrepancies are due to the difficulty of getting the proper volume of water into each of the tubes. It should be possible to reduce this variation with further experience.

All orthophosphate concentrations were reduced by more than half by the time the experiment was terminated, but there was no consistent pattern as to which initial concentration was reduced the most. Greatest reduction in orthophosphate during the study period occurred in the 1.06 phosphorus + glucose tube (Figure 3) which also produced the largest crop of algae (Table 4, 17 August). In both sets of tubes the 0.45 mg/1 concentration ended in an intermediate position relative to the others. These differences can be explained on the basis of variations in biological activity in the tubes. However, the amount of reduction was not always strictly proportional to the inferred bio-activity. In the "phosphate-only" series the tube showing the greatest reduction in orthophosphate (2.26 mg/1; Figure 3) supported the greatest standing crop of algae as indicated by chloro-

Table 3. Phosphorus and nitrogen concentrations in experimental tubes, American Falls Reservoir, Idaho during summer 1971.

	Soluble Ortho-P	Total Ortho-P	Total Soluble-P	Total-P	Nitrite-N	Nitrate-N	Ammonia-N
1. Phosphate only controlled							
Control							
7-29	0.00	0.00	0.02	0.09	0.000	0.11	0.53
8-2	0.01	0.00	0.00	0.05	0.003	0.08	0.37
8-19	0.00	0.01	0.08	0.07	0.001	0.14	0.61
.005 mg/1							
7-29	0.00	0.00	0.01	0.06	0.005	0.11	0.45
8-2	0.00	0.00	0.01	0.04	0.001	0.10	0.40
8-19	0.00	0.01	0.01	0.05	0.000	0.16	0.40
.01 mg/1							
7-29	0.00	0.03	0.01	0.08	0.000	0.11	0.66
8-2	0.00	0.00	0.00	0.02	0.001	0.10	0.25
8-19	0.00	0.01	0.05	0.01	0.000	0.13	0.56
.45 mg/1							
7-29	0.75	1.08	0.84	1.26	0.000	0.11	0.53
8-2	0.39	0.41	0.64	0.84	0.000	0.10	0.43
8-19	0.21	0.23	0.52	0.54	0.000	0.12	0.37
1.06 mg/1							
7-29	1.07	1.05	2.18	2.17	0.001	0.11	0.61
8-2	0.80	0.85	1.03	1.18	0.000	0.11	0.15
8-19	0.46	0.49	0.91	1.08	0.000	0.12	0.50
2.26 mg/1							
7-29	1.24	1.27	1.24	1.41	0.001	0.12	0.61
8-2	1.03	1.07	1.30	1.49	0.000	0.11	0.15
8-19	0.04	0.02	0.30	0.17	0.003	0.15	0.75

	Soluble Ortho-P	Total Ortho-P	Total Soluble-P	Total-P	Nitrite-N	Nitrate-N	Ammonia-N
2. Phosphate and Glucose controlled							
Control							
7-29	0.00	0.00	0.00	0.06	0.001	0.11	0.43
8-2	0.00	0.00	0.00	0.00	0.001	0.10	0.00
8-19	0.00	0.01	0.00	0.01	0.001	0.11	0.69
.005 mg/1							
7-29	0.00	0.00	0.00	0.03	0.003	0.12	0.48
8-2	0.00	0.00	0.00	0.05	0.001	0.11	0.69
8-19	0.00	0.01	0.00	0.01	0.001	0.12	0.53
.01 mg/1							
7-29	0.00	0.00	0.00	0.04	0.001	0.10	0.48
8-2	0.00	0.00	0.01	0.05	0.001	0.10	0.21
8-19	0.01	0.00	0.07	0.05	0.001	0.11	0.43
.45 mg/1							
7-29	0.47	0.49	0.74	0.74	0.000	0.11	0.40
8-2	0.42	0.44	0.74	0.78	0.003	0.12	0.00
8-19	0.11	0.14	0.27	0.39	0.001	0.12	0.45
1.06 mg/1							
7-29	0.78	0.79	0.85	0.90	0.000	0.12	0.40
8-2	0.52	0.53	0.92	0.99	0.001	0.13	0.40
8-19	0.00	0.01	0.05	0.06	0.001	0.12	0.56
2.26 mg/1							
7-29	1.44	1.44	2.55	2.53	0.003	0.12	0.40
8-2	1.45	1.51	2.73	2.97	0.000	0.12	0.35
8-19	0.42	0.44	0.83	0.98	0.001	0.11	0.40

