Ecology of the diatom communities of Soda Butte Creek, Montana and Iron Springs Creek, Wyoming

by Frank James Pickett

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Botany
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Abstract:
Diatoms, collected from plexiglass plates, and water chemistry samples were taken and analyzed biweekly in 1972 from five stations on the upper portion of Soda Butte Creek, Montana, one above and four below the entry of seepage from a mine tailings dump.

Soda Butte Creek was found to be of the calcium-magnesium-bicarbonate type. Total iron increased markedly from a mean of .2 mg.l-1 above to 6.7 mg.l-1 below the seep, and pH was depressed slightly from a mean of 8.32 to 7.80.

A total of 33 genera and 171 species and varieties of diatoms were identified. Dominant diatoms were: Hannaea arcus, Achnanthes lanceolata, Gomphonema angustatum, and Diatoma hiemale var. mesodon.

The diatom flora was adversely affected in the area of the seep, where chlorophyll and diatom counts were nil. The next station, 1.5 miles downstream, showed few ill effects from the tailings drainage. The relatively high pH for the "acid" mine drainage allowed the ferric material to precipitate quickly. The addition of an approximately two times greater volume of dilution water from tributary streams also increased recovery.

The diatom flora of another stream of the area, Iron Springs Creek, Wyoming, was compared to that of Soda Butte Creek due to the contrasting nature of the two streams' water chemistry. Iron Springs Creek was of the sodium-potassium-bicarbonate type. Cocconeis placentula var. lineata was the dominant diatom found in Iron Springs Creek. The multivariate statistical techniques of principle components and cluster analysis suggested that unique diatom communities existed in the two streams and that the monovalent:divalent cation ratio was the best discriminator between the streams.

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Date May 22, 1978

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ABSTRACT

Diatoms, collected from plexiglass plates, and water chemistry samples were taken and analyzed biweekly in 1972 from five stations on the upper portion of Soda Butte Creek, Montana, one above and four below the entry of seepage from a mine tailings dump.

Soda Butte Creek was found to be of the calcium-magnesium-bicarbonate type. Total iron increased markedly from a mean of .2 $mg \cdot \ell^{-1}$ above to 6.7 $mg \cdot \ell^{-1}$ below the seep, and pH was depressed slightly from a mean of 8.32 to 7.80.

A total of 33 genera and 171 species and varieties of diatoms were identified. Dominant diatoms were: *Hannaea arcus, Achnanthes lanceolata, Gomphonema angustatum,* and *Diatoma hiemale* var. *mesodon.*

The diatom flora was adversely affected in the area of the seep, where chlorophyll and diatom counts were nil. The next station, 1.5 miles downstream, showed few ill effects from the tailings drainage. The relatively high pH for the "acid" mine drainage allowed the ferric material to precipitate quickly. The addition of an approximately two times greater volume of dilution water from tributary streams also increased recovery.

The diatom flora of another stream of the area, Iron Springs Creek, Wyoming, was compared to that of Soda Butte Creek due to the contrasting nature of the two streams' water chemistry. Iron Springs Creek was of the sodium-potassium-bicarbonate type. *Cocconeis placentula* var. *lineata* was the dominant diatom found in Iron Springs Creek.

The multivariate statistical techniques of principle components and cluster analysis suggested that unique diatom communities existed in the two streams and that the monovalent:divalent cation ratio was the best discriminator between the streams.

INTRODUCTION

In 1972, the National Park Service awarded contract number 2-101-0387 to Dr. John C. Wright of Montana State University to undertake limnological investigations in Yellowstone and Glacier National Parks. This paper details a study of the benthic diatoms and water chemistry on Soda Butte Creek near Cooke City, Montana, and Iron Springs Creek near Old Faithful Geyser in the Yellowstone National Park area. These two streams were studied to determine the impact of mine tailings drainage on Soda Butte Creek and sewage lagoon percolation and run-off on Iron Springs Creek.

A survey of Soda Butte Creek was conducted in 1967 by Mills and Sharp (1968) to determine if the stream was receiving pollution from the old McClaren mill tailings located at Cooke City, Montana. They found smaller numbers of aquatic insects immediately below the mill tailings than in other sections of the stream and increasing numbers at locations progressively downstream from the tailings. In 1969 the Kennecott Copper Corp. leveled and shaped the mill tailings and covered them with two to four feet of topsoil (Hill 1970 and Duff 1972). Soda Butte Creek was also re-routed around the area of the reclaimed tailings. Hill (1970) sampled Soda Butte Creek about a year after the rehabilitation and found that the stream immediately below the tailings had about the same chemical qualities as before reclamation.

