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Factors affecting the production of Tally Lake

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FACTORS AFFECTING THE PRODUCTION

OF TALLY LAKE

By

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CHAPTER 1

INTRODUCTION

As public concern about a quality environment has increased in recent years, so also has scientific research in this sphere become more active. Most of the water quality work has been concerned with bodies of water which are grossly polluted by Montana standards. The Flathead Drainage is becoming a focal point for water related research in Montana because of the large amounts of this resource found there. However, very little is yet known about water quality and those factors affecting it in the Flathead. Recently, a study was prepared by the staff of the University of Montana Biological Station at Yellow Bay on Flathead Lake (Seastedt and Tibbs, 1974). The report discusses those factors which the authors feel are affecting water quality, indicates water quality problems, and suggests future research concerning these problems. It may be possible to maintain water quality in the Flathead Drainage by evaluating the factors mentioned, (ie. population, recreation, agriculture, livestock wastes, and forest management) and implementing any necessary corrective measures.

Tally Lake is one of the lakes specifically mentioned in the report of Seastedt and Tibbs. Those authors stated that it could provide excellent opportunities to study both the general problems which are encountered throughout the drainage, and some unique to the lake itself. Despite the lake's oligotrophic characteristics, at some seasons the lake is evidently subjected to significant pollution insults. A large bloom of noxious *Anabena flos-aquae* was observed during mid-summer 1972 (Seastedt and Tibbs, 1974). Those authors suggested that without further analysis they could only guess that the large clear-cuts and the many cattle found in the basin were affecting production of the lake. Tally Lake is interesting not only because it affords the opportunity to evaluate these aspects of land use on water quality, but also because of its physical characteristics (ie. great depth, yellow-brown water color, inlet-outlet position, and morphometry) which make it a truly unique system.

This study was initiated to achieve the following objectives:

1. To measure nutrient and bacterial contamination of waters draining clear-cut and livestock grazing areas.
2. To measure nutrient levels and standing crop in Tally Lake.
3. To evaluate the affects of waters draining clear-cuts and livestock grazing areas on Tally Lake production.
4. To make recommendations concerning water quality in the Tally Lake District and the Flathead Drainage in general.

CHAPTER II

REVIEW OF THE LITERATURE

Cultural eutrophication, or the increased rate of aging of lakes due to man's activities, is not a phenomenon unique to modern times. Cowgill and Hutchinson (1970) believe that the increase in water level, production of a blue-green algae bloom, and rapid sedimentation of organic matter in the Italian Lago di Monterosi between 390 and 150 B.C. was due to cutting of timberlands on one side of the lake.

More recently, the Hubbard Brook Study (Bormann et al. 1968, Likens et al. 1970) provided dramatic evidence of extreme nutrient enrichment of waters due to deforestation. By cutting all tree growth to no taller than 1.5 meters, and then treating with an herbicide, Bromacil, the investigators effectively deforested a small drainage. A nutrient and water budget was then determined over the course of two years. Stream flow increased considerably, as high as 36% greater than prior to cutting. The most pronounced effect was a 46-fold increase in stream concentrations of nitrate. This was believed to be the result of eliminating plants and thus interrupting the nitrogen cycle. Normally plants utilize the ammonia and nitrogen products of microbial degradation of organic matter. With the removal of the plant life, the ammonia is oxidized to nitrate which is swept out of the forest ecosystem with the increased run-off.

Nimlos (1972) has warned against application of this data to logged areas in Montana. He maintains that there is little comparison between deforestation as experimentally simulated by Likens et al. and normal logging practices. Further, the nutrient lost from a logged area would depend upon the amount of organic litter available for decomposition. Nimlos maintains that soils in old stands in the Northeast, the Likens study was done in New Hampshire, have 4-6 inches of litter. In Montana's dry forest zone (Ponderosa pine and Douglas fir) less than one-half inch usually accumulates.

Hansmann and Phinney (1973) studied effects of logging on the attached algae of coastal streams in Oregon; comparing clear-cut, patch cut, and uncut drainages. These forests more nearly approximate those found in Montana. They found temperature and sediment load increased and decreased dissolved oxygen concentrations in those streams draining clear-cut drainages. They also observed changes in the algal community structure with once rare species becoming dominant. Increased algal production was also observed in the clear-cut stream.

Weisel and Newell (1970) studied water quality of headwater streams in Western Montana. They found a correlation between stream turbidity and soil disturbance associated with logging. Increased temperature and sediment in the streams of Western Montana are especially critical factors because this is the last refuge of the endangered Western Slope cutthroat trout. No correlation between logging and increased nutrient levels in the streams was given in the work of Weisel and Newell.

A study done by the Department of Biological and Agricultural Engineering, North Carolina State University (Anon. 1971), investigated the importance of animal wastes in agricultural run-off with respect to water quality management in the southeastern United States. Results indicated that while a stream draining a beef pasture site was more polluted than would be expected from natural sources, (mean ortho-phosphate value, 1.1 mg/liter), the pollution was extremely low compared to the wastes produced. This was considered to be due to the spreading of the wastes by the animals' grazing behavior. A dairy operation however, showed that while only fractions of the dairy wastes reached the stream, the amounts were sufficient to cause gross pollution conditions (mean orthophosphate value, 4.6 mg/liter).

A wide range of techniques are available to investigators concerned with the primary production of organic matter of water bodies. Measurements of primary production can be made using aquatic macrophytes, phytoplankton, or periphyton (Wetzel, 1964). Periphyton standing crop was measured in Tally Lake since aquatic macrophytes are few and the phytoplankton community is not suitable for studying point sources of pollution, such as lake inlets, as it can move throughout the lake. The periphyton community has also been shown to be quite sensitive to environmental changes (Cairns et al. 1972). In this discussion of periphyton production, periphyton is best described by the definition of Aufwuchs given in Ruttner (1952), "Aufwuchs comprises all attached organisms (except the macrophytes), including such forms as sponges and Bryozoa, which are usually considered as benthos by American authors; also included are the various forms living free within the mat of sessile forms."

Sladeckova (1962) reviews many of the available techniques for sampling and measuring production of the periphyton community. Some of the problems involved in sampling include: affects of currents (Dumont, 1969), type and amount of available substrate for colonization (Pieczynska, 1967, Pieczynska and Spondniewska, 1963, Arthur and Horning, 1969, Beers and Neuhold, 1968) storm generated waves which can dislodge the periphyton (Olson and Odlaug, 1971) and light and temperature (Patrick, 1971).

The range of techniques for measuring periphyton production includes: gravimetric analysis (Sladacek and Sladacek, 1964), ^{32}P material balance method in which ^{32}P is added to the sampling area its uptake is measured (Elwood and Nelson, 1972), ^{14}C material balance method (Olson and Odlaug, 1972, Wetzel, 1964, 1965), chlorophyll extraction with acetone (Bahls, 1971, Todd, 1971, APHA, 1971), pH, O_2, and CO_2 changes as water passes over periphyton community in artificial streams (Kevern, Wilhm and Van Dyne, 1966), and dichromate oxidation (Maciolek and Kennedy 1964).

CHAPTER III

THE STUDY AREA

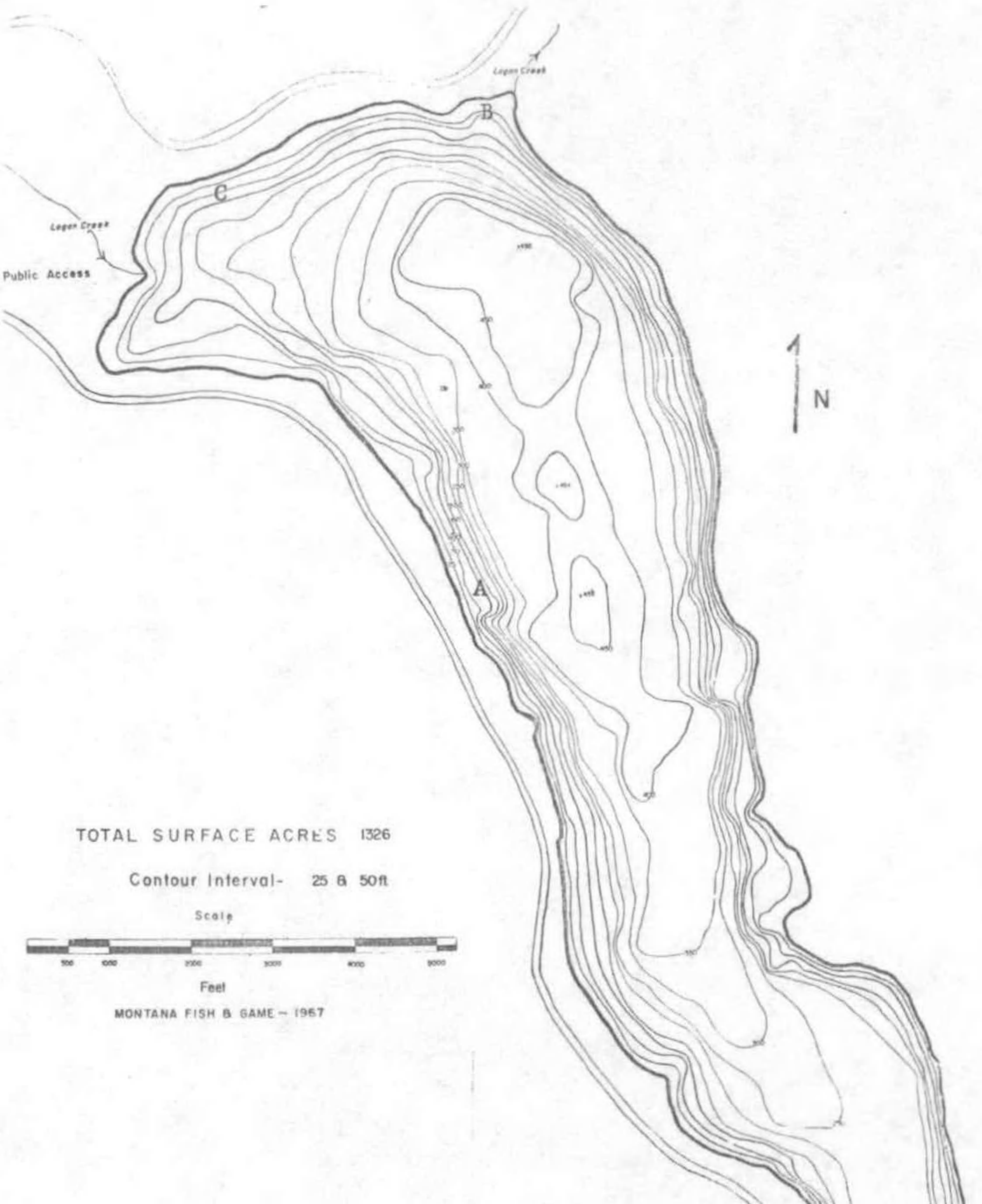
The Lake

Tally Lake is a beautiful body of water located in the Flathead National Forest 30 road miles north of Kalispell and 8 road miles west of Whitefish. The combination of faulting along the east shore and glacial overdeepening of the basin have resulted in a lake which most closely fits Hutchinson's (1957) description of a fjord lake; lakes formed below the snow line by glacial overdeepening of narrow valleys. In many respects Tally Lake resembles the Nordfjord lakes described by Strom (1932).

