PLANKTON POPULATION STRUCTURE IN THE LOWER COEUR D'ALENE RIVER, DELTA, AND LAKE

A Thesis

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AUTHORIZATION TO PROCEED WITH THE FINAL DRAFT:

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ABSTRACT

Plankton communities in the lower Coeur d'Alene River, delta, and adjacent lake waters and the lower St. Joe River were investigated over an 18-month period to determine relationships of the physico-chemical environment with community composition and seasonal succession.

The plankton organisms present in the Coeur d'Alene River followed similar seasonal cycles in composition to those in the delta and open waters of the lake but were considerably lower in numbers. Plankton populations were higher and more diversified in the St. Joe River than in the Coeur d'Alene River during the summer of 1970.

Wind action, river discharge, turbidity, conductivity, and allochtanous material apparently influence plankton communities in both the Coeur d'Alene River and delta. Dissolved oxygen, alkalinity, and pH were not considered limiting factors on the biological community. Settling ponds have improved the quality of the river waters with respect to suspended solids but have not eliminated the high concentrations of heavy metals toxic to the biological community.

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INTRODUCTION

Coeur d'Alene Lake has received large volumes of domestic and industrial wastes from the Coeur d'Alene River for nearly 85 years. The major source of this pollution has been from extensive mining operations along the South Fork of the Coeur d'Alene River above Wallace, Idaho.

Kemmerer et al. (1923) noted lower numbers of plankton at the mouth of the Coeur d'Alene River near Harrison City than in the deeper, more oligotrophic portions of the lake. Ellis (1932) found the polluted portions of the river in 1923 to be nearly devoid of fish, benthic macroinvertebrates, and plankton. He also noted that Coeur d'Alene Lake near the mouth of the river had lower populations of phytoplankton, zooplankton, fish, and bottom organisms compared to the remainder of the lake.

The North Fork of the Coeur d'Alene River and the St. Joe River have not been subjected to as many environmental changes, brought about by the addition of domestic or industrial wastes, and are presumably in a condition similar to that of the South Fork prior to the addition of such wastes.

Zinc concentrations up to 21 ppm have been reported in the South Fork during low water periods. Sappington (1970), using unpolluted North Fork water, found that 96-hour TLm values for cutthroat trout fingerlings were 0.09 ppm zinc. Savage (1970) reported that siltation by mine wastes has been the main limiting factor in preventing the colonization of riffles in the South Fork and main Coeur d'Alene River by macrobenthic fauna. The installation of tailings ponds alone during 1968-69 had little effect on insect production in the polluted sections during the period of her observations.

The objectives of this study were (1) to describe plankton populations and seasonal variation in plankton community structure in the Coeur d'Alene River, delta, and open lake waters and (2) to measure seasonal changes in physicochemical factors and attempt to relate effects of these changes on the plankton community. Such information will provide a basis for evaluation of changes in future water uses or treatment in the drainage.

DESCRIPTION OF STUDY AREA

A. Geographical Location

Coeur d'Alene Lake is located in Kootenai County in the panhandle region of northern Idaho, at an elevation of 2124 feet. Construction of Post Falls Dam in 1906 on the Spokane River raised the water level approximately 12 feet. The lake occupies a narrow valley extending approximately 24 miles from Coeur d'Alene, Idaho, to the south.

Two major rivers, the Coeur d'Alene and St Joe, discharge into the southern portion of the lake. The headwaters of the Coeur d'Alene River originate in the Bitterroot Mountains between Montana and Idaho. The drainage area of approximately 4,000 square miles is comprised to two sub-drainages, the South Fork draining the famous Coeur d'Alene mining district and the North Fork in the Coeur d'Alene National Forest, which is relatively unaltered by man's activities. The South Fork joins the North Fork at Enaville to form the Coeur d'Alene River which flows 30 miles west into Coeur d'Alene Lake at Harrison, Idaho (Fig. 1). The St. Joe River with a watershed of about 1500 square miles also originates in the Bitterroot Mountains south of the Coeur d'Alene drainage. There has been little mining in the St. Joe watershed.

B. Physiography and Geology

Much of the drainage area around Coeur d'Alene Lake is mountainous with some narrow valleys characteristic of a glaciated region. The geology of the area adjacent to the lake has been described by Anderson (1940).