Iron Springs Creek is located adjacent to a series of sewage lagoons which receive all waste water from the Old Faithful area in Yellowstone National Park. No previous surveys of this stream have been conducted prior to this investigation. The purposes of this study were to determine whether the sewage lagoon percolation was polluting the stream and to compare Iron Springs Creek diatoms to those found in the chemically different waters of Soda Butte Creek.

Soda Butte Creek and Iron Springs Creek have little if any macrophyte and phytoplankton growth. The benthic algal community constitutes the major primary producer. Clear mountain streams often provide excellent habitat for diatom growth (Patrick and Reimer 1966), and this group of algae often dominates the benthic algae. This seems to be the case in both streams. The species composition and structure of benthic diatom communities have often been used to evaluate conditions in rivers receiving various kinds of pollution (Butcher 1974, Fjerdingstadt 1950, Patrick, Hohn, and Wallace 1954, Blum 1957, Hohn and Hellerman 1963, and Patrick 1963).

DESCRIPTION OF STUDY AREA

Soda Butte Creek is located in south central Montana and the northeast portion of Yellowstone National Park. U.S.G.S. maps and U.S. Forest Service aerial photographs indicate that Soda Butte Creek originates about one mile east of Cooke City, Montana, and flows in a southwest direction approximately 40.2 stream km (25 stream miles) before emptying into the Lamar River. The stream drains an area of approximately 259 km^2 (100 square miles). Major tributaries are Woody, Amphitheater, Pebble, and Sheep creeks. Soda Butte Creek originates at an elevation of about 2365 meters (7,760 feet) above mean sea level and has an average drop of 9.1 $m \cdot km^{-1}$ (48 $feet \cdot mile^{-1}$). Five sampling stations were established on the stream (Figure 1). Station 1 was located approximately 150 m (165 yards) above the area of the reclaimed tailings and was considered the control station. Station 2 was located about 21 m (23 yds) below the visual point of entry of seepage from the tailings area. Station 3 was situated approximately 2.4 km (1.5 mi) below the tailings area and immediately below the entrance of Woody creek. Station 4 was established approximately 15.1 km (9.4 mi) below the tailings area just inside the park boundary. Station 5 was located about 32.6 km (20.3 mi) below the tailings area and below the entrance of Pebble Creek. The substratum consisted of gravel in the riffle areas where the stations were located. Some boulders and rubble were present at the upper stations.