In addition to its great depth (492 feet) there are two other physical features of particular interest in Tally Lake: 1) The inlet and outlet (both named Logan Creek) are located at the north end of the lake (Illustration 1). Thus, unlike the situation obtaining in most lakes where water flows through the lake, it is possible that most of Tally Lake remains relatively uncirculated, with water flowing only through the north end. This could have important consequences for production in the lake if the inlet be the source of nutrients which caused the observed blue-green bloom. 2) Tally Lake water is yellow-brown. This is typical of many lakes on the continental shield where degradation of organic matter is slow, but is rather surprising is a mountain lake. The humic materials which

Illustration 1. Morphometric map of Tally Lake showing locations of the three sampling stations.

Illustration 1



give this color to water have long been recognized in soil extracts, however their complex composition is still unknown.

Geology, Soils, Vegetation, and Climate

As noted above, the dominant geologic force in the Flathead was continental glaciation working upon the fine grained carbonates, argillites and quartzites which form the bedrock. The bedrock is covered with highly permeable glacial deposits which are very stable, presumably due to their permeability (Dils et al. 1972). In the Tally Lake area, the Whitefish series, a gray-wooded soil occurring on well drained silty materials of calcareous origin, is the predominant soil. Dils et al. (1972) point out that the permeability of the glacial deposits and the soils is very important to water quality.

Vegetation in the Tally Lake area consists largely of mountain alder (*Alnus tenuifolia*) along the banks of Logan Creek, lodgepole pine (*Pinus contorta*), western larch (*Larix occidentalis*), douglas fir (*Psuedotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*). Of interest is the fact that the west shore is dominated by western larch while the east shore is dominated by douglas fir and ponderosa pine. This distribution seems to be associated with differences in sunlight and rainfall.

The climate is considered to be intermediate between the maritime climate of the Pacific Northwest and the continental climate of the Midwest (Dils et al. 1972). Kalispell has an average annual precipitation of 15.02 inches with the maximum in May or June (Dils et al. 1972). Logan Creek, which drains a substantial portion of the Tally Lake District, has never reached peak flow as late as June and frequently does so in April. Maximum stream flow for Logan Creek is of the order 10-12 cfs. The precipitation in 1973 was very different from this average. During 1972-1973 precipitation in the area was the lowest in recorded history with snow pack in the high mountains reaching only 40% of the yearly average.

The Drainage and Land Use

Use of the lake perimeter is restricted to a campground located at the NW end of the lake, and the accompanying boat launch ramp. The campground can accomodate 180 people at a time. Because the epilimnion becomes so warm (ca 20^{o} Centigrade), and the wind speed is rarely high, Tally Lake is very popular for water skiing (Gary Meyer, Tally Lake Ranger Station, pers. comm.). It has been observed however, that skiiers and fishermen tend to limit their activities to the north end of the lake.

Star Meadow (Illustration 2) is about 5 miles by dirt road west of Tally Lake. In the meadow the three creeks which drain the logged higher country converge to form Logan Creek. The beef cattle which graze here are of interest to this study. Mr. Sproul of the Sproul Bros. Ranch provided the information that he kept approximately 70 head of cattle and a few horses in the meadow. In total he felt there were probably 100 head of cattle in the Star Meadow area. During the winter these cattle are kept in barns which are usually flooded by spring run-off water covering the entire meadow with 2 to 3 feet of water (Mr. Sproul and Gary Meyer, pers. comm.).

Illustration 2. Map of Tally Lake drainage basin showing location of the sampling sites. One-half inch = one mile.

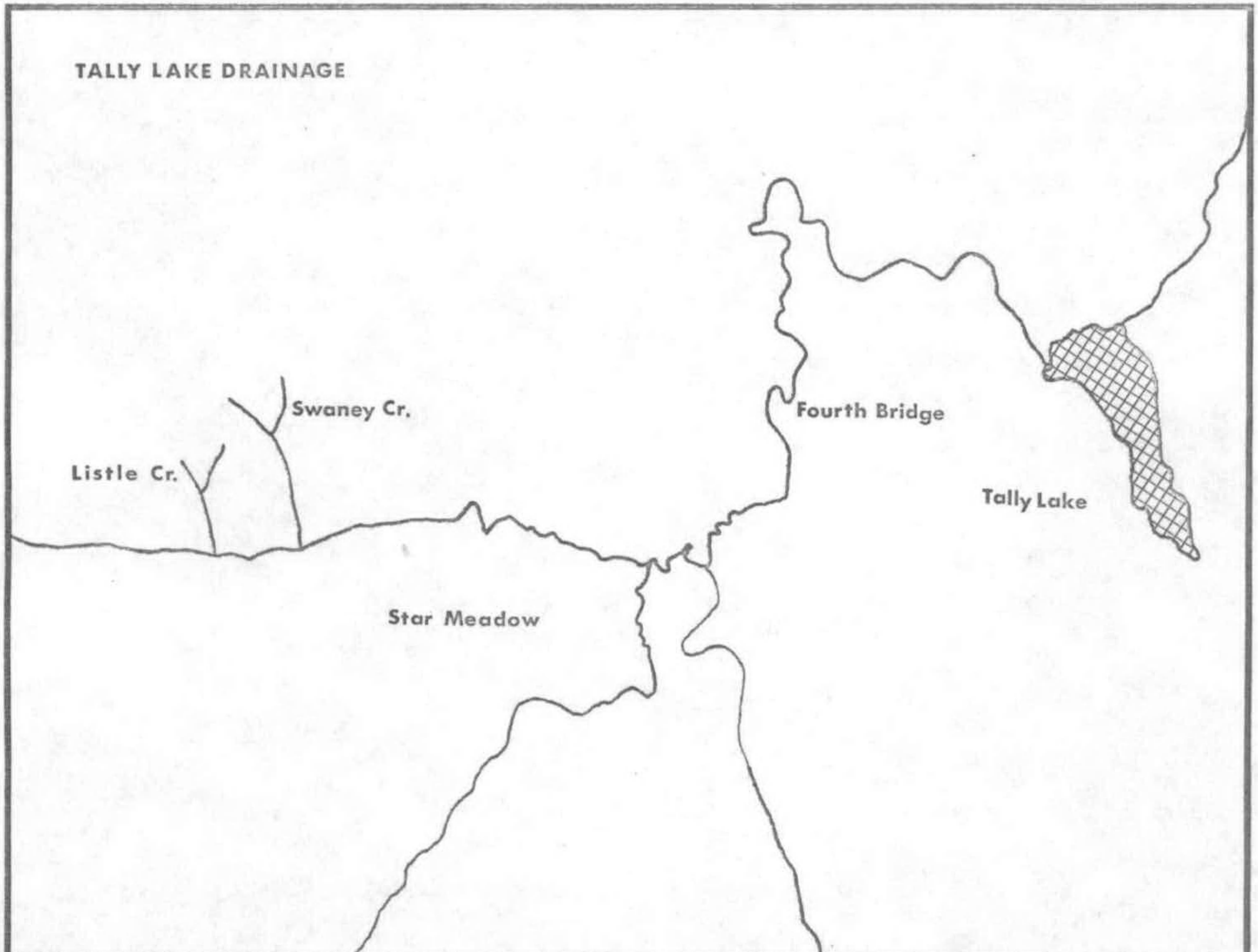


Illustration 2

It was this seasonal phenomenon which was believed to be exerting adverse effects upon water quality in the drainage.

Extensive logging operations and the roads associated with them can be seen in the Tally Lake area, both from the road and from the U.S. Forest Service's aerial photographs of the area.

CHAPTER IV

MATERIALS AND METHODS

In the spring of 1973, six stations were established in the lake and its drainage (Illustrations 1 and 2). Every week water samples were taken from each of these stations:

Station	Location
Listle Creek	Approximately five miles upstream from Star Meadow, this creek drains an area which was clear-cut in 1972.
Swaney Creek	Located three miles upstream from Star Meadow, this area was clear-cut in 1968.
Fourth Bridge	This station is located one mile downstream from Star Meadown on Logan Creek.
A	Located at a point approximately one mile from the northern end of the lake, in the littoral zone of the west shore.
B	Located in the littoral zone of the lake at its outlet.
C	This station was established in the littoral zone of the lake near the inlet.

Two streams draining clear-cuts of different ages were chosen for sampling in order to determine if the length of time since cutting could be affecting their impact on water quality.

The inlet and outlet are both located at the northern end of the lake. For this reason the possibility that inlet water was moving only through the northern end of the lake had to be considered.

Station A was therefore established as a control for the inlet and outlet stations.

In the lake, water samples were taken at each station from depths of 1,3,7, and 9 meters using a 3-liter Van Dorn Bottle. Water samples from streams and lake were transported to the lab in 1-liter glass bottles. These were rinsed twice and then filled with the sample water. The bottles were then placed in ice chests and kept cool using a chemical refrigerant (brand: Blue Ice). All analyses were completed within 24 hours of collection.

Chemical Parameters

Bicarbonate alkalinity and pH determinations were carried out in the field. A color comparator kit was used to determine pH, whereas bicarbonate was measured by titration with 0.02 N sulfuric acid.

Further chemical tests were undertaken after the water samples had been filtered through Millipore filters (.45 micron pore size) which had been soaked in distilled water for at least 24 hours prior to use (APHA, 1971). The tests were carried out using methods and materials supplied by the Hach Chemical Company, and a Bausch and Lomb Spectronic 20. The Spectronic 20 was equipped with a red light source and filter for ortho-phosphate and total filtrable phosphate determinations.

Test	Method (Hach)
Total Filtrable Phosphate	Persulfate digestion (APHA, 1971) to release phosphate from organic matter. Stanna Ver method for ortho-phosphate.

Test	Method (Hach)
Ortho-phosphate	Stanna Ver method
Ammonia	Nesslers Reagent method
Nitrate	NitraVer IV method
Silica*	Amino Acid method
Dissolved Oxygen*	Modified Azide-Winkler method, using PAO. Three hundred ml. water samples were fixed in the field.

Physical Parameters

Temperature readings were taken at all stations and depths using a thermometer calibrated in degrees Centigrade.

Secchi disc readings were taken at each lake station using a 20 cm. diameter, black and white, plastic secchi disc.