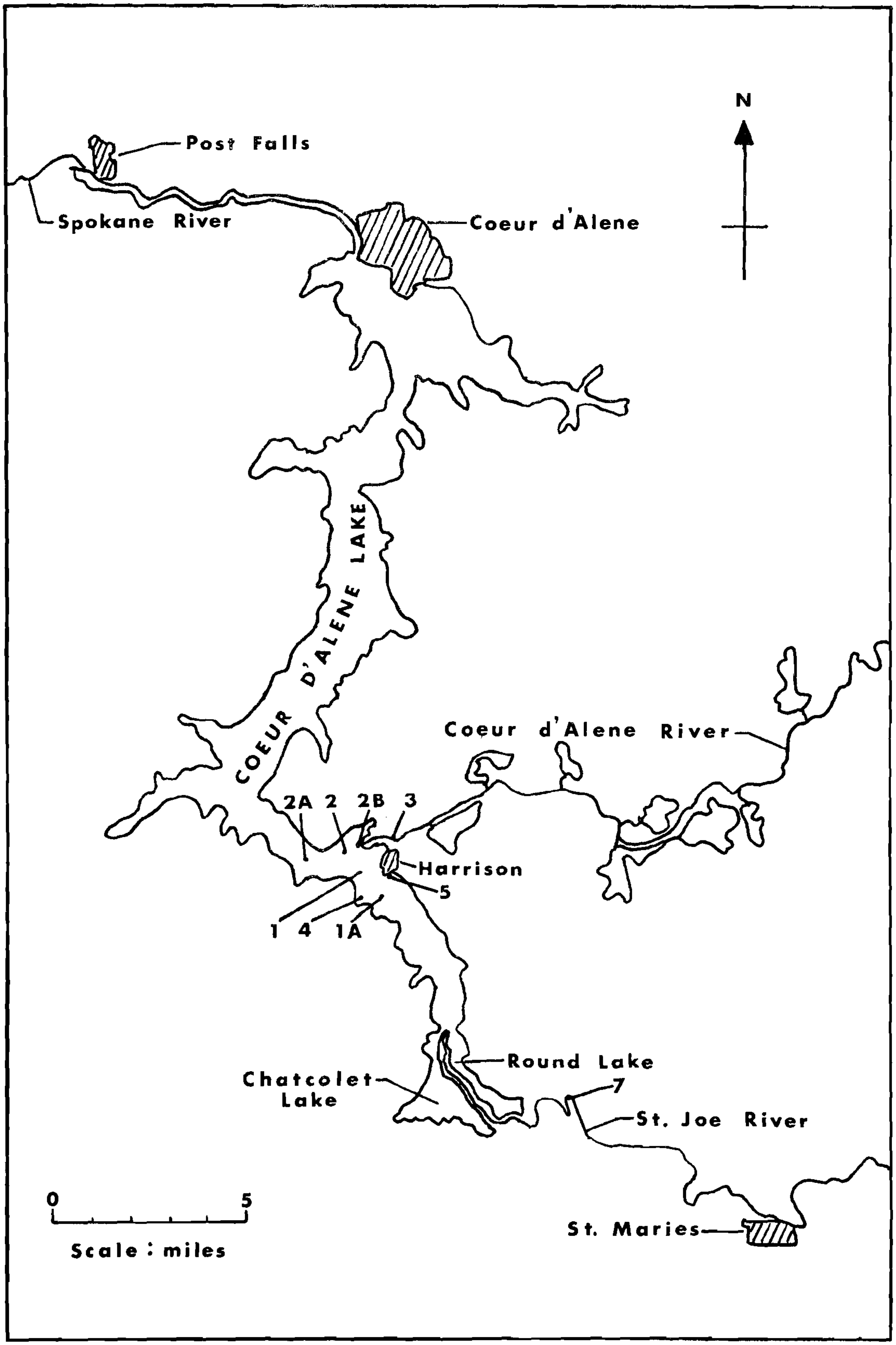


Fig. 1.--Coeur d'Alene Lake and station locations.

Precambrian sedimentary and metamorphic rocks underlie the Coeur d'Alene drainage basin, whereas the St. Joe watershed consists mainly of sedimentary Algonkian or Precambrian Belt Series. In addition to glacial drift and alluvium, five major rock types occur beneath and adjacent to the lake. These are quartzites, argillites, shales, gneisses, and basalts. At several locations around the lake, the basalts have been removed by erosion, leaving the lake shore of metamorphosed rocks.

C. Climate

The climate of the area surrounding the lake is intermontane. Nearness to the Pacific Ocean, prevailing winds, and topography have given northern Idaho a milder climate than its latitude indicates. Winters are not severe for extended periods, and the summers are long and warm with little precipitation. Many of the storms and prevailing winds approach the lake from the southwest. Average annual rainfall and temperature at St. Maries, Idaho, near the southern end of the lake are 28.7 inches and 47.5 F, respectively (Figs. 2 and 3).

D. Morphometry

Lake Coeur d'Alene is the second largest lake in Idaho. Although comparatively narrow, it is 24 miles long. Surface elevation is 2124 feet above sea level with a maximum fluctuation of 6 feet annually. The southern arm of the lake extends in a southeasterly direction. The northern portion, which includes approximately two-thirds of the lake, lies in a north-northwest direction, thus exposing that portion of the lake to the prevailing southwest winds.

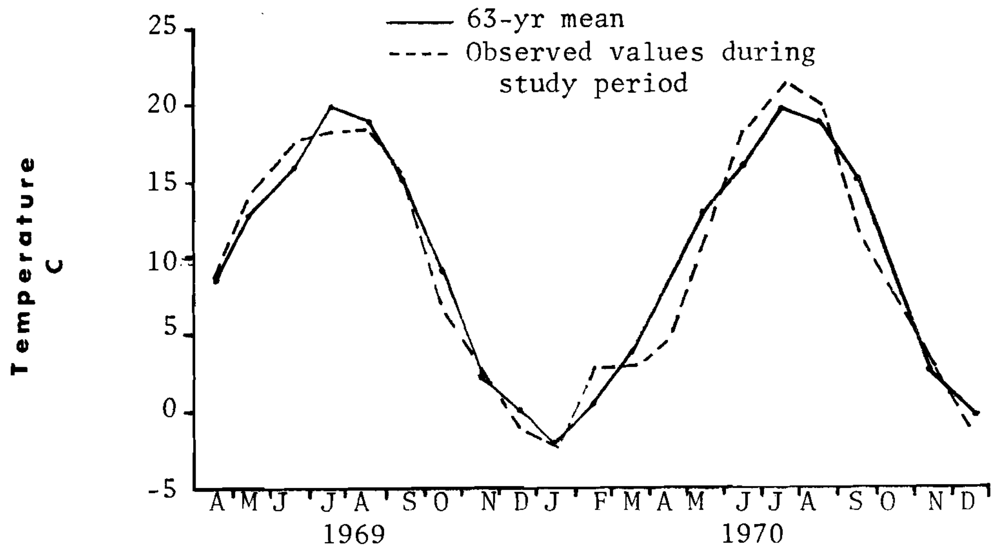


Fig. 2.--Average monthly and observed air temperature at St. Maries, Idaho.