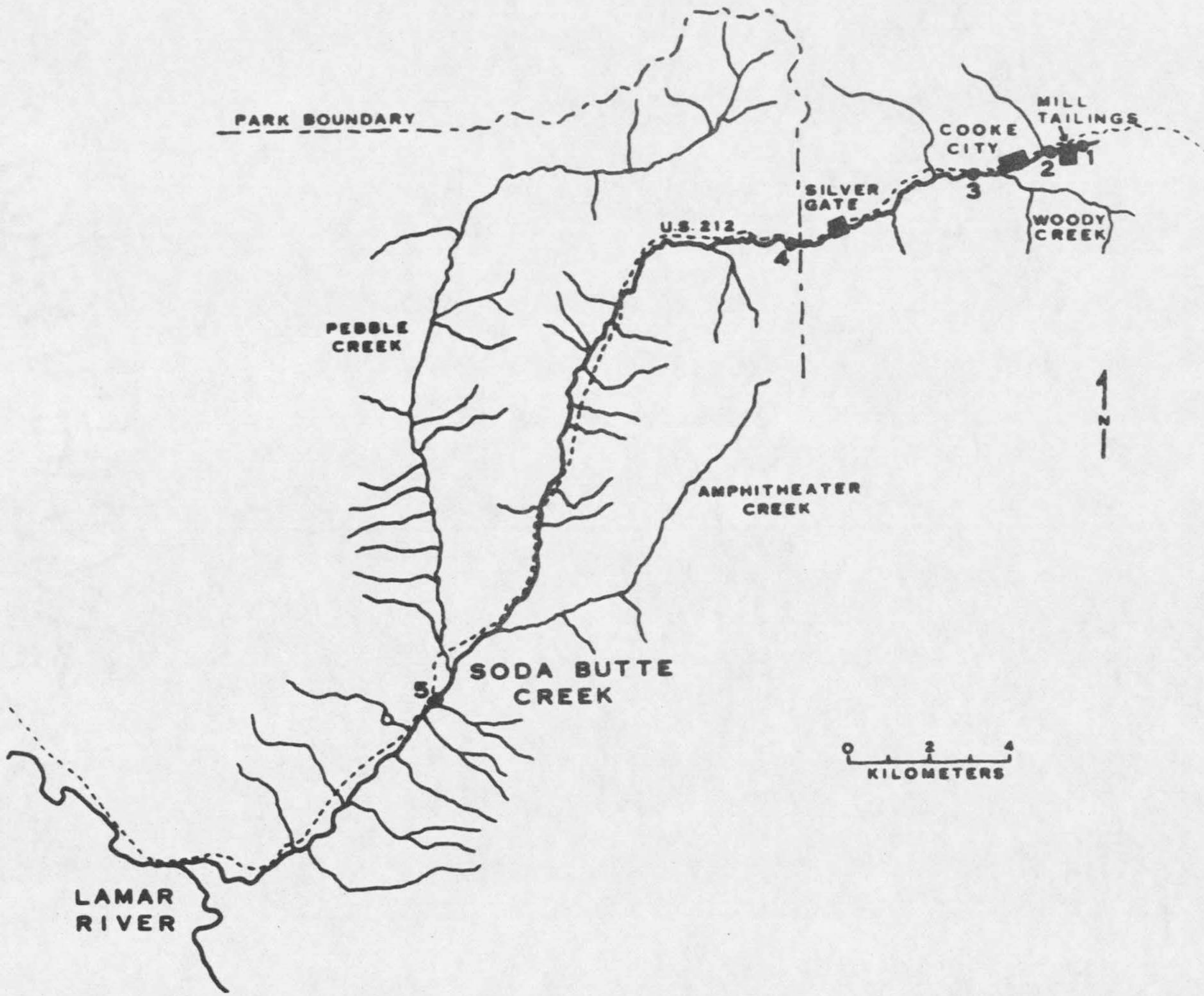

Figure 1. Map of Soda Butte Creek showing location of the sampling stations and the Yellowstone National Park boundary.

The substratum at Station 2 was covered by large deposits of ferric hydroxide giving the stream bottom a dark red color.

Iron Spring Creek is located in the southwest portion of Yellowstone National Park near Old Faithful Geyser. It originates at an elevation of about 2,380 m (7,800 ft) above mean sea level and flows north about 6.8 km (4 mi) before emptying into the Little Firehole River at an elevation of 2,220 m (7,280 ft). Two sampling stations were established on the stream. Station IS1 was located 56.7 m (62 yds) upstream from the Old Faithful sewage lagoons, and Station IS2 was about 293 m (320 yds) downstream from the ponds. Water entered the stream from several hot springs located along the 1,052 m (1,150 yds) of stream channel separating Stations IS1 and IS2. During September, volumes of .24 m^3 $sec.^{-1}$ (8.5 c.f.s.) were measured at Station IS1 and .30 m^3 $sec.^{-1}$ (10.7 c.f.s.) at Station IS2.

METHODS

Water samples and diatom collections from artificial substrates were made according to the schedule in Table 1.

Table 1. Sampling schedule of water chemistry and diatom collections from artificial substrates.

Date	Water Chemistry		Diatoms	
	Soda Butte	Iron Springs	Soda Butte	Iron Springs
5 May 72	X			
9 June 72	X			
24 June 72	X	X		
8 July 72	X	X		
21-22 July 72	X	X	X	X
4 August 72	X	X	X	X
18 August 72	X	X	X	X
31 August 72	X	X	X	X
18 September 72	X	X	X	X
29 September 72	X	X	X	X
17 October 72	X		X	
11 November 72	X			

Chemical and Physical Determinations

Dissolved oxygen concentration, temperature, and pH were determined in the field. The standard Winkler method was used for oxygen analysis (APHA 1965). Temperature was taken with a mercury thermometer. A Beckman Model G and an Orion Ion Analyzer Model 407 were used to determine pH.

Concentrations of nitrite, nitrate, ortho-phosphate, sulfate, calcium, magnesium, flouride, chloride, and total alkalinity were all determined as described by the American Public Health Association (1965). A Baush and Lomb Spectronic 20 was used in all colorimetric determinations.

Zinc and copper were determined by atomic absorption with a Beckman DU Flame Spectrophotometer. Sodium and potassium were determined by emission with the same spectrophotometer. Iron was determined using the Hach Ferrover® method (Phenanthroline), and manganese was analyzed by the Leuco Base Method (Strickland and Parsons 1972).