To measure stream depth of Logan Creek as it enters Tally Lake, a stream gauge was placed in Logan Creek at a point 100 yards above its entrance into the lake.

Biological Parameters

Weekly periphyton samples were collected following a scheme based in part on the work of Dumont (1969). Four sampling devices were placed, each one on successive weeks, at every lake station, in eleven meters of water. Thus each week it was possible to remove and replace a device which had been incubating in the lake for four weeks. Each sampling device consisted of a buoy, four sampling trays, attached by means of eye hooks to a nylon rope allowing them

* Tests not carried out on stream waters.

to rotate with currents, and a weight. Each sampling tray was designed to hold four pairs of two by three inch glass slides held back to back (Illustration 3). The trays were constructed of Hemlock because it does not contain any chemicals which might influence the growth of periphyton (Dr. Fred Shafizadeh, Wood Chemistry Laboratory, University of Montana, pers. comm.).

Two techniques were used to measure the standing crop of the periphyton community found on the slides: 1) Dichromate oxidation and 2) Chlorophyll extraction. The dichromate oxidation (Maciolek, 1962) is a chemical procedure by which all organic matter in the sample is oxidized in a known volume of dichromate. By titrating the dichromate remaining following completion of the oxidation, a value for the oxygen consumed in the reaction is obtained. This value can then be transformed to gram calories per cm^2.

When the weekly periphyton samples were obtained, three of the eight slides from each sample tray were immediately immersed in the dichromate solution. At the laboratory the flasks containing slides and solution were placed in a boiling water bath for three hours to complete the oxidation. The values of $gcal/cm^2/28$ days which I obtained are not a measure of primary production since they include zooplankton, bryozoans, and fungi. Rather, they can be viewed only as approximations of standing crop on the slides for than four week period.

In contrast to the dichromate oxidation procedure, the chlorophyll extraction technique attempts to measure the standing crop of primary producers. The basis for the technique assumes that standing

Illustration 3. Periphyton Sampling Tray.

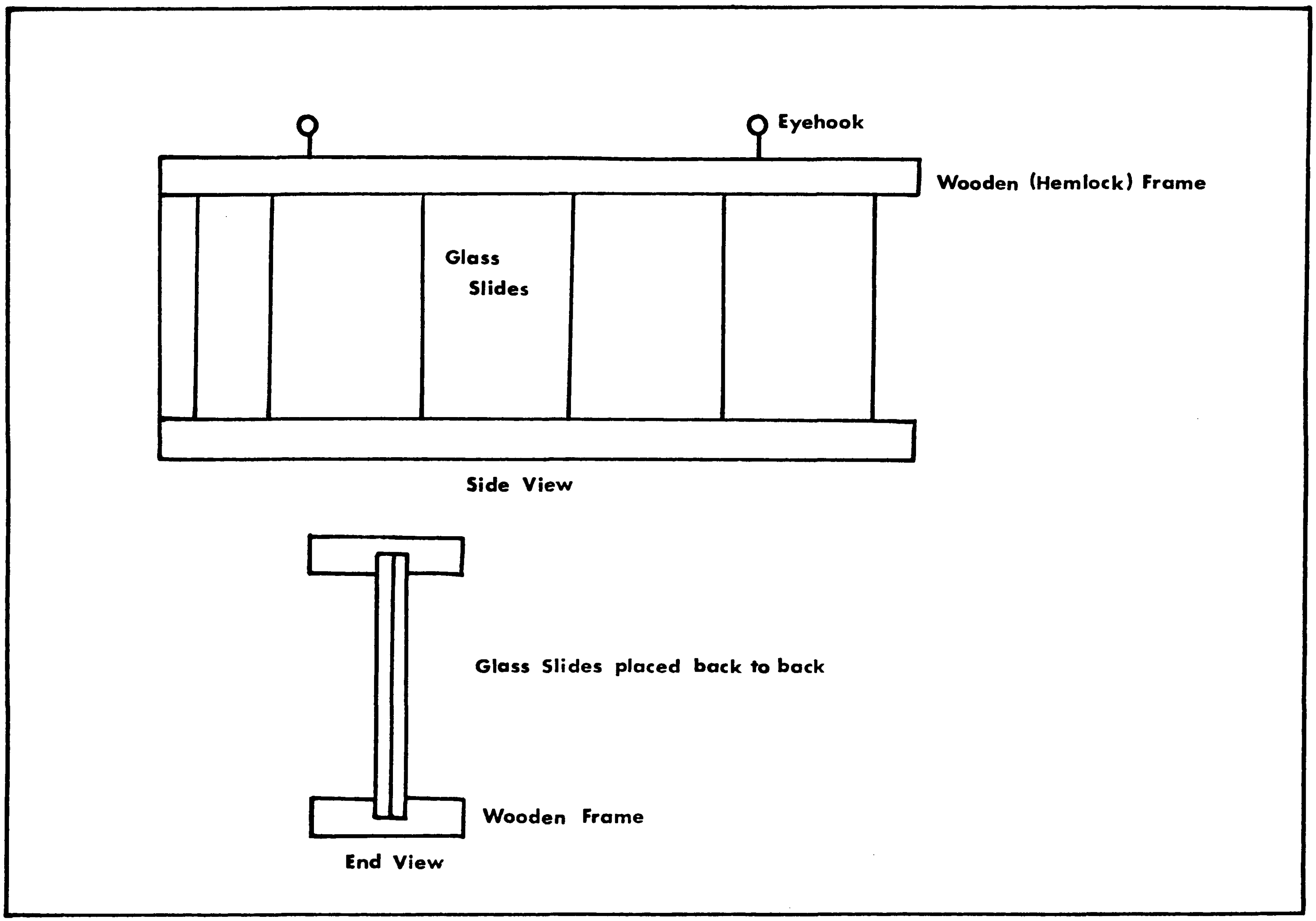


Illustration 3

crop is proportional to chlorophyll concentration. There are some difficulties with this assumption since chlorophyll concentration in algal cells can vary with environmental conditions and the physiological condition of the cell. Despite these problems chlorophyll is a widely used index for production and standing crop.

After the initial three slides were placed in the dichromate solution, four of the remaining five slides were placed in a darkened box and transported to the laboratory. They were then frozen, rupturing the algal cells and facilitating leaching of the chlorophyll by acetone. The slides were then placed in 40 mls. of 95% acetone and allowed to steep for forty-eight hours in a refrigerator. The acetone solution was then centrifuged and its optical density was read on a Bausch and Lomb Spectronic 20. The concentration of chlorophylls a,b, and c were calculated following the formulas given in Standard Methods (APHA, 1971). This gave a measure of standing crop of the primary producers on the slides. This could then be used as a comparison for the total standing crop derived from the dichromate oxidation.

The final slide of the eight from each sampling tray was scraped clean with the algae, zooplankton, bryozoans and other associated organisms being preserved in 6:3:1 (water:ethanol:formalin) for future identification.

Fecal streptococci and total coliform measurements were made on waters from Listle Creek, Swaney Creek, and Fourth Bridge stations. Three hundred ml. water samples were taken in autoclaved glass bottles and kept cool as described above. Replicate dilutions of 10^0, 10^{-1}, and

10^{-2} were placed on Difco agars using the membrane technique (APHA, 1971). The cultures were incubated for forty-eight hours at 37°C. and then counted.

CHAPTER V

RESULTS

A lake represents a complex interaction of physical, chemical, and biological factors. It is therefore impossible to consider any biological data independently of chemical and physical results. It it impractical, however, to present all three at once. In this chapter the results of physical, chemical, and biological studies will be presented in separate sections. In the discussion following, an attempt will be made to synthesize the results and show how they describe production in Tally Lake.

Physical Results

Illustrations 4 and 5 graphically present the results of secchi disc and temperature readings taken on a weekly basis from July 27-October 27, 1973, at station A. Stations B and C show the same results. By early May a thermocline had become established between 3 and 7 meters. It strengthened through the summer, until September 28 when the lake became isothermal to a depth of 9 meters. Secchi disc depths ranged from 5.2-6.1 meters until September 7 when the range changed to 7.0-7.9 meters.

The stream depth, as recorded on the stream gauge, showed a steady decrease from the date of installation (April 27) when the gauge showed 23 inches, until it was removed on September 21 when

Illustration 4. Secchi disc depth, in meters, and water temperature, in degrees Centigrade, at station A from 7/27-9/7 , 1973.

Illustration 5. Secchi disc depth, in meters, and water temperature, in degrees Centigrade, at station A from 9/21-10/27, 1973.