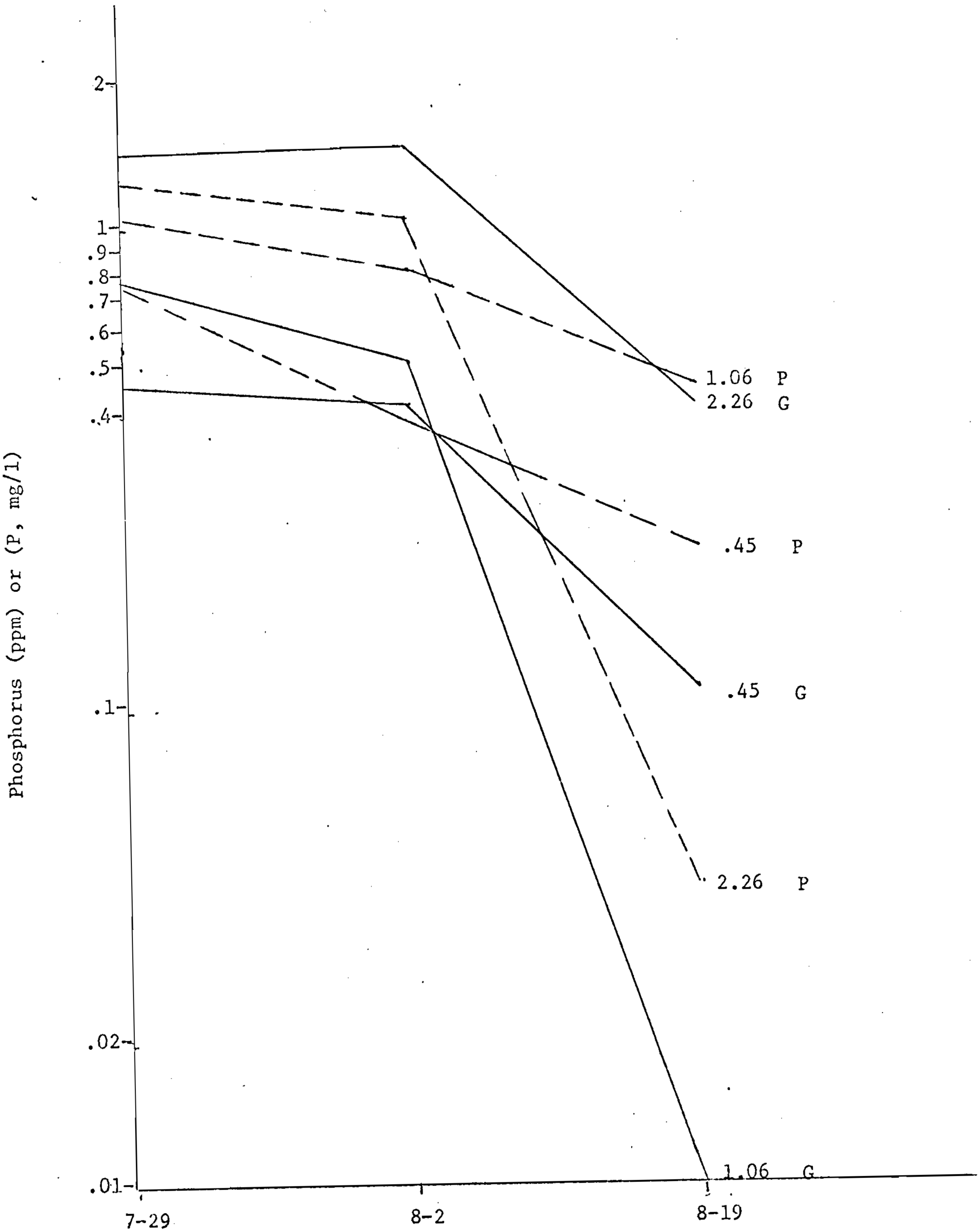

Figure 4. Soluble orthophosphate concentrations in both sets of experimental tubes (P-phosphate only; G-phosphate plus glucose).

Table 4. Organic carbon, chlorophyll _a_, and total number of algae in experimental tubes containing various concentrations of orthophosphate and a control containing reservoir water. In addition, each tube received the equivalent of 2 mg/l glucose.

	C	.005	.01	.45	1.06	2.26
Organic Carbon (cal/l)						
Dissolved						
29 July	0.00	0.00	1.40	9.14	0.00	3.28
2 August	1.64	0.00	13.60	5.44	0.00	0.48
19 August	0.94	2.84	7.10	15.62	7.58	7.10
Particulate						
29 July	0.94	11.70	6.54	0.00	1.88	9.36
2 August	10.88	4.36	9.80	10.88	6.52	3.26
19 August	4.28	8.52	6.62	8.04	8.04	30.30
Chlorophyll a (mg/m^3)						
29 July	0.53	0.00	0.00	0.27	0.27	0.00
3 August	0.27	0.00	0.00	0.00	0.00	0.00
14 August						0.53
17 August	0.00	0.00	0.00	0.00	88.11	2.67
20 August	0.00	0.05	0.00	0.00	1.34	1.01
Total Cells ($x10^3$/ml)[1]						
2 August	1.6			4.1		3.5
9 August	1.0			6.2		3.2
19 August	0.1			0.1		3.0

[1] Expressed as totals of individuals of _Melosira_ and _Fragillaria_ and colonies of _Aphanizomenon_.

phyll a values (Table 5) and vice versa (1.06 mg/l tube). The highest chlorophyll a content was also recorded in the tube showing the greatest reduction of orthophosphate (1.06 mg/l) in the"phosphorus + glucose" series, but the reverse relationships did not hold.

The investigators presently lack an explanation as to why algal growth did not increase progressively with increasing concentrations of nutrients. Differential growth and shading by attached forms growing on the sides of the tubes is a possible answer, but this factor was not measured.

Total phosphate values showed almost identical patterns to those for orthophosphate; although, as would be expected, they were always somewhat higher (Table 3). Again, most of the values appeared to be in the soluble form except in the control and the two lowest concentrations were presumably present mainly in the algae.

Nitrate and ammonium-nitrogen concentrations generally varied little and remained relatively high in all tubes through the study (Table 3). A few (questionable) exceptions were noted for ammonia in the 1.06 and 2.26 mg/l phosphate-only and in the phosphorus + glucose control and 0.45 mg/l tubes on 2 August.

Cell count data was obtained from all of the experimental tubes. However, only that data from the control tubes, the 0.45 mg/l phosphorus and phosphorus + glucose enriched tubes and the 2.26 mg/l phosphorus and phosphorus + glucose tubes is reported here. Growth of plankton in both control tubes declined during the experimental period during August 1971 except for one single exception (Figure 5 and 6). The exception to this statement involved the growth of

Table 5. Organic carbon, chlorophyll a, and total number of algae in experimental tubes containing various concentrations of orthophosphate and a control (C) containing only reservoir water.

	C	.005	.01	.45	1.06	2.26
Organic Carbon (cal/1)						
Dissolved						
29 July	4.22	0.00	0.00	6.54	0.00	2.80
2 August	5.44	0.00	11.84	1.64	0.00	14.68
19 August	0.00	1.42	8.52	4.74	0.00	12.30
Particulate						
29 July	0.00	0.00	0.46	5.38	0.00	9.82
2 August	7.08	4.90	5.98	8.70	3.26	5.44
19 August	23.20	18.46	0.00	19.40	16.56	0.00
Chlorophyll a (mg/m^3)						
29 July	0.00	0.00	0.27	0.64	0.53	0.80
3 August	0.00	0.00	1.08	0.80	0.80	0.53
14 August						5.34
17 August	1.07	0.53	0.00	1.60	0.00	10.68
20 August	0.27	1.34	0.00	0.53	0.00	2.40
Total Cells ($x10^3/ml$)[1.]						
2 August				3.5		17.0
9 August				6.1		42.2
19 August				0.1		1.2