The monovalent:divalent cation ratio was calculated in the following manner:

$$M : D = \frac{Na^{+}\ meq.\ell^{-1} + K^{+}\ meq.\ell^{-1}}{Ca^{++}\ meq.\ell^{-1} + Mg^{++}\ meq.\ell^{-1}}$$

Estimates of stream discharge were computed from individual flowmeter and stream depth measurements made at uniform intervals across the stream. Stream discharge was the flow through the stream crossectional area.

Chlorophyll and Autotrophic Index

A plexiglass plate with a collecting surface area of 140 cm^2 was bolted vertically to a ½ inch concrete reinforcing rod which had been driven into the stream bed. The plate was oriented so that the top edge was approximately 10 cm below the water surface and the collecting surface was at an approximate angle of 150° to the current flow. After a period of four weeks, the plate was carefully removed from the water and inserted into its individual black plastic bag. The plates were frozen until chlorophyll analyses were conducted, usually the following day. The accumulated biomass was scraped with a single-edged razor blade from an area of 140 cm^2 on each plate. The upstream side was always scraped. The scrapings were dissolved in enough 90% acetone to result in an absorbance reading between 0.1 and 0.7 (80% and 20% transmittance respectively). The acetone mixture was shaken vigorously and placed in a light-proof test tube and refrigerated at 0°C for at least 20 hours. At the end of the extraction period, the entire acetone extract was spun in a clinical centrifuge at high speed for ten minutes. The acetone-phytopigment supernate was then decanted and brought up to the original volume with 90% acetone. The remaining particulate fraction was transferred to preweighed Vycor® crucibles for the biomass analysis. The absorbance of the phytopigment extract was then measured on a Beckman DU Spectorphotometer Model 2400. The centrifuged particulate remainder from the chlorophyll extraction was oven dried at 105°C for 24 hours and weighed on a Mettler Type H16 Balance. Chlorophyll production per unit area was calculated from Parsons' and Strickland's (1972) equations.

Biomass was then determined by incineration of the material at 600°C for one hour and by calculation of the weight loss (ash-free dry weight). The autotrophic index is the ratio of grams ash-free dry weight to grams chlorophyll *a*.

Diatom Studies

Diatom material was scraped from outside the area delimited for chlorophyll determination on the plexiglass substrate. The diatoms were then cleaned using the boiling nitric acid potassium dichromate technique described by Hohn and Hellerman (1963). The cleaned material was then mounted in a medium of high refractive index, according to the method used by the Federal Water Pollution Control Administration (1966).

Each slide was examined using oil immersion. Successive fields were observed, from the edge of the coverslip inward, until approximately 400 diatom cells were identified and tabulated. The slide was then scanned at 430X for additional species that were not found during the initial count. The percentage or abundance of each taxon was computed for each slide. Taxa which were observed during the scan count but not during the initial count were tabulated with a t (trace). This counting method was used by Thomasson (1925) as well as Roeder (1966) and Cholnoky (1960, 1968).

Diatom community diversity (d) was calculated for each sample using the equation (Margalef 1951): $d = \frac{m - 1}{\ln N}$ where m equals the number of species and N equals the number of diatom cells counted.

Taxonomic keys used for diatom identification were Hustedt (1930), Cleve Euller (1951), FWPCA (1966), and Patrick and Reimer (1966), (1975).

RESULTS: SODA BUTTE CREEK

Chemical and Physical Determinations

The range and mean values for chemical and physical analyses are presented in Table 2. The complete results of the determinations are given in the Appendix (Tables 25 through 45).

Iron, manganese, and sulfate exhibited a sharp increase in concentration at Station 2, followed by a gradual decrease downstream. The values found at Station 5 were similar to those found at Station 1 (control station). Average increases at Station 2 over Station 1 were as follows: manganese--57 times, iron--39 times, sulfate--10 times. Recovery of the stream to control levels was essentially complete for manganese and sulfate by Station 4. Iron concentrations generally decreased at successive downstream stations during most of the year, but during the spring runoff period this pattern was reversed with increasing iron levels at successive downstream stations. The reversed pattern probably resulted from the scouring effect upon the stream bed, produced by high current velocity and silt load.

Total hardness, calcium, and magnesium levels rose sharply below the tailing seepage. At Station 3, the concentrations fell below Station 1 levels. The decrease at Station 3 was due to dilution by Woody Creek. Levels then gradually rose to pre-seep concentrations at Station 5.