Illustration 4

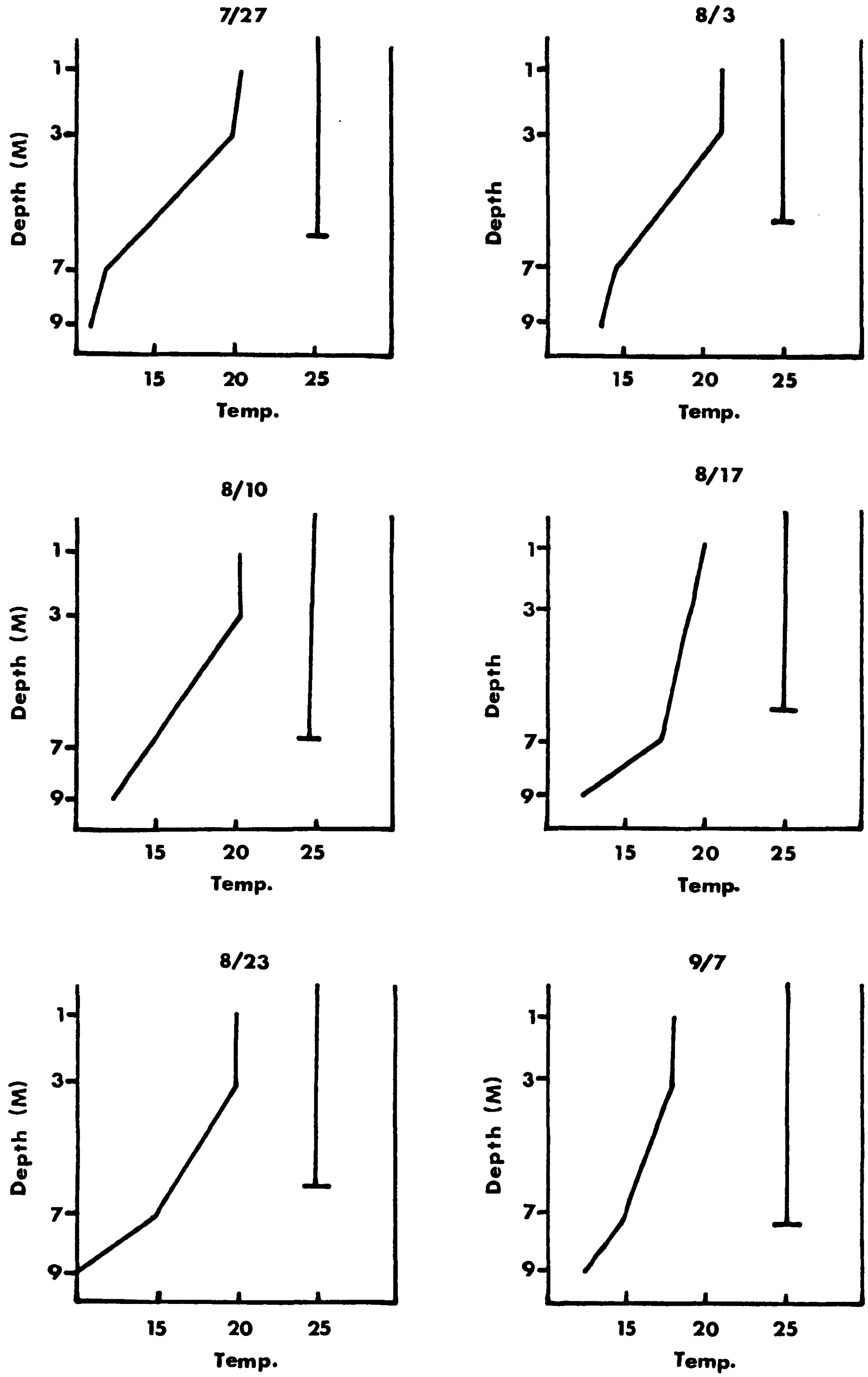
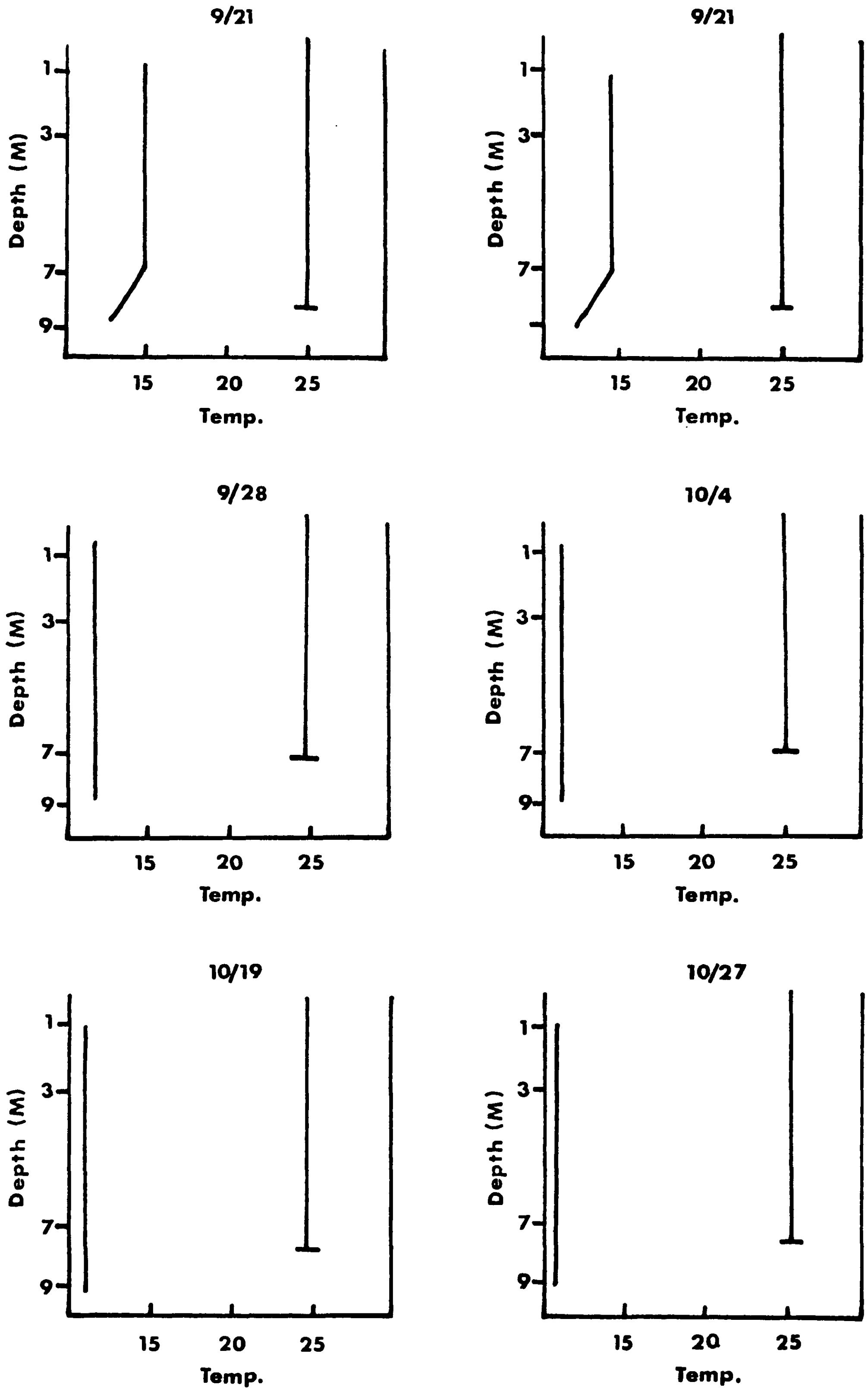


Illustration 5



it showed 9 inches. Flow measurements were not taken because a flow meter was not available.

Chemical Results

Bicarbonate alkalinity is a measure of the amount of bicarbonate buffer present in waters. It is clear that the amount of bicarbonate present plays a large role in determining whether water is alkaline or acidic, thus it is very closely associated with pH. Illustrations 6 and 7 show the relation between alkalinity and pH at depths of 1 and 9 meters at station A. During May and June the alkalinity and pH of the 1 and 9 meter stations were the same. Beginning in July the pH and alkalinity declined at 9 meters. They returned to previous levels after the fall overturn of the lake.

Alkalinity measurements in Listle Creek, Swaney Creek, and Logan Creek at Fourth Bridge show Listle Creek alkalinity (160 ppm) consistently higher than Swaney Creek (120 ppm) or Fourth Bridge (120 ppm).

Silica is used by diatoms to fashion their frustules. Illustration 8 presents the silica dynamics from 5/21-9/15, 1973. The low values in May indicate that diatoms were utilizing the silica. The higher values as the summer progressed suggests fewer diatoms were present as that time.

Dissolved oxygen values from May 21- August 10 are presented in the Appendix. The values remained in the 7 to 9 ppm range as one might expect in a lake of this depth.

Illustration 6. Alkalinity (ppm) and pH at station A in one meter of water from 7/27 to 10/27, 1973.

Illustration 7. Alkalinity (ppm) and pH at station A in 9 meters of water from 7/27 to 10/27, 1973.