1. Expressed as totals of individuals of Melosira and Fragillaria and colonies of Aphanizomenon.

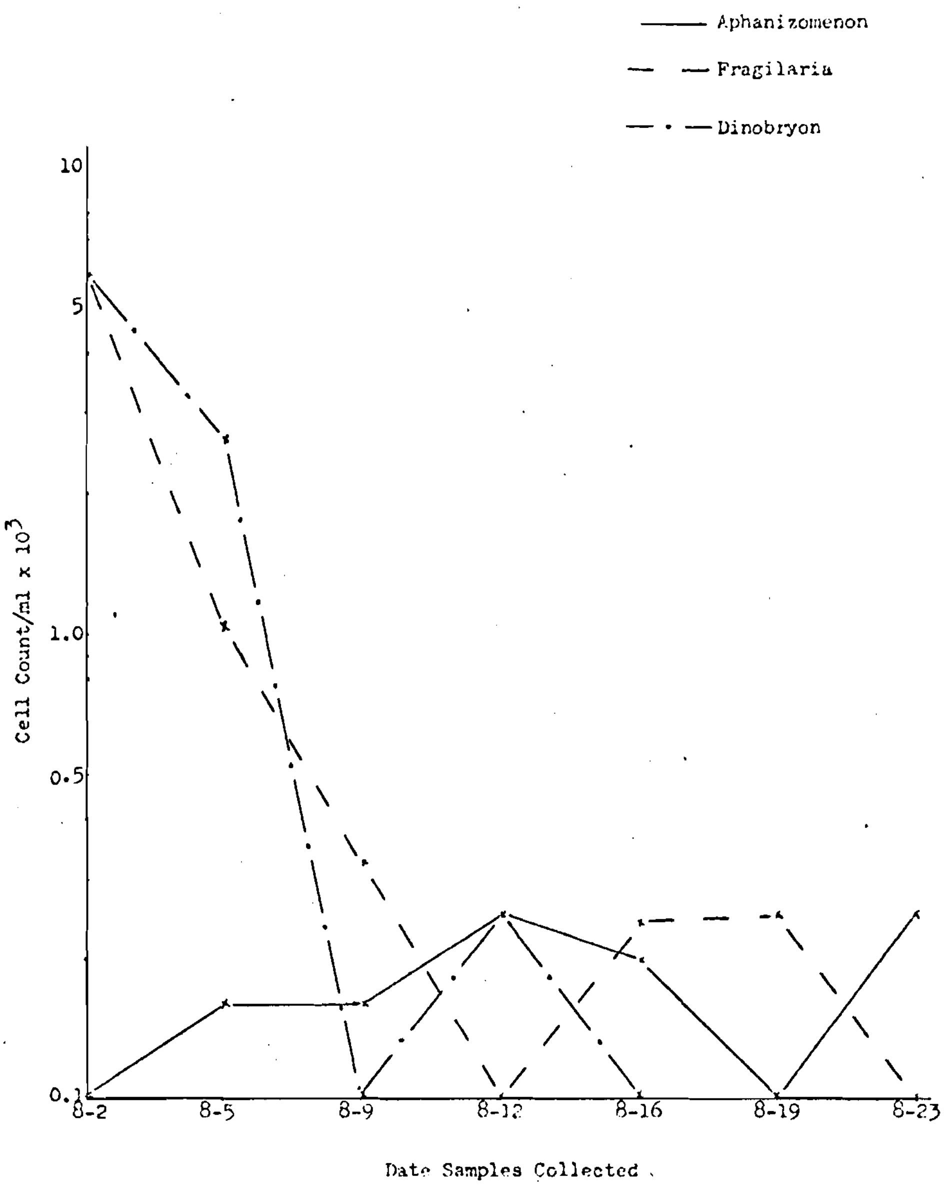

Figure 5. Cell counts for three dominant phytoplankters in the glucose control tube.

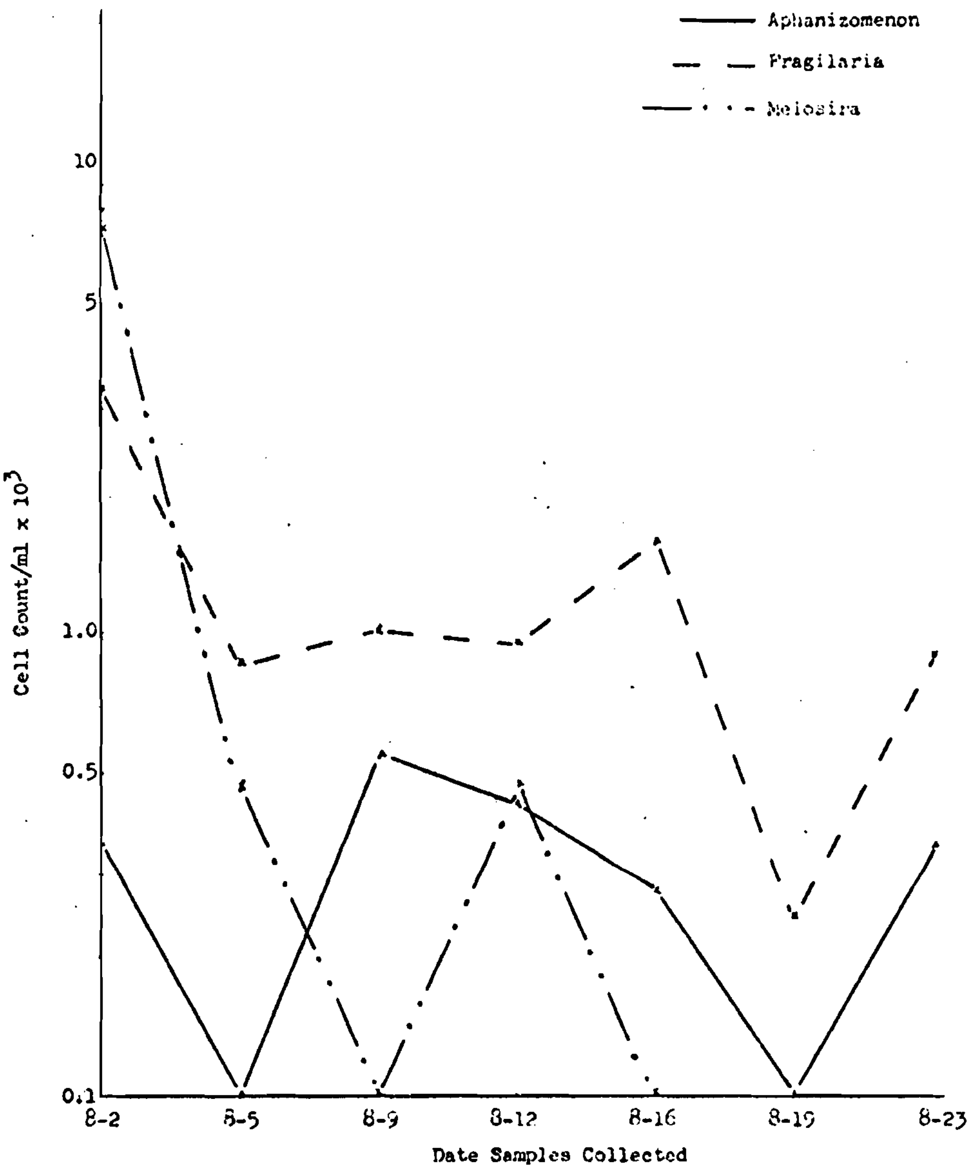

Figure 6. Cell counts for three dominant phytoplankters in the phosphorus control tubes.

Aphanizomenon flos-aquae which increased slightly in the glucose-control tube and fluctuated widely in the phosphorus control tube. Changes in numbers of planktonic organisms in both control tubes present the same kind of pattern with a decline in numbers occuring during the first week of the experiment. Species composition of the plankton in the two control tubes differed only in that Dinobryon was initially one of the more abundant forms in the glucose-control tube, while its counterpart in the phosphorus control tube was the filamentous diatom Melosira.