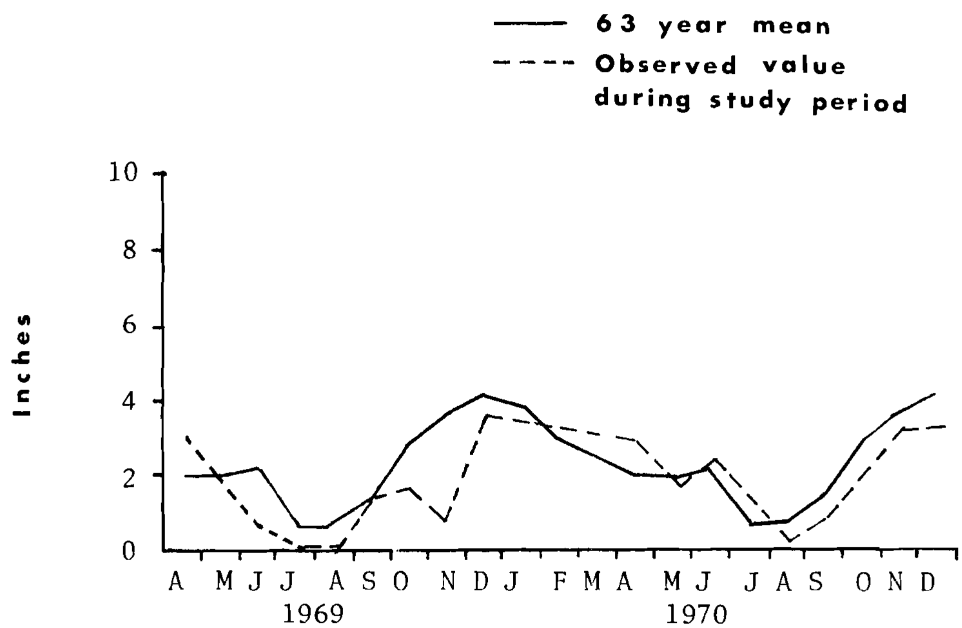


Fig. 3.--Average monthly and observed precipitation values at St. Maries, Idaho.

The depth gradually increases from the southern end of the lake to within 3 miles of the outlet, where it again begins to decrease (Kemmerer et al., 1923). The deepest recorded point (56 meters) lies off Three Mile Point in the northern narrows.

MATERIALS AND METHODS

A. Location of Stations

Selection of stations was based on depth, which ranged from 6 meters near the mouth of the Coeur d'Alene River to 20 meters at the lake's center off Spokane Point, and location with regard to the Coeur d'Alene River effluent. The following six stations (Fig. 1) were established:

Station 1, off Spokane Point on a line with Harrison, Idaho, near the center of the lake;

Station 2-B, within the Coeur d'Alene River channel near the river's mouth;

Station 3, within the Coeur d'Alene River channel approximately 1/2 mile upstream from the river's mouth;

Station 4, approximately 100 yards offshore in the center of Clealand Bay;

Station 5, approximately 80 yards offshore, just south of the public parking area at Harrison's beach; and

Station 7, approximately 4 1/2 miles upstream from the lake in mid-channel of the St. Joe River.

In November, 1969, three new stations were established, and three of the previously mentioned stations were discontinued until the following summer. The location of these stations were as follows:

Station 2, approximately 300 yards offshore near the mouth of the Coeur d'Alene River;

Station 1-A, approximately 300 yards offshore from Clealand Point towards the center of the lake; and

Station 2-A, approximately 300 yards offshore and 1/4 mile north of Harlow Point.

Stations 2-B, 4, and 5 were discontinued until June, 1970. The amount of wind exposure varied considerably with stations. Station 2-B was affected considerably by prevailing northwest winds due to its shallow depth during low-water periods. The length of open water increased to a maximum at this station, and high turbidity was evident during windy periods. Stations 1, 2, and 2-A were subjected to frequent northwest winds, but, due to their increased depth and distance from the river's mouth, the effects were not as evident. Stations 1-A, 4, and 5 were exposed to occasional easterly winds from the Coeur d'Alene River valley and lighter south winds. Stations 3 and 7 in the rivers were not exposed to windy conditions as were the lake stations.

B. Sampling Schedule

Limnological features were studied at the six stations established in May, 1969, weekly from May until September and bi-weekly during October, 1969. Beginning in November, 1969, samples were taken monthly until May, 1970, and bi-weekly thereafter until November, 1970. In addition, stations 1-A and 2-A were sampled periodically from December, 1969, to October, 1970. During the period June through October, 1970, stations 2-B, 4, 5, and 7 were sampled bi-weekly.

Collections were made in the late morning and early afternoon. Sampling was done from an outboard motor boat with the aid of a hand-operated winch.