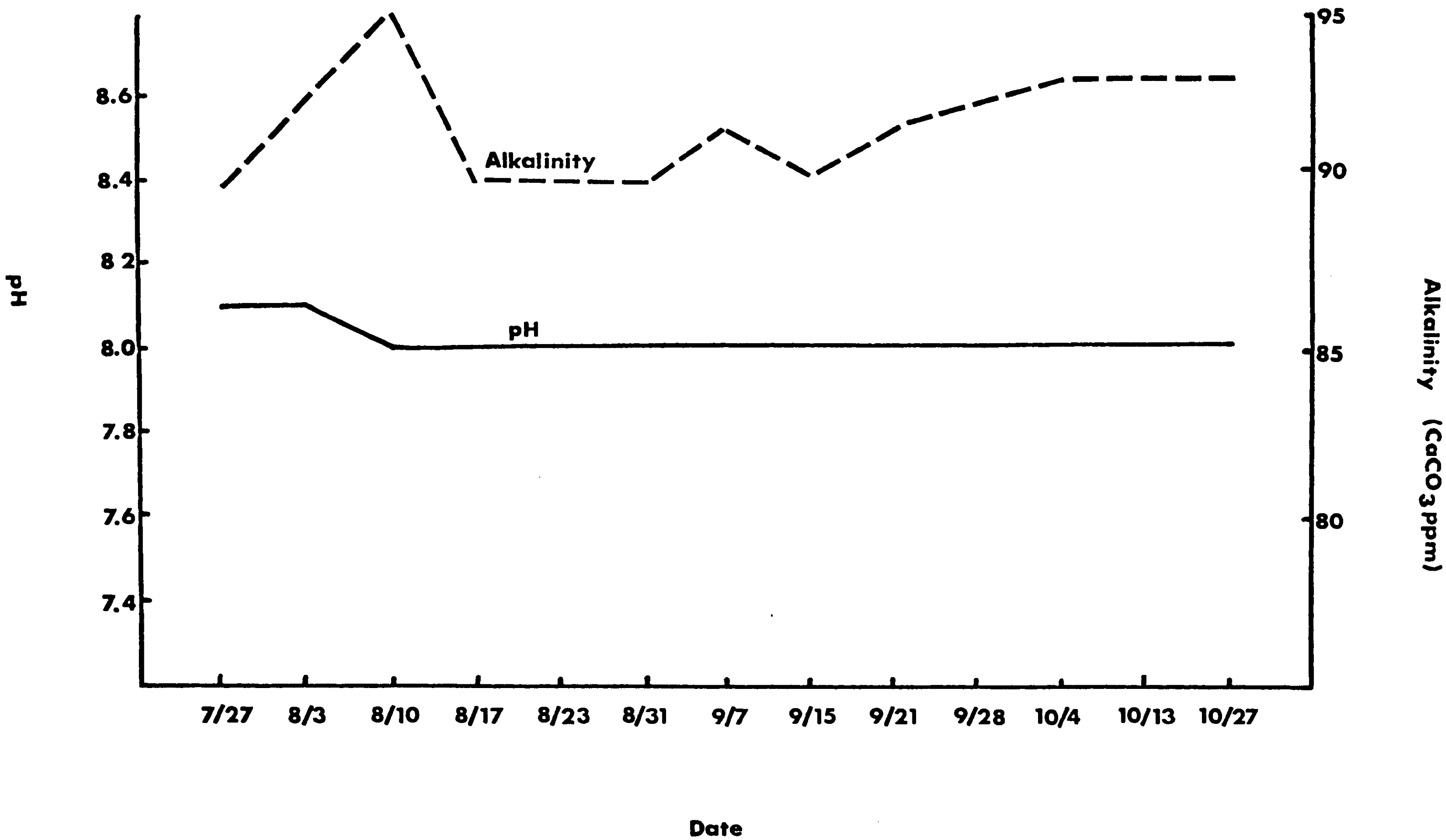


Illustration 6

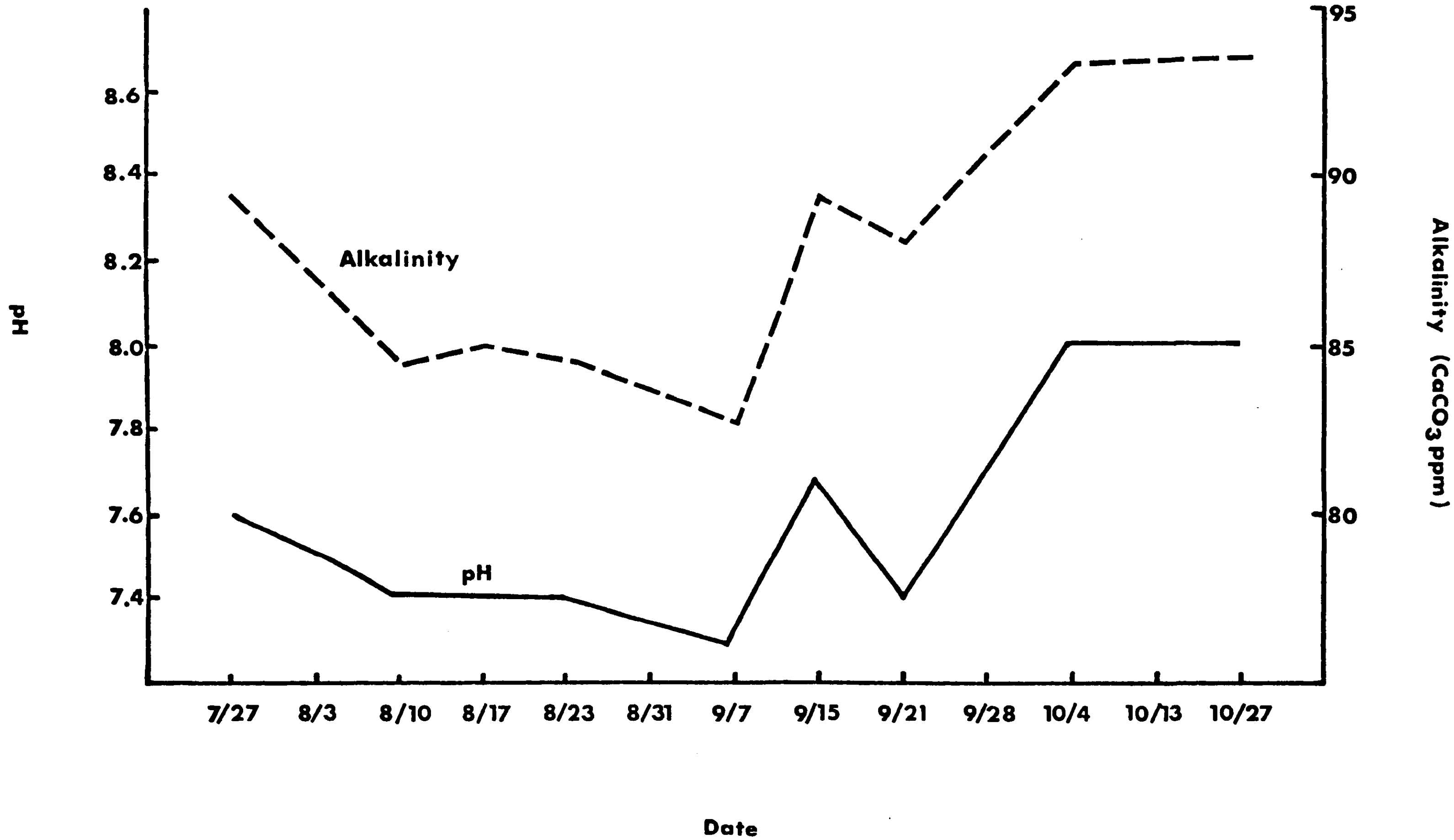


Illustration 7

Nitrate and ammonia values for the lake stations are presented in the Appendix. Interestingly, nitrate levels, which might indicate clear-cut influences were very low (station A, mean value was 0.004 ppm and the range was 0.001-0.007 ppm). This indicates very little influence from the clear-cuts on stream nitrate levels. Ammonia values, on the other hand, were higher (station A, mean value was 0.38 ppm and the range was 0.25-0.56 ppm). This may be due to cattle wastes.

Illustration 9 presents the ortho-phosphate concentrations for the lake stations. The variations in ortho-phosphate which were observed were not a consequence of stream flow as it declined steadily throughout the study period. The large and rapid decrease in ortho-phosphate from 8/23 to 9/7 is particularly noteworthy. The values for total filtrable phosphate show the same trends as the ortho-phosphate values and may be found in the Appendix.

Biological Results

The fecal streptococci and total coliform data are presented in Table 1. All stream stations show very high total coliform counts. The presence of fecal streptococci in Listle and Swaney Creeks was surprising. Only eight cattle had potential access to this area and they would have had to traverse over three miles of mountainous terrain to reach Swaney Creek, the closer of the two drainages.

The dichromate oxidation data for all stations and depths is presented in the Appendix. For each station the data from 1 and 3 meters depths is very similar and standing crop values are much

Illustration 8. Silica (ppm) at station A in one meter of water, from 5/21 to 9/15.

Illustration 9. Ortho-phosphate at station A in one meter of water, from 7/27 to 11/4.

Table I. Total Coliform (TC) and Fecal Streptococci (FS) at Listle Creek (LC), Swaney Creek (SC), and Fourth Bridge (FB). Number of colonies per 25 mls. , 10^{-2} dilution.