In both experimental tubes with intermediate nutrient concentration (0.45 mg/l), plankton organisms were of greater abundance throughout the experimental period than in control tubes (Figure 7 and 8); and there was considerably more variation in numbers of organisms at various sampling dates. Dominant organisms included Aphanizomenon, Anabena, Fragilaria and Dinobryon.

In the experimental tubes receiving the highest concentration of added nutrients (2.26 mg/l phosphorus and phosphorus + glucose), growth of planktonic organisms achieved their highest levels (Figure 9 and 10). Moreover, in the phosphorus enriched tube both Aphanizomenon and Anabena exceeded 10,000 cells/ml during the period 9 August to 19 August 1971. Both of these organisms are bluegreen algae and routinely constitute the more common nuisance forms of algae associated with eutrophic bodies of water. In addition to the bluegreen algae Fragilaria also occurred in both tubes containing the highest amounts of added nutrients and Dinobryon was present in the phosphorus enriched tube during the early portion of the experimental period.

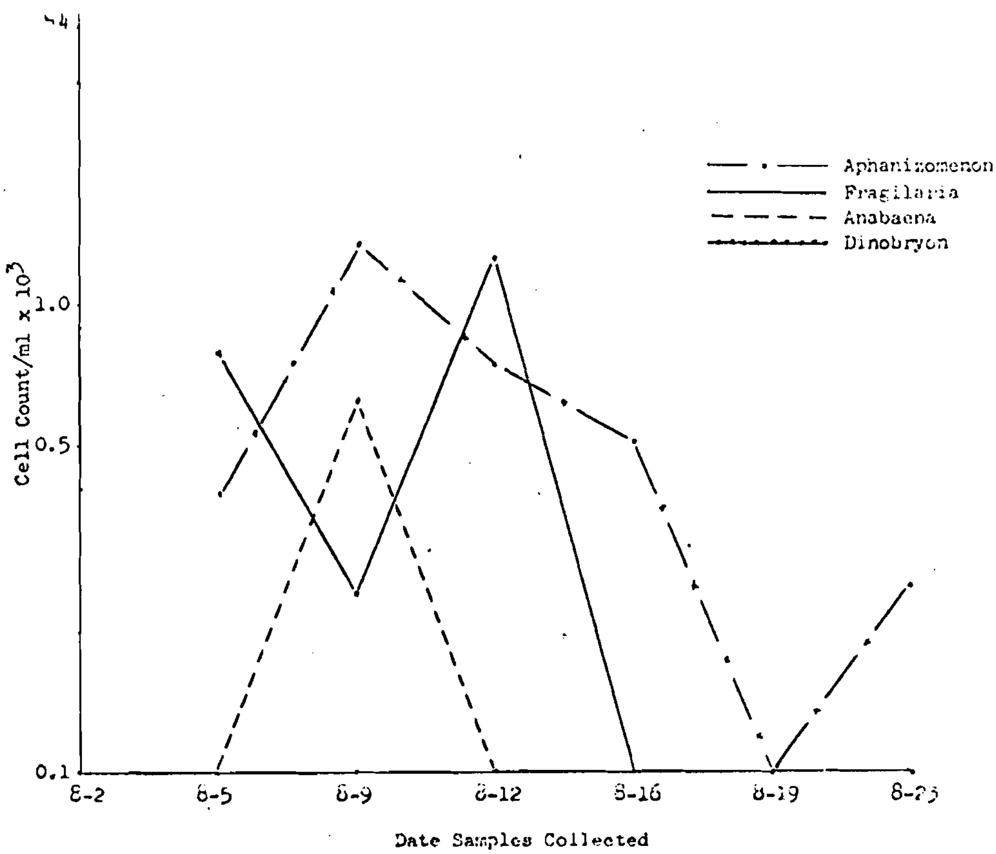

Figure 7. Cell counts for four dominant phytoplankters in the intermediate phosphate + glucose tube (0.45 ppm).

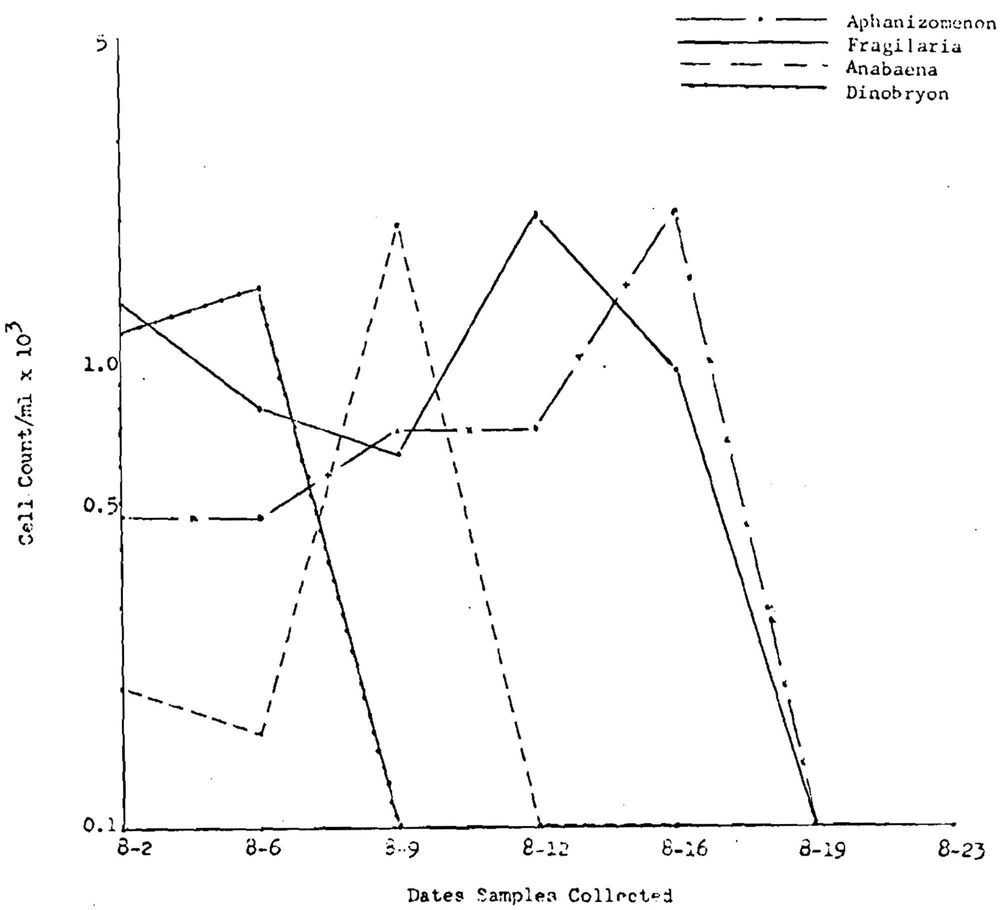

Figure 8. Cell counts for four dominant phytoplankters in the intermediate phosphate tube (0.45 ppm).