Table 2. Ranges and mean values for chemical and physical analyses of Soda Butte Creek

Variable	Station 1	2	3	4	5
Zinc $(mg \cdot \ell^{-1})$	0.0 - .035 T	0.0 - 0.035 T	0.0 - .035 T	0.0 - .025 T	0.0 - .04 T
Temperature (C°)	0.5 - 6.0 3.2	0.5 - 6.7 4.0	0.0 - 9.0 4.4	0.0 - 11.3 5.9	1.0 - 13.7 8.0
Turbidity (JTU)	0.3	75.0	15.0	4.0	1.5
Dissolved Oxygen $(mg \cdot \ell^{-1})$	8.3 - 10.8 10.0	8.4 - 10.0 8.9	8.6 - 11.0 10.0	8.6 - 11.2 9.9	8.3 - 11.2 9.6
Potassium $(mg \cdot \ell^{-1})$	0.39 - 0.70 0.60	0.39 - 2.19 1.03	0.20 - 1.33 0.60	0.27 - 0.82 0.52	0.59 - 1.29 1.02
Nitrate No_2-N $(mg \cdot \ell^{-1} NO_3N)$	0.002 - 0.038 0.018	0.001 - 0.047 0.019	0.0 - 0.052 0.014	0.0 - 0.034 0.017	0.0 - 0.042 0.008
Chlorophyll "a" accrual $(mg \cdot m^{-2})$	0.11 - .04 3.12	0.0 - 0.0 0.0	0.72 - 12.34 4.08	.83 - 18.86 7.24	0.65 - 15.99 7.41
Total Iron $(mg \cdot \ell^{-1})$	0.07 - 0.28 0.17	0.68 - 21.45 6.70	0.50 - 5.05 1.76	0.16 - 3.18 1.18	0.05 - 4.88 .93
Manganese $(mg \cdot \ell^{-1})$	0.001 - 0.012 0.004	0.001 - 0.880 0.227	0.001 - 0.102 0.061	0.001 - 0.030 0.008	0.001 - 0.029 0.006
Sulfate $(mg \cdot \ell^{-1})$	5.0 - 8.4 6.4	11.4 - 191.0 64.4	2.0 - 15.5 8.6	2.0 - 12.2 7.9	2.5 - 11.8 6.2

Table 2. Continued

Variable	Station 1	Station 2	Station 3	Station 4	Station 5
Total Hardness ($mg \cdot \ell^{-1} CaCO_3$)	62.0 - 117.0 99.1	60.0 - 170.0 135.9	26.0 - 73.8 49.9	41.0 - 86.4 59.4	53.0 - 105.8 80.43
Calcium ($mg \cdot \ell^{-1} Ca^{++}$)	20.0 - 37.5 32.4	18.8 - 65.7 40.7	10.4 - 28.5 16.3	8.4 - 36.7 18.9	14.4 - 33.5 21.9
Magnesium ($mg \cdot \ell^{-1} Mg^{++}$)	2.9 - 7.3 5.6	3.2 - 21.3 9.5	.7 - 4.3 3.1	2.2 - 5.6 3.9	1.3 - 10.9 6.4
Alkalinity ($mg \cdot \ell^{-1} CaCO_3$)	56.5 - 115.5 98.0	52.0 - 128.0 92.0	36.0 - 77.5 51.6	38.8 - 104.5 62.6	47.4 - 120.0 81.8
pH	7.87 - 8.84 8.32	6.95 - 8.20 7.80	7.58 - 8.47 8.08	7.95 - 8.66 8.29	7.93 - 8.85 8.39
Sodium ($mg \cdot \ell^{-1}$)	0.23 - 3.04 1.13	0.12 - 3.47 1.21	1.50 - 6.21 3.64	1.84 - 4.78 3.49	1.50 - 3.50 2.86
Phosphate ($mg \cdot \ell^{-1} PO_4$-P)	0.0 - .013 0.003	0.0 - .008 0.002	.02 - .061 0.035	.024 - .058 0.033	.018 - .044 0.033
Copper ($mg \cdot \ell^{-1}$)	0.0 - 0.10 T	0.0 - 0.07 T	0.0 - 0.04 T	0.0 - 0.05 T	0.0 - 0.05 T
Discharge ($m^3 \cdot sec^{-1}$)	.065 - 1.325 .430	.079 - 1.994 .610	.295 - 7.556 2.452	.481 - 6.553 2.343	1.526 - 2.393 1.908

The total alkalinity of Soda Butte Creek was not changed by seep entry from the mine tailings, but decreased at Station 3 due to dilution by Woody Creek. Downstream from Station 3, alkalinity values gradually increased to near control levels by Station 5. The pH fell at Station 2 and then gradually recovered to control levels at Station 4. The pH values ranged from 7.61 to 8.85, which is within the limits of most natural fresh waters (Hutchinson 1957).