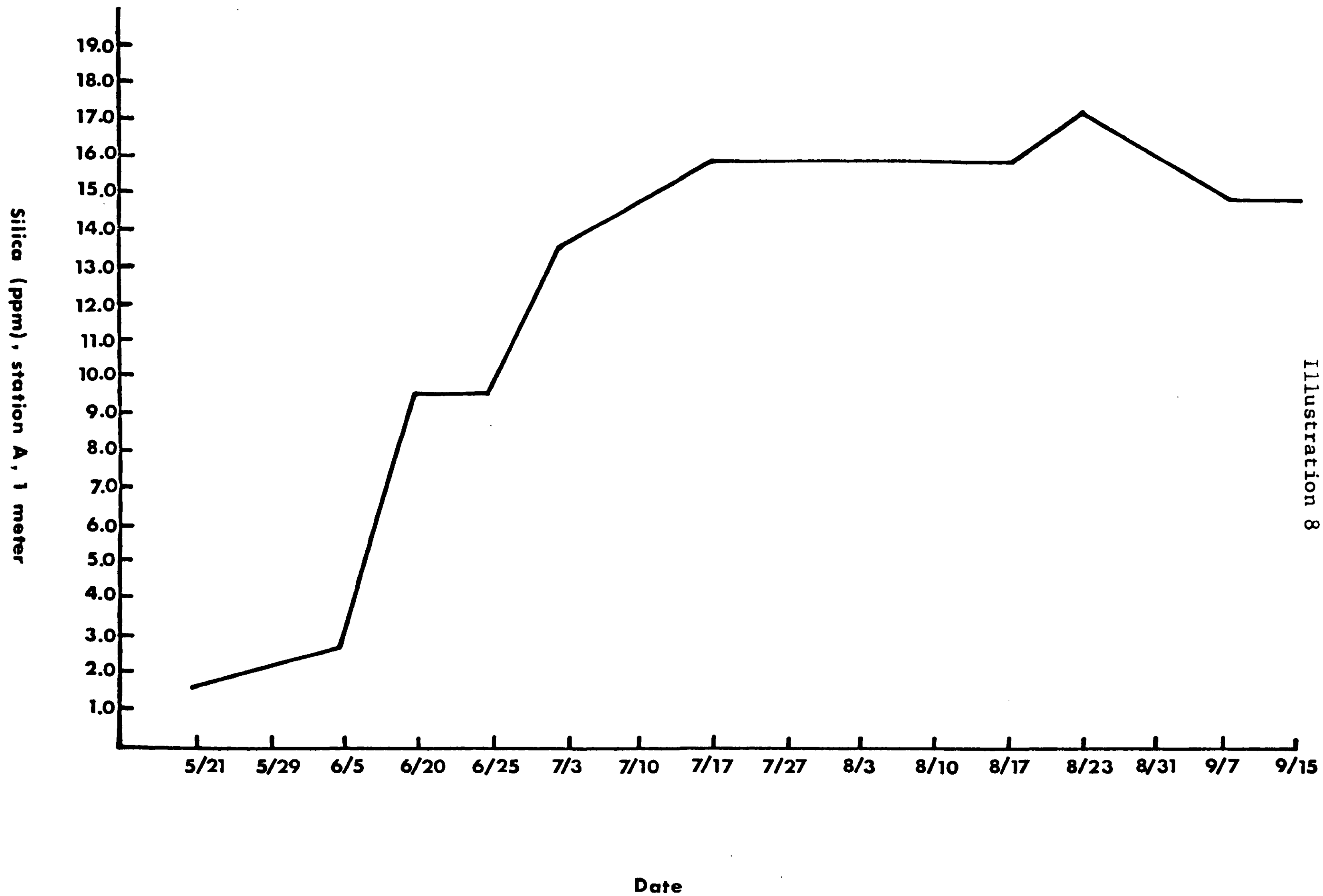


Illustration 8

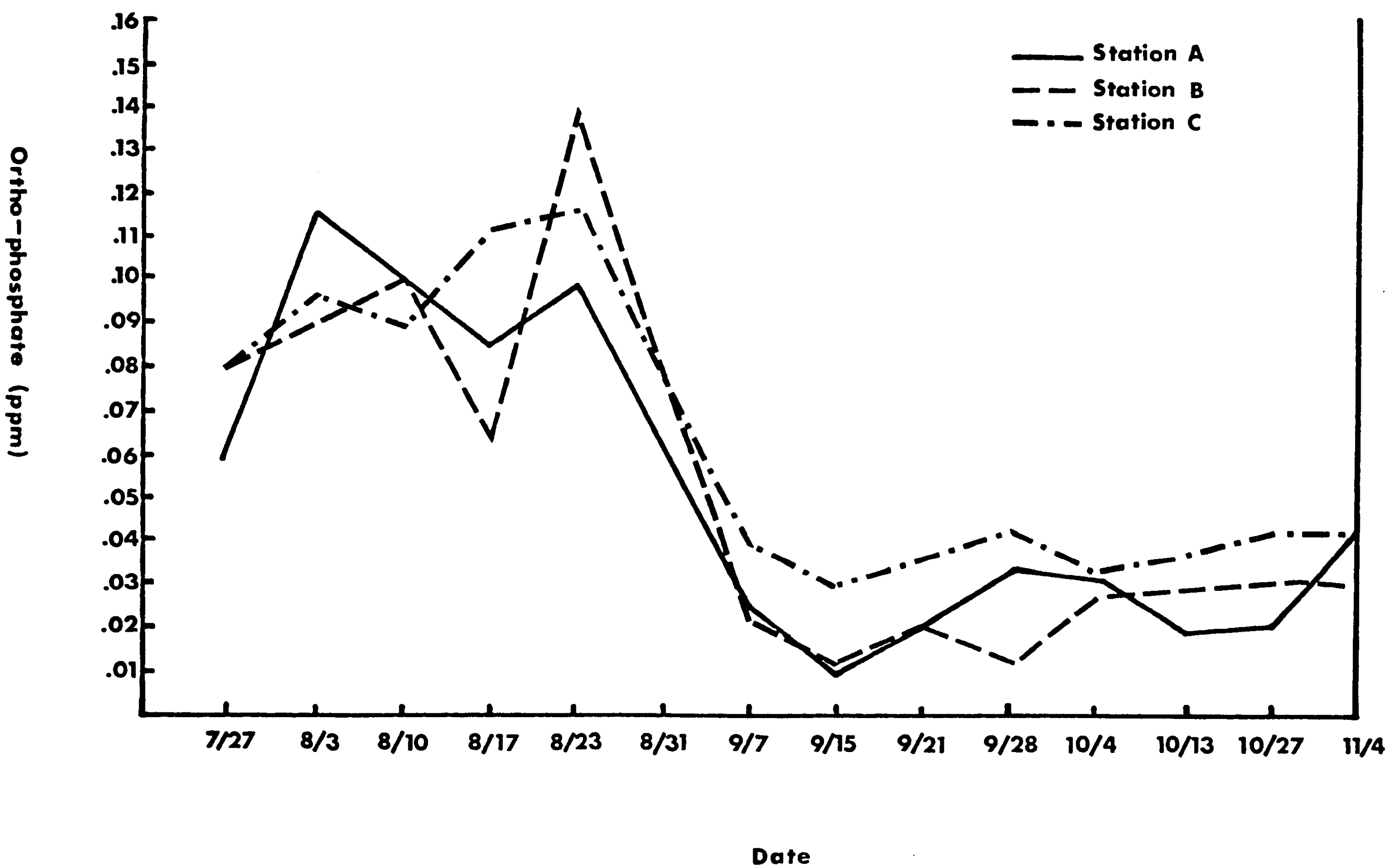


Illustration 9

TABLE I

Total Coliform and Fecal Streptococci

Date	LC		SC		FB	
	TC	FS	TC	FS	TC	FS
6/25	3.5	0	1.5	3	100	1
7/3	-	-	-	-	19	1
7/10	70	0	100	0	100	3
7/17	100	5	100	23	100	11
7/27	100	7	100	30	100	110
8/3	100	70	100	48	100	13
8/10	100	-	100	-	100	-
8/23	100	19	100	43	100	20
9/15	-	-	-	-	100	1
9/21	-	-	-	-	100	8
9/28	-	-	-	-	9	1
10/13	-	-	-	-	100	4

greater than at 7 and 9 meters. Light was probably limiting prod- at these depths resulting in low values. Illustrations 10,11, and 12 depict the dichromate oxidation and chlorophyll extraction values for standing crop obtained from 1 meter at stations A,B, and C respectively. In each illustration the dichromate oxidation and chlorophyll estimates of standing crop generally show the same trends. Station A showed a steady decline in standing crop beginning in mid-August. The standing crop at station B was considerably lower, with the exception of September 21. Standing crop values at station C were very erratic.

The five most abundant genera of algae in 1 meter of water at station A are given on a weekly basis in Table 2. It can be seen that during the course of the summer the community changes from one dominated by diatoms to a community consisting largely of *Mougeotia*, a genus of green algae. *Anabena flos-aquae* is conspicuously absent.

Taxonomic data on fish and zooplankton of Tally Lake are given in the Appendix.

Illustration 10. Chlorophyll Extraction (mg chl/liter) and Dichromate Oxidation (gcal/cm^2) standing crop at station A, one meter, from 7/27 to 11/4.

Illustration 11. Chlorophyll Extraction (mg chl/liter) and Dichromate Oxidation (gcal/cm^2) standing crop at station B, one meter, from 7/27 to 11/4.

Illustration 12. Chlorophyll Extraction (mg chl/liter) and Dichromate Oxidation (gcal/cm^2) standing crop at station C, one meter, from 7/27 to 11/4.

Table 2. Five Most Abundant Periphyton Genera from station A, one meter, from 7/3 to 10/27.