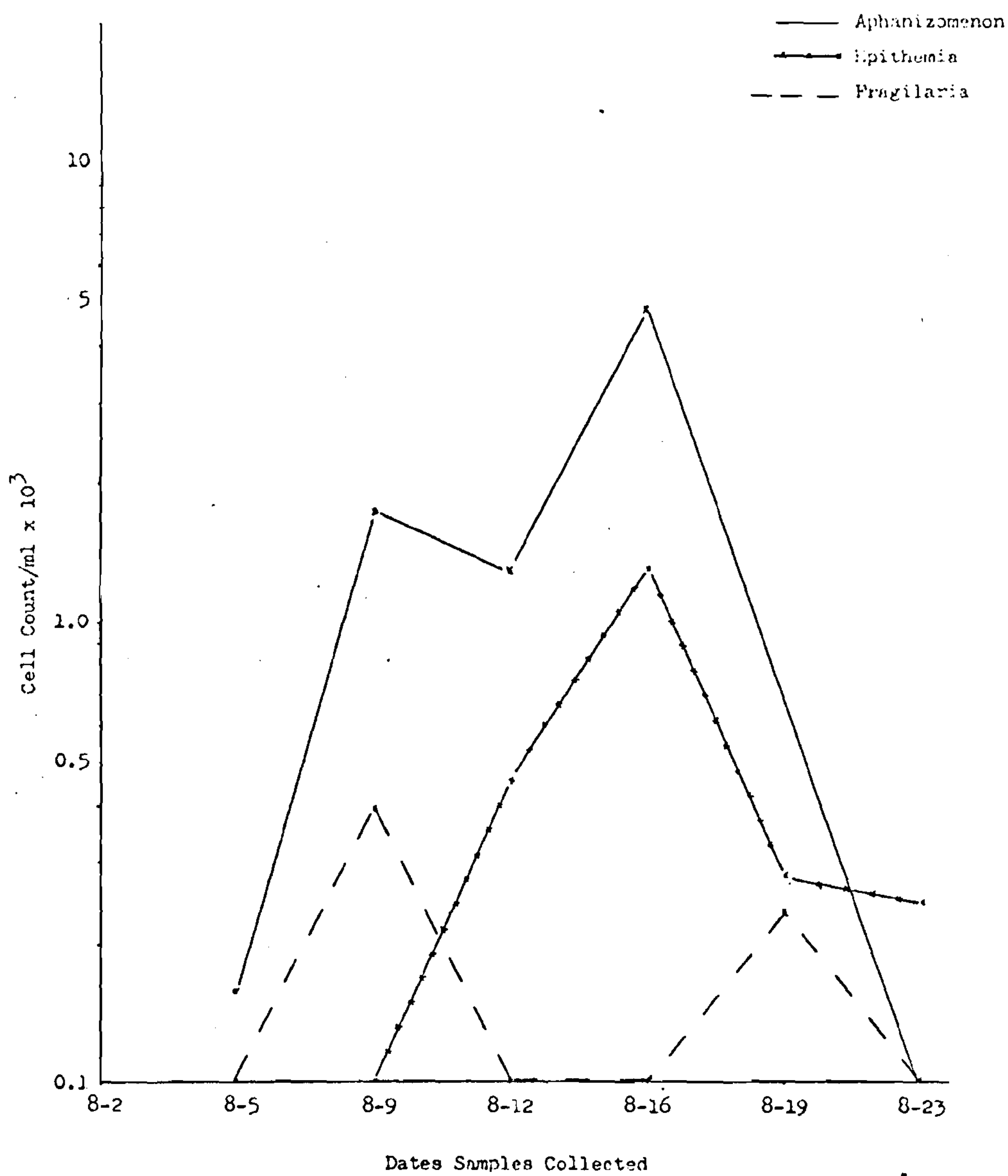

Figure 9. Cell counts for three dominant phytoplankters in the high concentration phosphate + glucose tube (2.26 ppm).