C. Chemical and Physical Methods

Water temperature readings were collected with a Yellow Springs portable indicator, and measurements were recorded to the nearest 0.1 C. Dissolved oxygen readings were taken with the same portable indicator and recorded to the nearest 0.1 mg/liter. Both temperature and dissolved oxygen readings were taken at the surface and at 1-meter intervals.

Water analysis consisted of determining carbonate and bicarbonate alkalinity, hydrogen-ion concentrations, and electrical conductivity.

Measurements were taken at the surface, 3, 7, 9, 12, and 15 meters at all stations except at 2-B, 4, and 5, where only the surface and 3-meter depths were collected. Alkalinity was determined by titrating with .02N sulfuric acid using phenolphthalein and methyl orange as indicators (Standard Methods, 1965). The pH was determined by using a Hellige color comparator. Conductivity was measured with a portable conductivity meter and recorded in micromhos per square centimeter. Analysis of pH and alkalinity were made as soon as possible in the field or in a field laboratory near the lake. A 2-liter plastic Van Dorn sampling bottle was used to obtain water samples from the depths.

Water transparency was determined by lowering an 8-inch Secchi disk and recording the average depth at which it disappeared and reappeared.

Lake level readings were obtained from the Washington Water Power Company at Coeur d'Alene, Idaho, and river discharge readings from the United States Department of Interior, Water Resource Division, Sandpoint, Idaho. Annual temperature and precipitation readings for St. Maries, Idaho, were obtained from the United States Department of Commerce (1969-70).

D. Plankton Methods

Net plankton were collected using a modified Miller plankton sampler. The metered net was constructed by modification of a design for the Miller Sampler (Miller, 1961). The device consisted of a plastic (PVC) cylinder equipped with a Gemware flow meter and digital counter and a No. 20 mesh conical net and plankton bucket. The body of the cylinder is 60 cm long with a 10.5-cm inside diameter; the net is 90 cm long. Both the plankton bucket and conical netting were replaced twice during the period of investigation to reduce any possible loss in efficiency due to clogging and fraying of the meshes. Since nannoplankton were also measured, it was not necessary to apply a net phytoplankton efficiency.

Samples consisting of five vertical hauls, from 4 meters, were taken at stations 1, 2-B, 3, 4, and 5 from June through October, 1969. The net was raised at approximately 0.5 meters per second (Ricker, 1932). All five hauls at one station were combined to represent net plankton standing crop for the strata. After each sample, the bucket was removed and the contents emptied into a 2-ounce screw-top bottle. The bucket was then washed with an alcohol-formalin preservative to insure complete recovery of all organisms. Before each succeeding station was sampled, the net was washed in the lake with the bucket removed.

During the period November, 1969, to November, 1970, two vertical hauls were taken from the bottom to the surface, at stations 1, 2, and 3 and periodically at stations 1-A and 2-A. The latter two stations were used as controls to compare parameters at stations 1 and 2 throughout the study. This was to determine if either station 1 or 2 were being affected by the Coeur d'Alene River. The two net plankton hauls were counted separately and averaged to represent the standing crop. The samples were handled in the same manner as those from the top 4 meters. In addition, the top 4 meters were again sampled at stations 1, 2-B, 3, 4, and 5 for the period June through October, 1970. Station 7, in the St. Joe River, was sampled for net plankton and nannoplankton during the period June through September, 1970.

A total count of plankton Crustacea and Rotifera was made in each of three 1-milliliter counting chambers. A mechanical stage and a Whipple Ocular grid served as guides to insure complete coverage of the chamber.

After the zooplankton were counted, net phytoplankton counts were made using the method by Millipore (1969). A subsample of the net plankton sample was filtered on a 25-mm diameter type HA Millipore filter mounted in a 125-ml filter flask. A total of 10 fields was selected at random and enumerated with the aid of a Whipple ocular grid and a phase scope. Colonies, individual cells of colonial and filamentous forms, and unicellular forms were all considered to be separate units.

The zooplankton were identified using keys and techniques described by Ward and Whipple (1959) and by Pennak (1953). Phytoplankton were identified using keys and techniques described by Smith (1950), Ward and Whipple (1959), and Prescott (1954).

Samples of nannoplankton (all phytoplankton passing through a No. 20 mesh net and less than 70 microns in size) were obtained using the Van Dorn sampler and a No. 20 mesh Wisconsin plankton net. Samples from the top 4 meters were taken at the surface and at 1-meter intervals. Samples representing the bottom-to-surface standing crop were taken at the surface and at 3, 5, 7, 9, 12, and 15 meters depending on the station depth. Two liters from each depth were filtered through the No. 20 mesh net into a 5-gallon container. The combined samples from each depth were then mixed and a 1-liter aliquot drawn off. These samples were then filtered on a 47-mm diameter type HA Millipore filter and counted in the same manner as the net phytoplankton. The amount of nannoplankton present determined the volume of the sample filtered.

RESULTS

A. Physical Features

1. Transparency

Transparency of Coeur d'Alene Lake ranged from a low of 2 feet in February, 1970, to a maximum of 16 feet during August, 1969. The highest transparency occurred during the summer months and the lowest during the fall and winter (Fig. 4A). The Coeur d'Alene River exhibited higher transparencies than the lake during late winter and early spring, prior to peak discharge. A low of nearly 3 feet occurred during June, 1969, and a high of 11 feet in October, 1969. The St. Joe River ranged from a low of 7 feet to a high of 12.5 feet during the summers of 1969-70.