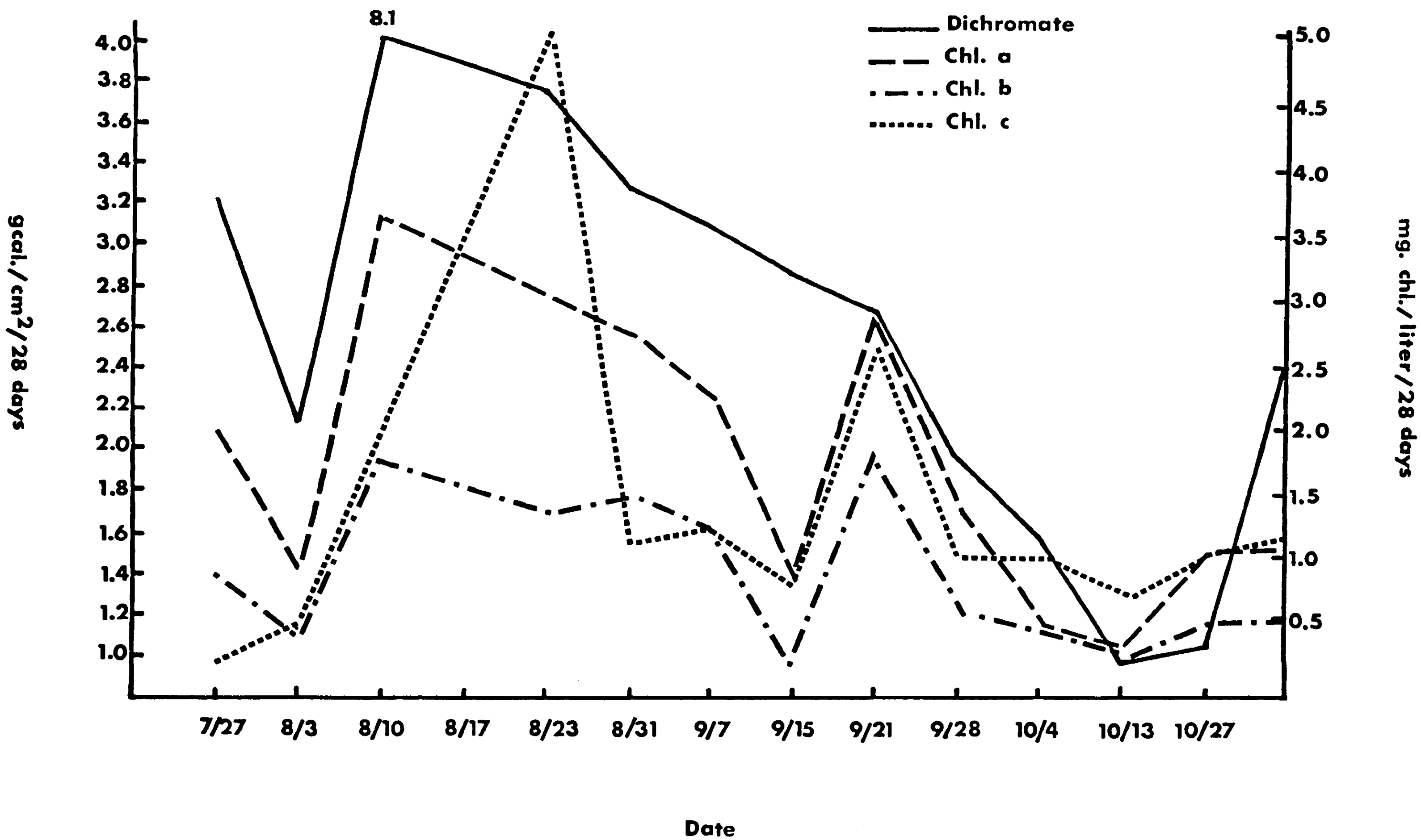


Illustration 10

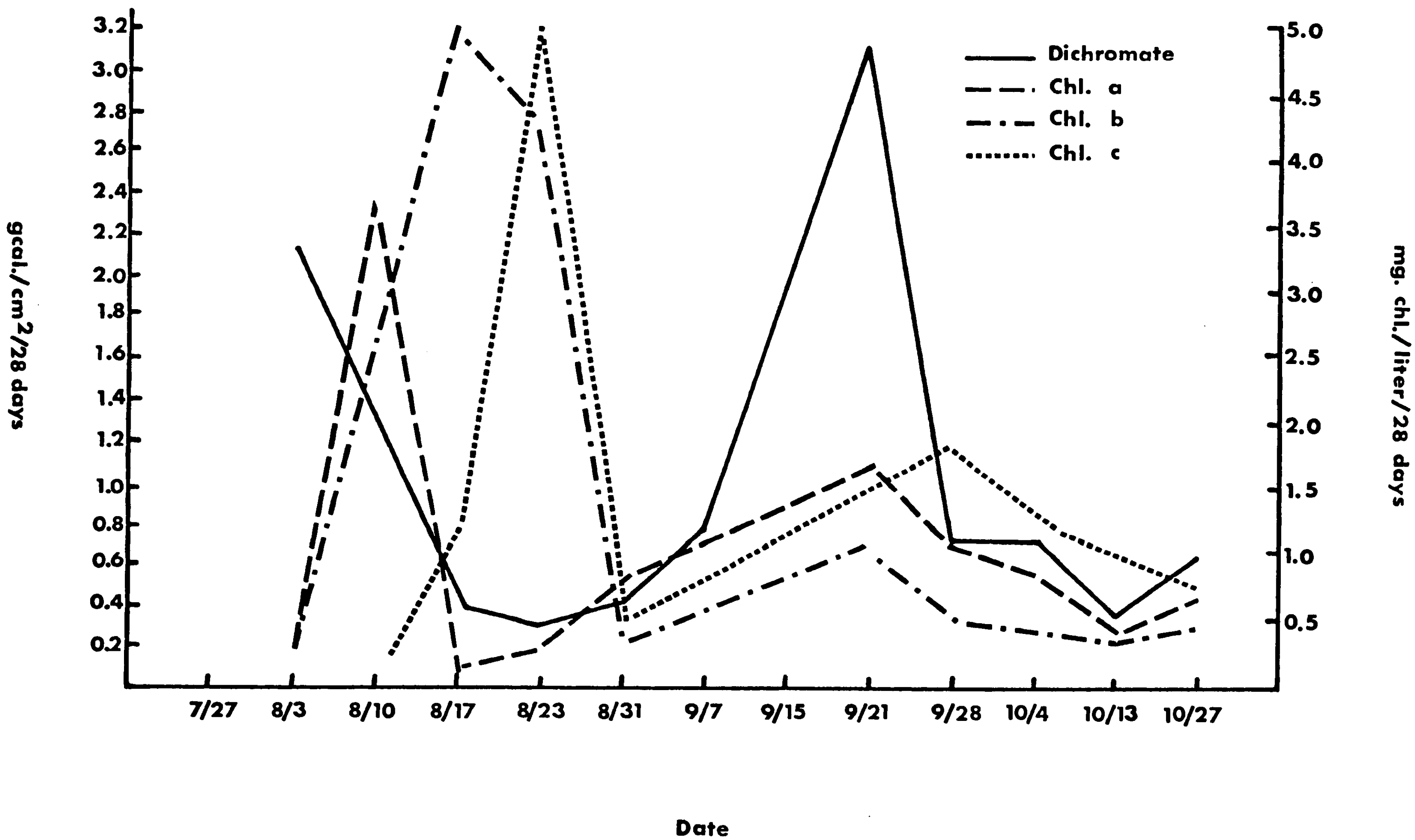


Illustration 11

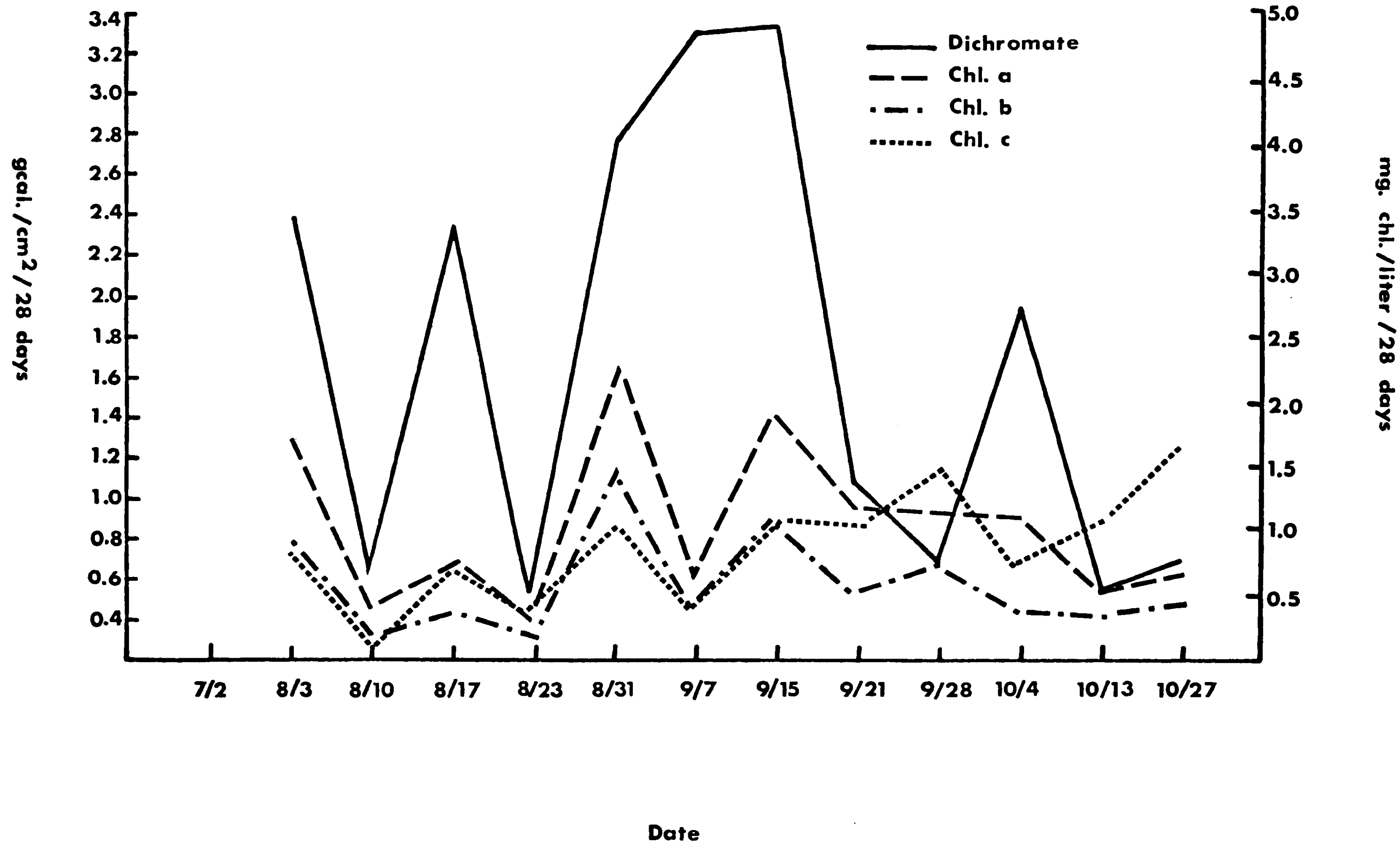


Illustration 12

TABLE 2

Five Most Abundant Periphyton Genera

7/3	7/10	7/27	8/3
Synedra	Synedra	Pinnularia	Pinnularia
Tabellaria	Tabellaria	Cymbella	Cymbella
Gompnonema	Pinnularia	Synedra	Gomphonema
Cymbella	Gomphonema	Mougeotia	Synedra
Pinnularia	Cymbella	Tabellaria	Tabellaria
8/10	8/17	8/23	8/31
Pinnularia	Pinnularia	Mougeotia	Mougeotia
Cymbella	Cymbella	Pinnularia	Synedra
Synedra	Mougeotia	Cymbella	Cymbella
Gomphonema	Gomphonema	Gomphonema	Gomphonema
Tabellaria	Synedra	Synedra	Tabellaria
9/7	9/15	9/21	9/28
Mougeotia	Mougeotia	Mougeotia	Mougeotia
Pinnularia	Synedra	Synedra	Synedra
Cymbella	Pinnularia	Pinnularia	Pinnularia
Gomphonema	Dinobryon	Tabellaria	Cymbella
Synedra	Tabellaria	Cymbella	Gomphonema
10/4	10/19	10/27	
Mougeotia	Mougeotia	Mougeotia	
Pinnularia	Pinnularia	Gomphonema	
Cymbella	Cymbella	Pinnularia	
Synedra	Synedra	Tabellaria	
Gomphonema	Gomphonema	Fungi*	

* Despite being the dominant algal form during October, Mougeotia was not very abundant. During this time the slides were actually dominated by fungi and bryozoans.

CHAPTER VI

DISCUSSION

Before considering the data, it must be acknowledged that the absolute values of the chemical parameters measured, particularly ortho-phosphate, total filtrable phosphate, and nitrate may be imprecise. The techniques used were the best available at the field station. The chemical trends indicated in the Results are probably real, for they are consistently similar at all stations.

The primary objective of this study was to determine the source(s) of the nutrients responsible for the observed *Anabena flos-aquae* bloom, and to evaluate their impact on water quality. It will be recalled that no such bloom was observed in the year of the study. Almost certainly this was due to the low run-off during the study year. During a normal spring the barns in which the cattle over-winter are flushed by the annual flood in Star Meadow. This must cause a large amount of ortho-phosphate to enter the lake. The increased ortho-phosphate could then be responsible for the blue-green bloom.

The nitrate, ortho-phosphate, and total filtrable phosphate data do not indicate that the clear-cuts or livestock were contributing these nutrients in quantities sufficient to cause a bloom of blue-green algae. That the cattle were contributing ortho-phosphate is indicated by the fluctuations in these values and the results from the bacterial studies. It is rather disconcerting to see high fecal streptococci counts in Listle and Swaney Creeks. Stuart et al. (1971) have shown that the opening of a watershed, once closed to human activities, resulted in an unexpected decrease in bacterial contamination of the stream. They postulated that the human activities drove a large wild animal population from the area, thus resulting in the decrease. Thus it seems possible that wild animals may be responsible for the fecal streptococci in Listle and Swaney Creeks. There appears a strong liklihood that fecal streptococci in Logan Creek are due to the cattle.

The decreases in alkalinity and pH below the thermocline are very interesting. This would not be particularly noteworthy in a highly productive lake where the aerobic degradation of organic materials in the hypolimnion can cause an increase in carbon dioxide and a pH decrease. However, this is extremely unlikely in Tally Lake due to its great depth. Strom (1932) noted a similar reduction in pH while passing from epilimnion to hypolimnion in the very deep Nordfjord lakes whose dissolved oxygen curves were strikingly orthograde.

By considering secchi disc, silica, ortho-phosphate, standing crop and community structure data together, a reasonable picture of what occurs in the lake can be obtained. Temperate lakes often show a spring diatom increase with consequent low silica values. Community structure data shows that from June 3 until August 3 the periphyton was dominated by the diatom genera Synedra and Pinnularia. This would seem to be the end of the diatom bloom as silica values are rising from a May 21 low of 1.15 to 2.0 ppm silica. During this period of diatom domination, the secchi disc readings were in the range of 5.2 to 6.1 meters and the ortho-phosphate varied about the value 0.1 ppm.

On August 23 the situation in the lake changes considerably. The secchi disc readings suddenly increase to 7.0 to 7.9 meters, ortho-phosphate and production have attained their peaks and begin to drop and the periphyton community is now dominated by the green alga, *Mougeotia*. It appears that for some reason, it may be temperature, *Mougeotia* obtains a competitive advantage over the diatoms and, because green algae probably have higher ortho-phosphate demands (Vollenweider, 1968) than the diatoms, this causes the drop in ortho-phosphate concentration. This situation is maintained until September 28 when the lake becomes isothermal to a depth of 9 meters. At this point production declines at all stations and the pH and alkalinity values at 7 and 9 meters return to what they were prior to the summer stagnation.

Within this general framework it would be well to consider each station independently.

Station A

This station showed the greatest amount of production and least amount of weekly variation. The general account given above is based largely on data gathered at this station.

Station B

This station yields the same ortho-phosphate trend as station A, with a sharp decrease in ortho-phosphate in early September, but a completely different production record. This might be explained by the wind conditions noted on Tally Lake. On each sampling date a brisk wind coming from the outlet (SE) was noted at about 11:00 am. Blowing from this direction, the wind would not affect station A. Wind generated waves at stations B and C however, could cause periphyton organisms to be broken from the slides. Thus while standing crop would be low, production in the water column could be sufficient to deplete the available ortho-phosphate by late summer.