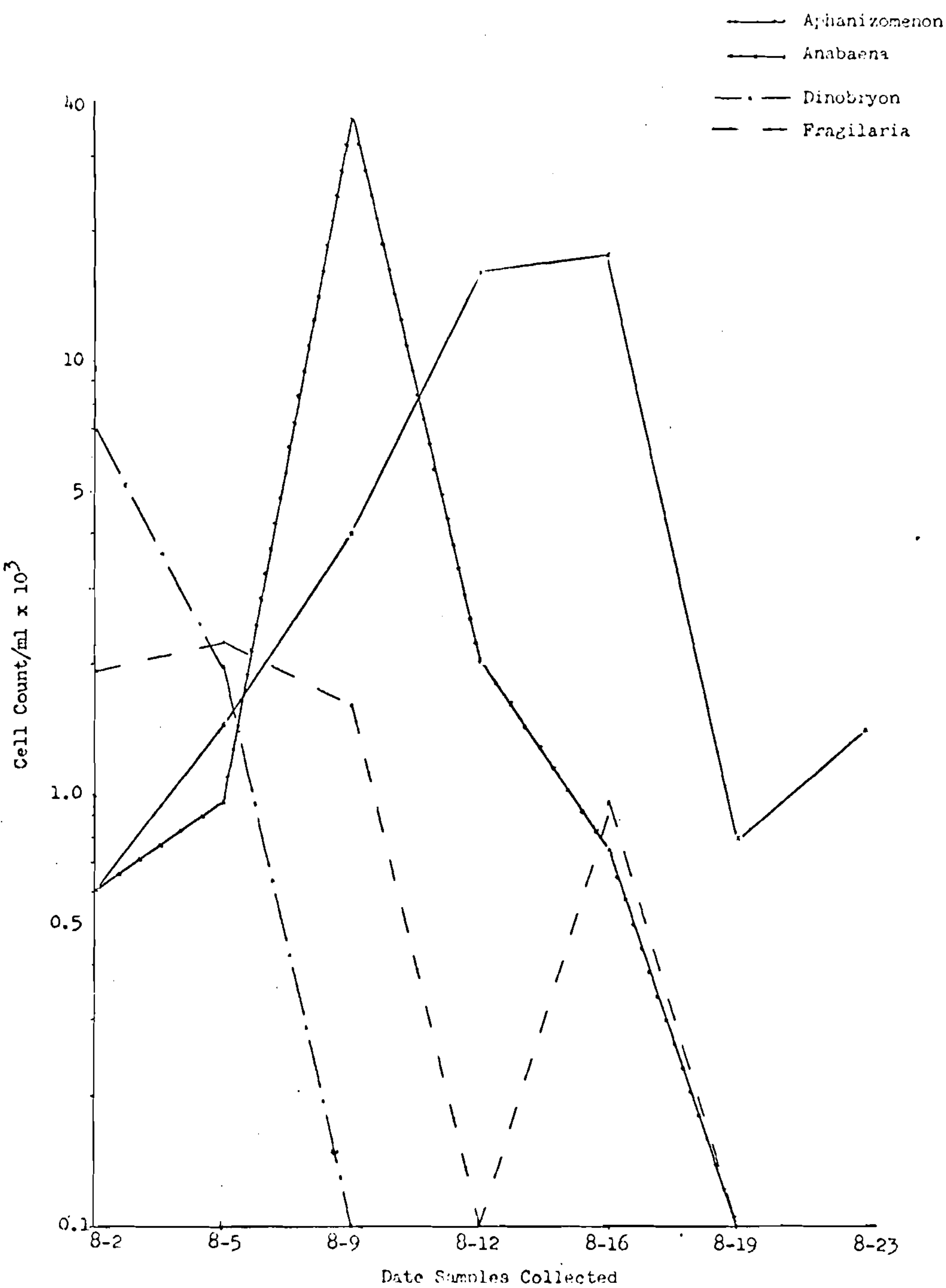

Figure 10. Cell count for four dominant phytoplankters in the high concentration phosphate tube (2.26 ppm).

DISCUSSION

One of the purposes of this pilot study was to evaluate the utility of several techniques as indices of algal growth. Particulate organic carbon is an indiscriminate measure of all suspended organic matter in the water. It does not distinguish between living and dead or algal and non-algal material. At present the analysis of plant pigments is the only rapid chemical method for estimating plant biomass in the particulate organic matter of the water (Strickland and Parsons 1968). By use of a correction for phaeophytin pigments the standing crop of the living fraction alone can be estimated. Cell counts are another means of evaluating changes in algal populations and have the advantage of providing information on the abundance of each species. But the method is time-consuming as indicated by our inability to count more than half of the samples collected.

No consistent relationship emerged between any two of the three parameters (Tables 4 and 5). Chlorophyll a appeared to be the most promising as a means for rapid evaluation of changes in plant standing crop. But additional work is needed to equate chlorophyll a concentrations to cell biomass rather than to cell numbers and to account for differences in chlorophyll content arising from differences in age of cells. Although time did not permit its evaluation, the gasometric analysis of algal productivity still appears promising.

Algae in American Falls Reservoir did not reach the peak numbers in 1971 achieved in other years, although total cell counts in those portions of the reservoir that were sampled did increase throughout the summer months. Failure of the development of bloom conditions may have been due in part to unusual water conditions. Draw-down of the reservoir during the irrigation season did not approach the normal levels. The unusually heavy snow pack which accumulated during the winter of 1970-71 provided an increased runoff throughout the summer months of 1971. This added flow could conceivably have resulted in considerable dilution in nutrient concentrations of the water, although data regarding water chemistries from other years are not available for comparison.

In the experimental tubes, particularly those receiving the highest concentrations of added nutrients (2.26 mg/l, growth of planktonic organisms especially Aphanizomenon and Anabena) reached levels 10 times more numerous than in the ambient water of the bay. The results of Aphanizomenon are a bit misleading and need additional clarification. Aphanizomenon occurs as a cluster of trichomes joined laterally to one another into small macroscopic, free-floating, feathery colonies. Size of individual cells is so small that when occurring as a packet of filaments or trichomes in the colony the counting of individual cells is impossible. Therefore, although our results are expressed as cell counts, they are actually colony counts and the number of individual cells for Aphanizomenon would be much greater. For this reason the analyses of plant pigments may be preferred for estimating plant biomass. A recent technique utilizing ATP content of living cells has been developed and might be incorporated into any additional study involving algal population dynamics in this and other bodies of water (Strickland and Parsons, 1968). Nevertheless, evidence from the cell count data makes it abundantly clear that additional nutrients, both phosphorus and phosphorus + glucose, elicited a dramatic response in terms of numbers of algae. This is shown most clearly by data from the experimental tubes receiving the greatest amounts of added nutrients.

Experience gained in the use of polyethelyne tubes as test chambers leads to the conclusion that they indeed represent a very promising way of approaching the complex problems involved in the relationship between nutrient supply and algal growth. The polyethelyne tubes appeared to be exceptionally durable over the time period required for this study. Although the tubes used were discarded at the end of the experimental period, it is possible that they might be used a second year after cleaning and storage. However, before using this approach, a cost comparison should be made between replacement with new tubes and the cost of cleaning and storage. Two problems were encountered in using the tubes that need attention prior to continued use of this technique: The first is the need to improve a method of suspending the tubes from some kind of a flotation collar such that carbon dioxide diffusion could occur unhindered; a second problem involves testing for optimum tube size. In this study the diameter of the tubes was dictated largely by the limited availability of plastic sheeting, and there are reports in the literature of tubes of much greater diameter having been used (Lund, 1971). It was also noticed during the experiment that considerable growth of periphyton, largely diatoms, appeared on the sides of the plastic tubes and thus resulted in some shading to the column of water contained in the tube. It is conceivable that this reduction in light intensity could have resulted in some depression in growth of algae in the tubes.

One of the problems that has been pointed out by numerous authors regarding the measurement of phosphorus in relation to algal growth involves the capacity of many algal species to accumulate phosphorus in what has been termed "luxury consumption". It was hoped to measure this luxury component of phosphorus uptake by enzymatic analysis. However, apparent inadequacies in the published technique (Fitzgerald, 1968) precluded carrying out this portion of the work.

It appears that laboratory studies could be initiated to supplement the kind of data resulting from the major techniques used in this study. In the laboratory it should be possible to determine ease of utilization of different carbon sources by the algae in question. In addition, conversion of sugar into forms of carbon that may be directly assimilated by plants was not measured in this study and should receive additional investigation. Nevertheless, the use of polyethylene tubes as *in situ* culture chambers appears to have considerable promise and warrants further studies of this type. To carry on an expanded program, however, would require significantly higher funding but could ultimately prove to be a valuable method for assessing the potential of various waters in supporting or contributing to nuisance blooms of algae.