Sodium and phosphate levels at Stations 1 and 2 were unchanged, but increased at Station 3. Sodium rose threefold and phosphate increased tenfold at Station 3 over the upstream levels. These higher levels remained essentially unchanged at the downstream stations.

Potassium levels ranged from 0.2 to 2.19 $mg \cdot \ell^{-1}$. A slight increase was noticed at Stations 2 and 5. Nitrate levels were low, ranging from 0.008 to 0.019 $mg \cdot \ell^{-1}$. Copper and zinc were usually found in undetectable amounts, but with slightly higher concentrations during periods of high water. Temperature increased gradually downstream, and ranged from 0°C at all stations to a maximum of 6°C at Station 1 and 13.7°C at Station 5.

The water at Station 2 was always observed to be much more "turbid" than the clear water upstream. Turbidity measurements were made in November when the diluting and scouring effects of heavy run-off were minimized. Station 2 had a turbidity of 75 JTU, which was a 250 fold increase over the turbidity of Station 1. Maximum dissolved oxygen concentrations were approximately 10 $mg \cdot \ell^{-1}$ during the entire study period.

Stream discharge values followed a pattern of maximum values in the spring gradually subsiding to minimum values in the fall. Run-off from melting snow swelled the discharge in Soda Butte Creek up to 20 times over fall discharge values (Table 3). The rampaging water carried high silt loads that continually scoured the stream bottom. The sandpaper texture of the stream bottom, noticed while wading the stream, indicated that the scouring action prevented successful algal growth.

Table 3. Discharge ($m^3 \cdot sec^{-1}$) of Soda Butte Creek by station and sampling date

Dates	Stations				
	1	2	3	4	5
24 June 72	1.325	1.994	7.556		
22 July 72	.402	.368	1.801	2.620	
18 Aug 72	.136	.119	.487	1.000	1.526
18 Sept 72	.105	.079	.620	1.059	2.393
11 Nov 72	.065	.093	.295	.481	1.804
2 June 73	.544	1.008	3.951	6.553	

Monovalent:Divalent Cation Ratio

M:D ratio varied from a mean of .03 at Station 1 to a mean of .18 at Station 3. Ratio values are presented in Table 4.

Table 4. Monovalent:divalent cation ratios for Soda Butte and Iron Springs Creeks from sample dates for which diatom data is available

	Soda Butte Creek Stations				Iron Springs Creek Stations	
Date	1	3	4	5	IS1	IS2
21 July 72	.037		.160		2.53	3.89
4 August 72	.034		.147		2.45	3.80
18 August 72	.026	.177	.117	.087	2.06	3.79
31 August 72	.026	.163	.110	.076	2.04	3.71
18 September 72	.026	.215	.154	.083	1.55	3.86
29 September 72	.027	.178		.084	2.52	4.19
17 October 72	.026	.167	.164	.100		
Mean	.03	.18	.14	.09	2.13	3.81

Chlorophyll, Biomass, and Autotrophic Index

Primary productivity was approximated by measuring the amount of chlorophyll "a" accrual on plexiglass substrata over a four-week growth period. Table 5 lists the chlorophyll accrual for each sampling period and the mean chlorophyll accrual for each station.

Table 5. Soda Butte Creek chlorophyll "a" accrual ($mg \cdot m^{-2}$) for all stations and sampling dates for a four-week growth period

Date	Station 1	2	3	4	5
8 July 72	0.28	0.0			
21 July 72	0.58	0.0		3.58	15.99
4 August 72	2.09	0.0		6.21	2.95
18 August 72	5.66	0.0	4.01	12.17	0.65
31 August 72	7.04	0.0	0.86	18.86	10.80
18 September 72	5.67	0.0	12.34	6.32	9.11
29 September 72	2.13	0.0	3.25	2.73	8.56
17 October 72	0.73	0.0	0.72	0.83	3.81
Mean	3.12	0.0	4.08	7.24	7.41

Generally the chlorophyll production was much higher at the warmer downstream stations than at the cooler upstream stations. Chlorophyll values ranged from 0.0 at Station 2 to 18.86 $mg \cdot m^{-2}$ at Station 4. With