The very high dichromate value of production noted on September 21 was probably due to the far greater number of cladocerans present on the slides on that date than at any other time.

Station C

Located near the inlet, this station should show influences from this potential source of nutrients. This is also the station most likely to have been disturbed because of its proximity to the campground. Logan Creek and Tally Lake data were examined for an explanation of the great variability in production which this station shows. Of the data gathered, the best fit, as at station A, is with ortho-phosphate. On August 3, 10, 17 and 23 ortho-phosphate and production vary in the same fashion. In the period from August 15 to September 15 production increased while ortho-phosphate was depleted; this may be due to the *Mougeotia*. Standing crop begins to decline on September 21. This, of course, is only one possible explanation of the variability. Others include effects of wind-generated waves as at station B, or tampering with the sampling devices by swimmers, fishermen (a lure was recovered from one of the devices), or water skiiers.

The data indicate that production in the lake was limited by ortho-phosphate. This conclusion lends weight to the hypothesis that ortho-phosphate from cattle waste was largely responsible for the *Anabena flos-aquae* bloom observed by Seastedt. Lakes supporting such blooms are not generally characterized by ortho-phosphate limited production. The ortho-phosphate concentration in 1972 when the bloom was observed must have been higher than in 1973. It seems reasonable to assume that this was due to the lack of run-off from Star Meadow in 1973.

CHAPTER VII

SUMMARY

Conclusions and Recommendations

1. There is considerable bacterial contamination of the waters draining both clear-cut and livestock areas.

2. There is no evidence of increased nutrient levels in waters draining clear-cut and livestock areas. This however may be an artifact due to the unusually low run-off.

3. The standing crop and nutrient levels in Tally Lake are indicative of an oligotrophic lake.

4. The production in the lake is probably ortho-phosphate controlled. The livestock in the drainage may be providing orthophosphate in large quantities during spring floods. This could be avoided by collecting the wastes prior to flooding and utilizing them as fertilizer in Star Meadow after the floods.

5. Measures should be taken throughout the Flathead Drainage to minimize the accessibility of waters to livestock.

Further Research

A continuation of this study during a year of normal run-off would provide an informative comparison to this work. It might also give definitive answers to those questions still unanswered.

A parameter not measured in this study, but which could greatly influence Tally Lake water chemistry, is the water color. As noted earlier, Tally Lake displays the yellow-brown color characteristics of lakes with substantial amounts of humic substances. Recent work (Ghassemi and Christman, 1968, Prakash and Rashid, 1968, Prakash et al. 1973) has shed light upon the properties of these humic substances and indicates that marine phytoplankton growth is stimulated by them. The source of these humic acids and their affect on production in Tally Lake would provide an interesting study.

The aquatic insect fauna of Logan Creek does not seem to conform to what one might expect in a mountain creek of this type in the Flathead (Jack Stanford, pers. comm.). Mr. Stanford, a University of Utah graduate student, has done considerable work with aquatic insects in the Flathead Drainage and is researching a thesis entitled "Stonefly Ecology of the Flathead River". Research into the insect fauna of Logan Creek could provide an interesting comparative study.

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APPENDIX

Dissolved Oxygen (ppm), Station A

	Depth			
Date	1m	3m	7m	9m
5/21	9.8	10.2	9.8	9.6
5/29	9.2	9.3	9.1	8.9
6/5	9.6	9.2	9.3	9.1
6/20	9.1	9.1	9.1	8.6
6/25	9.3	9.1	8.7	8.8
7/3	8.5	8.6	8.6	8.6
7/27	8.3	8.3	7.8	7.2
8/10	7.4	-	-	7.2

Station B

Date	1m	3m	7m	9m
5/21	10.0	10.2	10.2	9.8
5/29	9.6	9.5	9.5	9.0
6/5	9.5	9.6	9.5	9.2
6/20	9.0	9.0	8.7	8.7
7/3	8.4	9.8	7.6	8.4
7/27	7.9	8.0	8.0	7.4
8/10	7.7	-	-	7.0

Station C

Date	1m	3m	7m	9m
5/21	10.0	9.9	9.8	8.8
5/29	9.6	9.2	9.2	9.1
6/5	9.5	9.6	9.6	9.6
6/20	8.9	9.0	-	8.6
6/25	8.9	8.8	8.8	8.2
7/3	8.6	8.7	8.4	8.2
7/27	7.6	7.9	8.1	7.9
8/10	7.5	-	-	6.9

Nitrate Nitrogen (ppm), Station A

Date	Depth 1m	3m	7m	9m
5/21	0.003	0.004	0.004	0.003
5/29	0.004	0.005	0.004	0.003
6/5	0.003	0.003	0.004	0.004
6/20	0.003	0.003	0.003	0.004
6/25	0.003	0.003	0.004	0.004
7/3	0.006	0.004	0.004	0.009
7/10	0.004	0.005	0.006	0.005
7/17	0.005	0.005	0.005	0.003
7/27	0.004	0.003	0.002	0.005
8/3	0.004	0.001	0.003	0.003
8/10	0.008	0.008	0.007	0.005
8/17	0.004	0.005	0.007	0.006
8/23	0.001	0.000	0.001	0.000
9/7	0.005	0.006	0.007	0.006
9/15	0.006	0.005	0.006	0.003
9/21	0.003	0.002	0.003	0.002
9/28	0.003	0.003	0.003	0.005
10/4	0.006	0.007	0.006	0.005
10/13	0.006	–	0.005	–
10/19	0.006	0.004	0.006	0.006
10/27	0.009	0.005	0.006	0.010

Ammonia Nitrogen (ppm), Station A

Date	Depth 1m	3m	7m	9m
5/21	0.53	0.61	0.56	0.56
5/29	0.40	0.40	0.37	0.37
6/5	0.45	0.48	0.45	0.43
6/20	0.35	0.30	0.30	0.30
6/25	0.35	0.35	0.25	0.25
7/3	0.21	0.25	0.25	0.30
7/10	0.30	0.40	0.35	0.40
7/17	0.48	0.30	0.48	0.40
7/27	0.25	0.25	0.30	0.37
8/3	0.48	0.48	0.50	0.48
8/10	0.21	0.25	0.30	0.35
8/17	0.36	0.37	0.35	0.25
8/23	0.25	0.30	0.30	0.25
9/7	-	0.30	0.25	0.38
9/15	0.37	0.37	0.35	0.36
9/21	0.45	0.40	0.37	0.40
9/28	0.25	0.25	0.30	0.25
10/4	0.43	0.37	0.45	0.37
10/13	0.40	-	0.37	-
10/19	0.35	0.35	0.30	0.30
10/27	0.25	0.35	0.35	0.30

Total Filtrable Phosphate (ppm), Station A

Date	Depth 1m	3m	7m	9m
5/21	0.12	0.12	0.12	0.12
5/29	0.23	0.23	0.23	0.23
6/5	0.19	0.25	0.21	0.11
6/20	0.12	0.12	0.11	0.11
6/25	0.21	0.19	0.19	0.19
7/3	0.23	0.25	0.25	0.26
7/10	0.12	0.36	0.17	0.16
7/17	0.24	0.32	0.26	0.26
7/27	0.17	0.17	0.17	0.19
8/3	0.18	0.17	0.21	0.19
8/10	0.25	0.25	0.25	0.28
8/17	0.21	-	0.23	-
9/7	0.12	0.16	0.19	0.19
9/15	0.16	0.14	0.12	0.14
9/21	0.19	0.19	0.19	0.17
9/28	0.14	0.14	0.14	0.14
10/4	-	0.16	-.12	0.12
10/13	0.14	-	0.16	-
10/19	0.17	0.16	0.13	-
10/27	0.17	-.19	0.17	0.19

Dichromate Oxidation (gcal/cm^2/28 days), Station A

	Depth			
Date	1m	3m	7m	9m
7/27	3.20	1.85	0.37	0.288
8/3	2.10	2.65	0.42	0.609
8/10	8.1	3.70	0.64	0.583
8/23	3.67	4.3	0.536	0.231
8/31	3.20	2.80	0.804	0.021
9/7	3.13	4.39	0.504	0.315
9/15	2.86	4.47	0.257	0.000
9/21	2.66	1.94	0.464	0.443
9/28	1.94	4.85	0.992	0.380
10/4	1.56	3.16	-	0.126
10/13	0.718	1.48	0.147	0.147
10/19	0.760	1.57	0.633	0.422
10/27	2.40	2.80	0.718	0.274

Station B

7/27	-	1.27	0.350	0.227
8/3	2.12	-	0.252	0.160
8/17	0.390	0.584	0.217	0.108
8/23	0.315	0.357	0.231	0.231
8/31	0.441	0.168	0.147	0.147
9/7	0.777	0.546	0.210	0.294
9/21	3.08	1.01	0.295	0.316
9/28	0.760	0.316	0.211	0.168
10/4	0.760	0.316	0.211	0.168
10/13	0.289	0.253	0.316	-
10/19	0.654	0.485	0.359	0.401

Station C

7/27	-	1.55	0.473	-
8/3	2.39	2.29	0.168	0.210
8/17	2.36	3.88	0.499	0.195
8/23	0.525	0.357	0.126	-
8/31	2.75	0.882	-	-
9/7	3.28	0.460	0.231	0.168
9/15	3.32	1.56	0.192	-
9/21	1.03	0.359	0.612	0.401
9/28	0.67	0.886	0.377	0.168

Zooplankton Species Present

Rotifera

- _Lecane sp._
- _Kellicottia longispina_ (?)
- _Keratella cochlearis_ (?)

Cladocera

- _Daphnia longiremis_ (Sars)
- _Daphnia thorata_ (S.A. Forbes)
- _Bosmina longirostris_ (O.F. Muller)

Copepoda

- _Cyclops biscuspidatus_ (Claus)
- _Diaptomus ashlandi_ (Marsh)

Fish Species Present

Dolly Varden	_Salvelinus malma_ (Walbaum)
Cutthroat Trout	_Salmo clarki_ (Richardson)
Rainbow Trout	_Salmo gairdneri_ (Richardson)
Brook Trout	_Salvelinus fontinalus_ (Mitchill)
Mountain Whitefish	_Prosopium williamsoni_ (Girard)
Kokanee Salmon	_Oncorhynchus nerka_ (Walbaum)
Squawfish	_Ptychocheilus oregonensis_ (Richardson)
Peamouth	_Mylocheilus caurinus_ (Richardson)
Longnose Sucker	_Catostomus catostomus_ (Forster)
Largescale Sucker	_Catostomus macrocheilus_ (Girard)
Pumpkinseed	_Lepomis macrochirus_ (Linnaeus)