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APPENDIX I

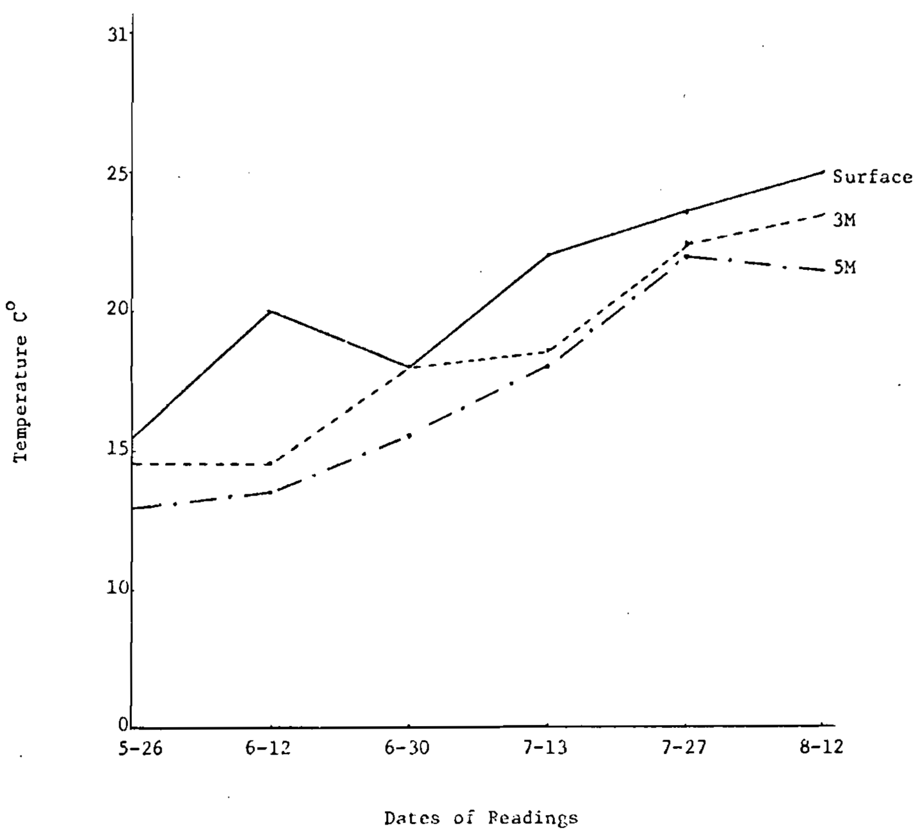

Figure A. Temperature profile for Big Hole Bay during summer of 1971.

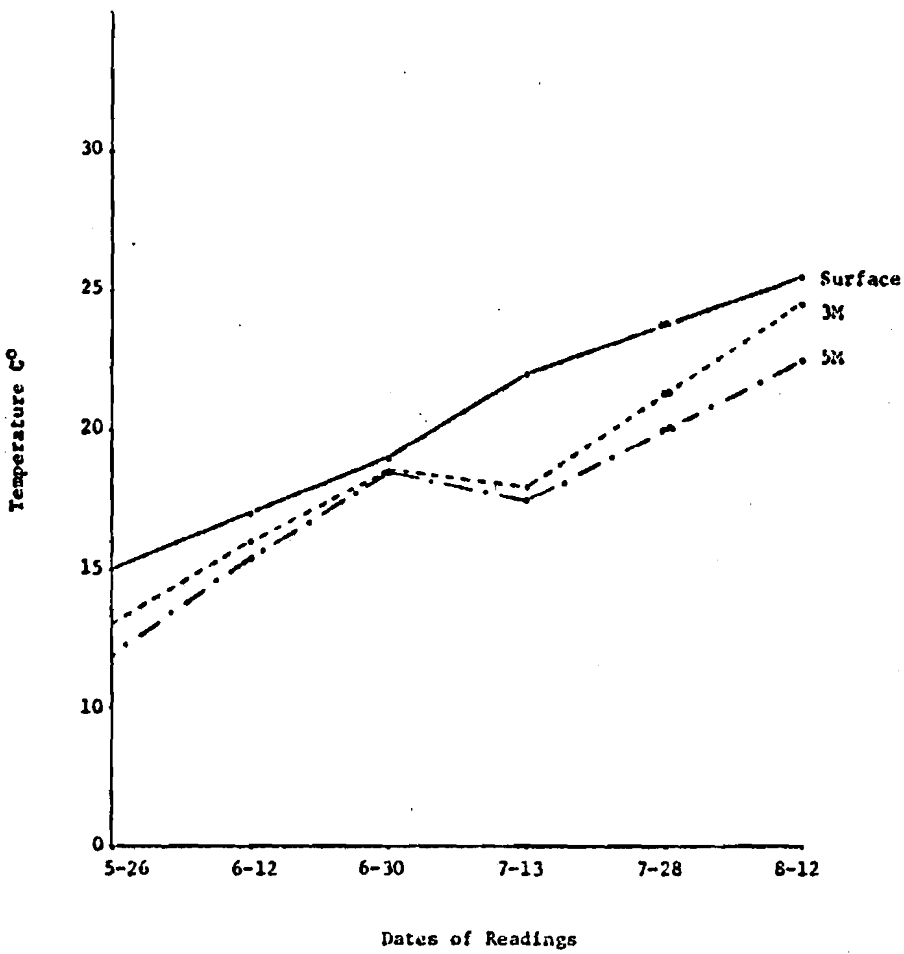

Figure B. Temperature profile for Sportsmans Park Bay during summer of 1971.