2. Water Level

Coeur d'Alene Lake level decreased in the spring after peak river discharge and stabilized at an elevation of 2128 feet during both summers. Maximum draw-down at Post Falls Dam was 4 feet beginning in late August and reaching a peak in November. Water level increased generally throughout the winter and reached a maximum during June (Fig. 4B).

3. River Discharge

Maximum discharge for both the Coeur d'Alene and St. Joe Rivers occurred during May and June (Fig. 4C). Low river discharge occurred during the summer and fall with less than 300 cfs in both rivers in September.

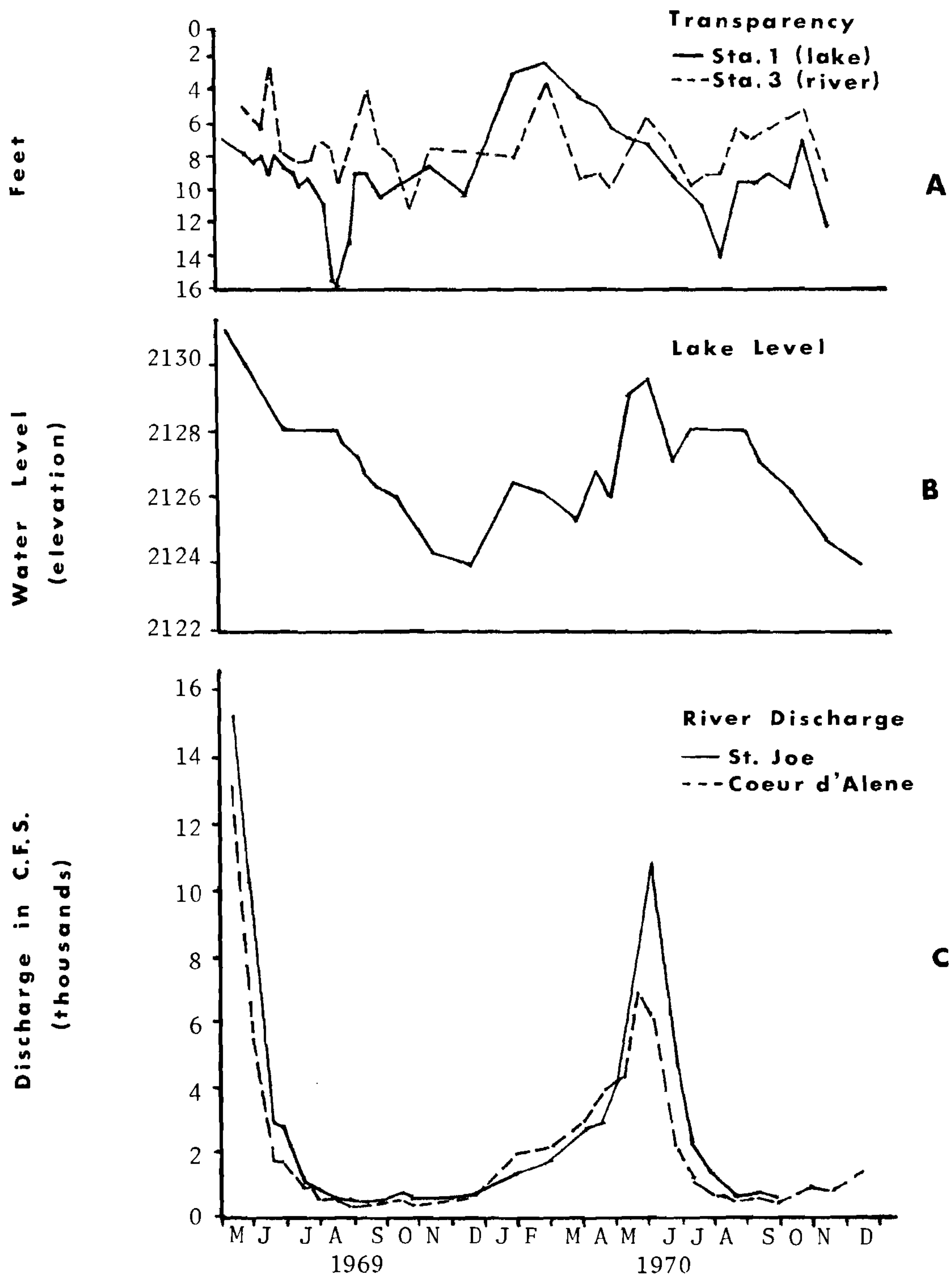


Fig. 4.--Physical features of Coeur d'Alene Lake and River and the St. Joe River. May, 1969, to December, 1970.

Seasonal discharge was similar in both rivers except during the spring of 1970 when the St. Joe exceeded the Coeur d'Alene by approximately 4000 cfs in early June.

4. Temperature

The lake remained nearly homothermous throughout the winter months until early May, when the surface waters began to warm rapidly. A thermocline existed between 2 and 13 meters from June to September, 1970 (Fig. 5). The lake remained stratified until the first week of October, followed by the fall overturn. Surface waters ranged from 3 C in January to 25 C during August.

The Coeur d'Alene River remained nearly homothermous throughout the period of study (Fig. 6A). Slight stratification existed through the summer months with a thermocline forming in the top 2 meters during early July, 1970. Similar temperature conditions existed in the St. Joe River (Fig. 6B). Surface waters ranged from 2 C in January to 25 C in July in the Coeur d'Alene River. Maximum surface water temperature in the St. Joe River (22 C) occurred during August.