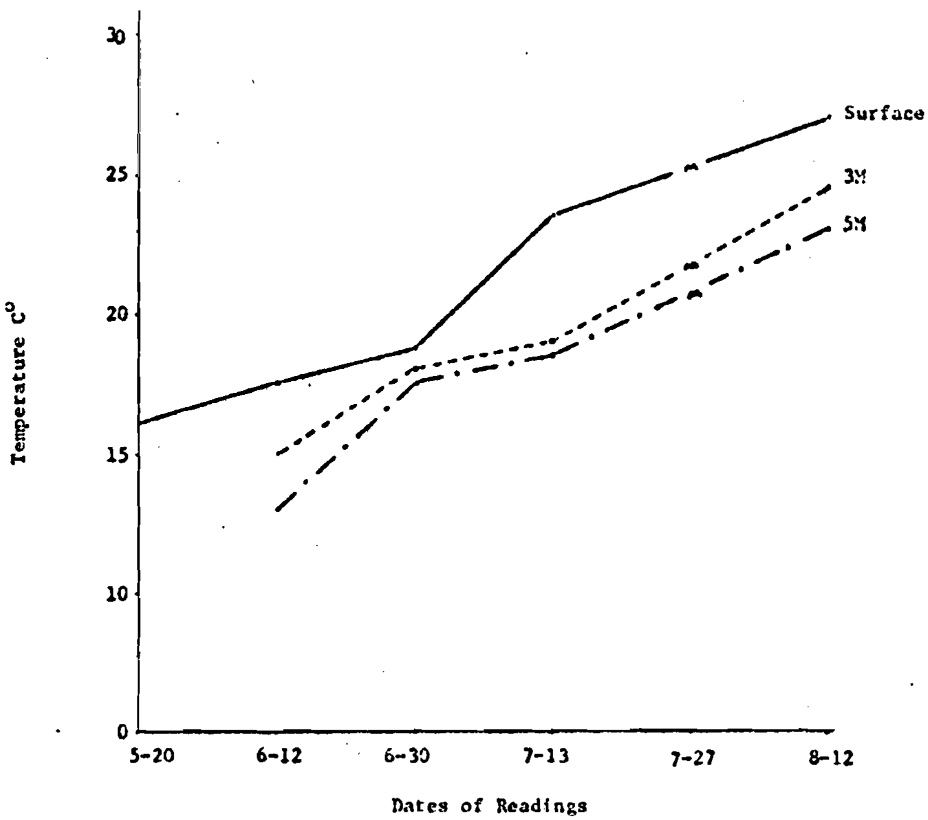

Figure C. Temperature profile for Seagull Bay during summer of 1971.

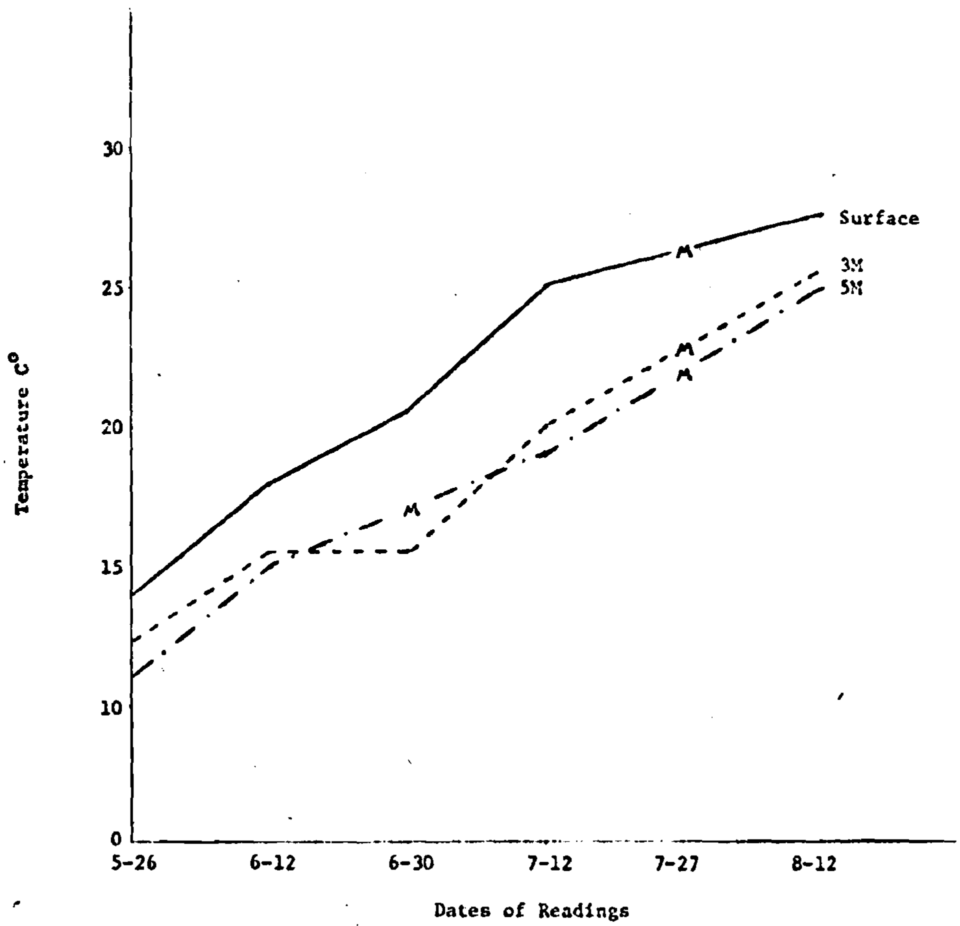

Figure D. Temperature profile for Bannock Creek Bay during summer of 1971.

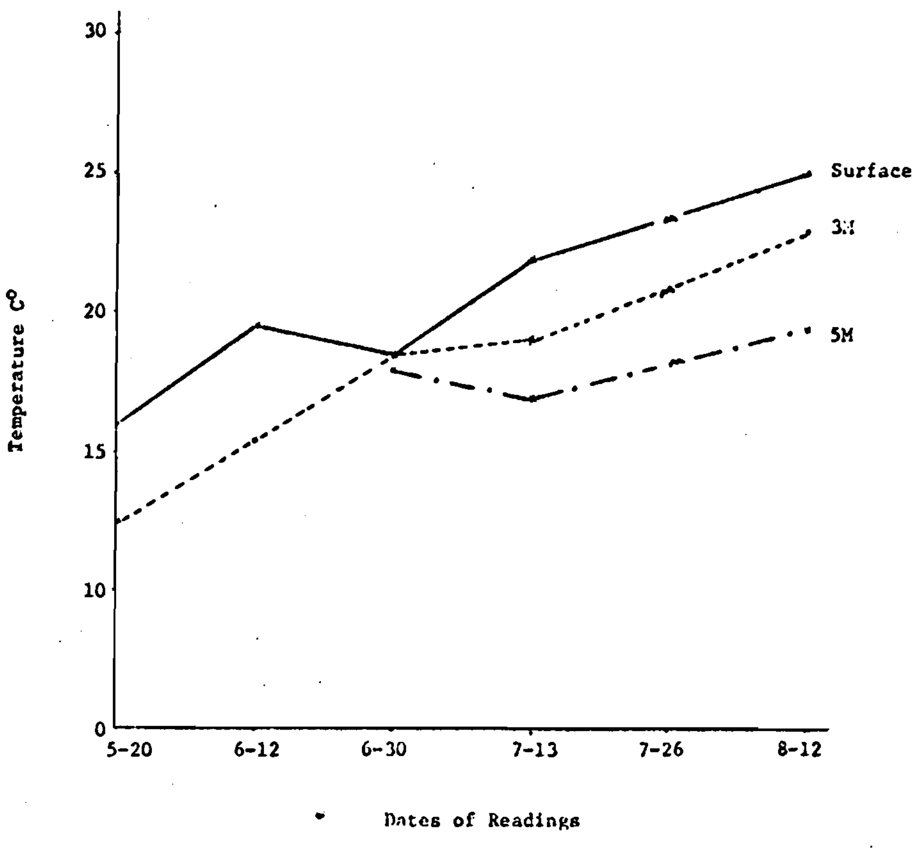

Figure E. Temperature profile for Unnamed Bay during summer of 1971.