B. Chemical Features

1. Dissolved Oxygen

Dissolved oxygen in the surface waters of the lake ranged from 5.0 to 11.3 mg/liter (Fig. 9A) at station 1 and 4.5 to 11.5 mg/liter in the delta (station 2) during the period November, 1969, through November, 1970 (Table 1). Maximum oxygen stratification occurred in July when 0.15 mg/liter was recorded near the bottom and 11.3 mg/liter in the surface waters at station 1 (Fig. 7).

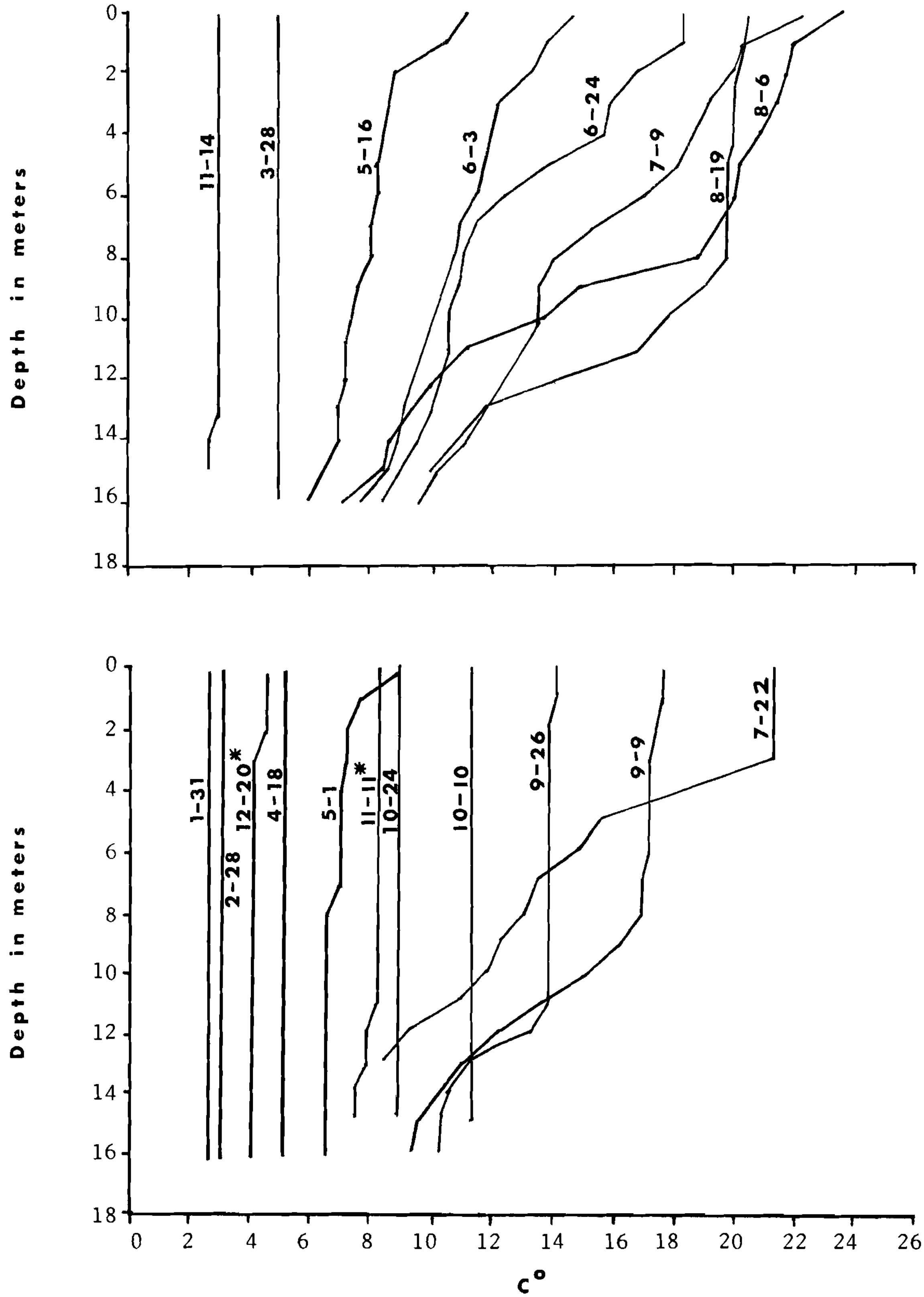
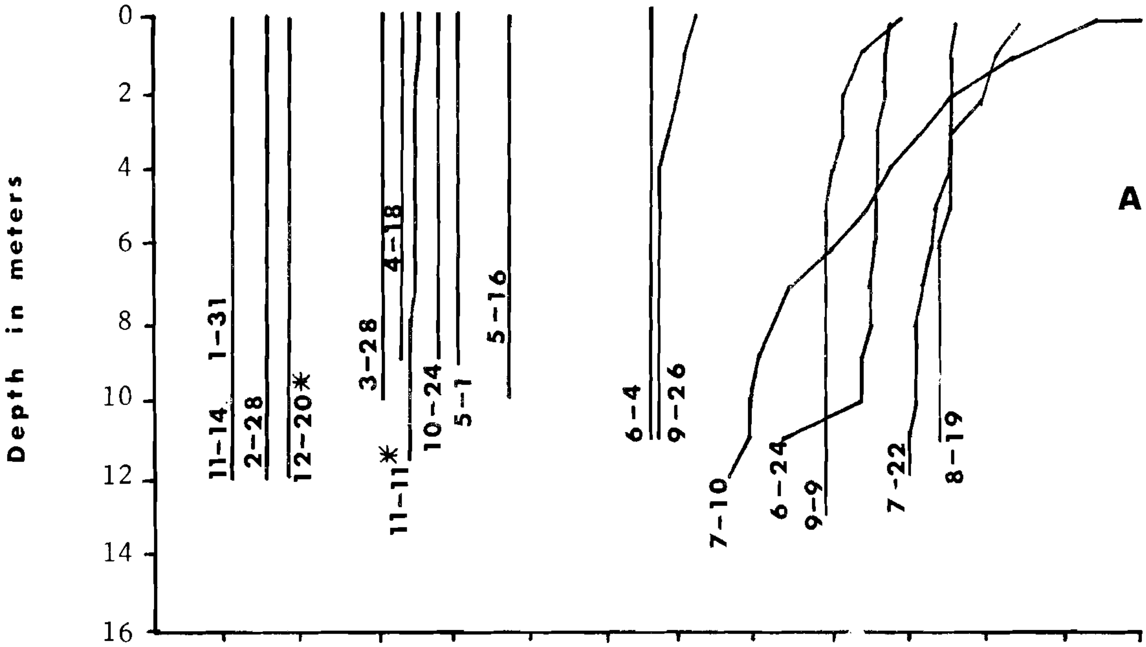


Fig. 5.--Water temperature profiles in Coeur d'Alene Lake (station 1). November, 1969, to November, 1970. *Pertains to 1969 observations. Numbers on each profile denote month and day.



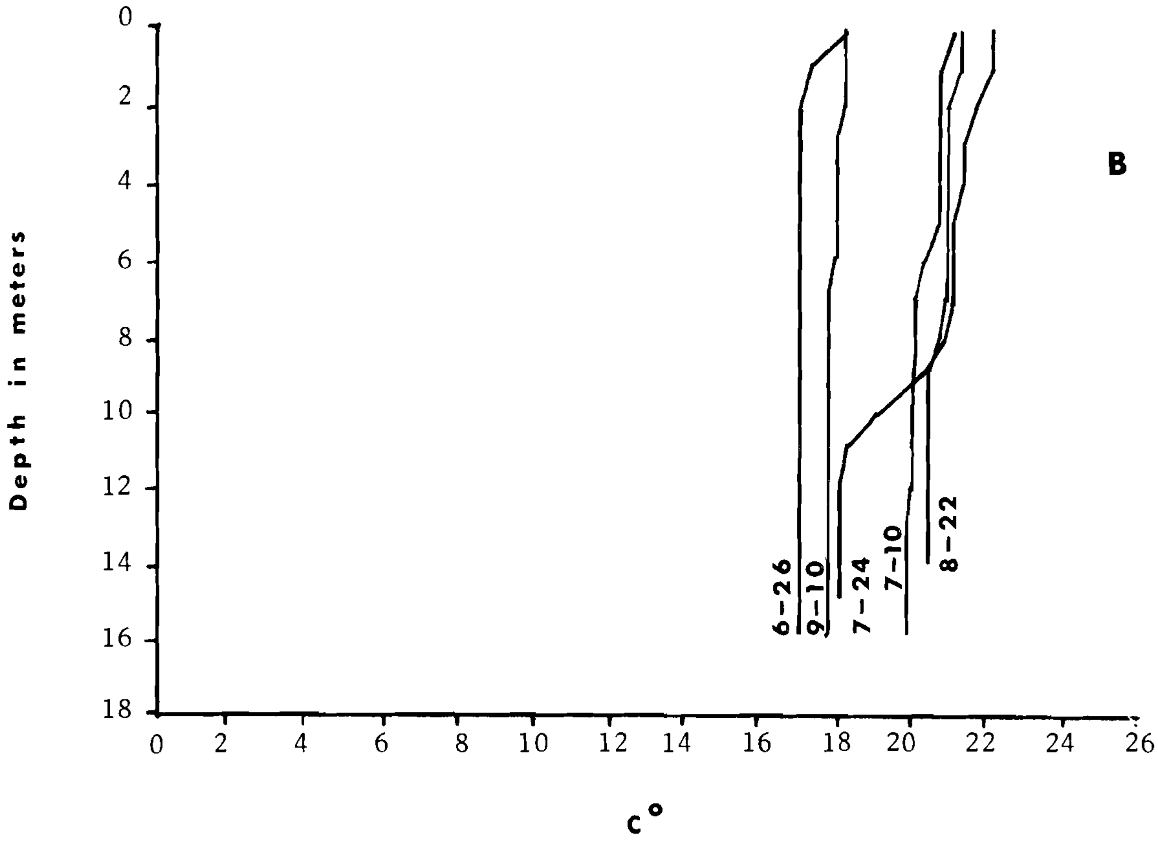


Fig. 6.--Water temperature profiles in the Coeur d'Alene River (A) and the St. Joe River (B). *Pertains to 1969 observations. Numbers on each profile denote month and day.

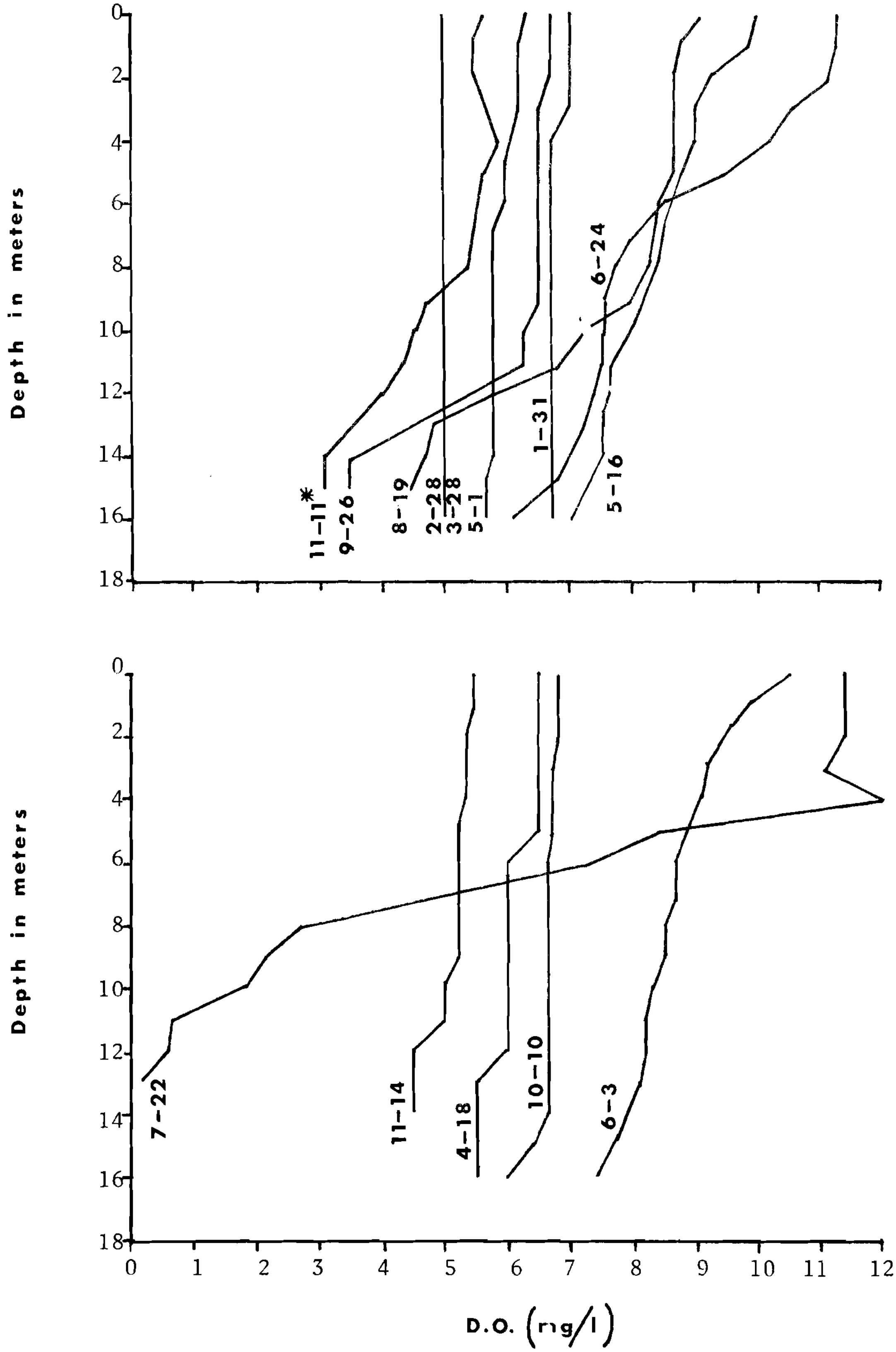


Fig. 7.--Dissolved oxygen profiles in the Coeur d'Alene Lake (station 1). *Pertains to 1969 observations. Numbers on each profile denote month and day.

Similar surface readings (4.8-11.4 mg/liter) occurred in the Coeur d'Alene River during the same period (Fig. 8A). Dissolved oxygen profiles were more homogeneous throughout the year in both rivers than in the lake, where stratification occurred from May through November.

The St. Joe River had a range of 6.2 to 14.7 mg/liter dissolved oxygen in the surface waters from June through October, 1969. During the summer of 1970, the range was 8.0 to 9.8 mg/liter. Oxygen stratification during the summer months was similar in both rivers with the exception of during July when the St. Joe became highly stratified (Fig. 8B).

2. Hydrogen Ion Concentration

Observations were similar in the lake stations with a pH range of 6.5 to 7.4. The Coeur d'Alene River was slightly more acidic (pH 6.1-7.2) during the same period (Fig. 9B). During the summers of 1969-70, the St. Joe River had a pH range of 6.4 to 7.5.

3. Specific Conductance

Specific conductivity was higher in the Coeur d'Alene River (Table 1) than in the lake. Maximum readings occurred during low discharge in the fall (Fig. 9D). No values above 50 micromhos were recorded at station 1 during the period November, 1969, to November, 1970. A maximum of 280 micromhos was recorded in November, 1969, at station 2. Other samples taken at station 2 remained below 100 micromhos. The St. Joe River during low water in 1969 had a maximum of 70 micromhos. No readings above 50 micromhos were recorded during the summer of 1970.

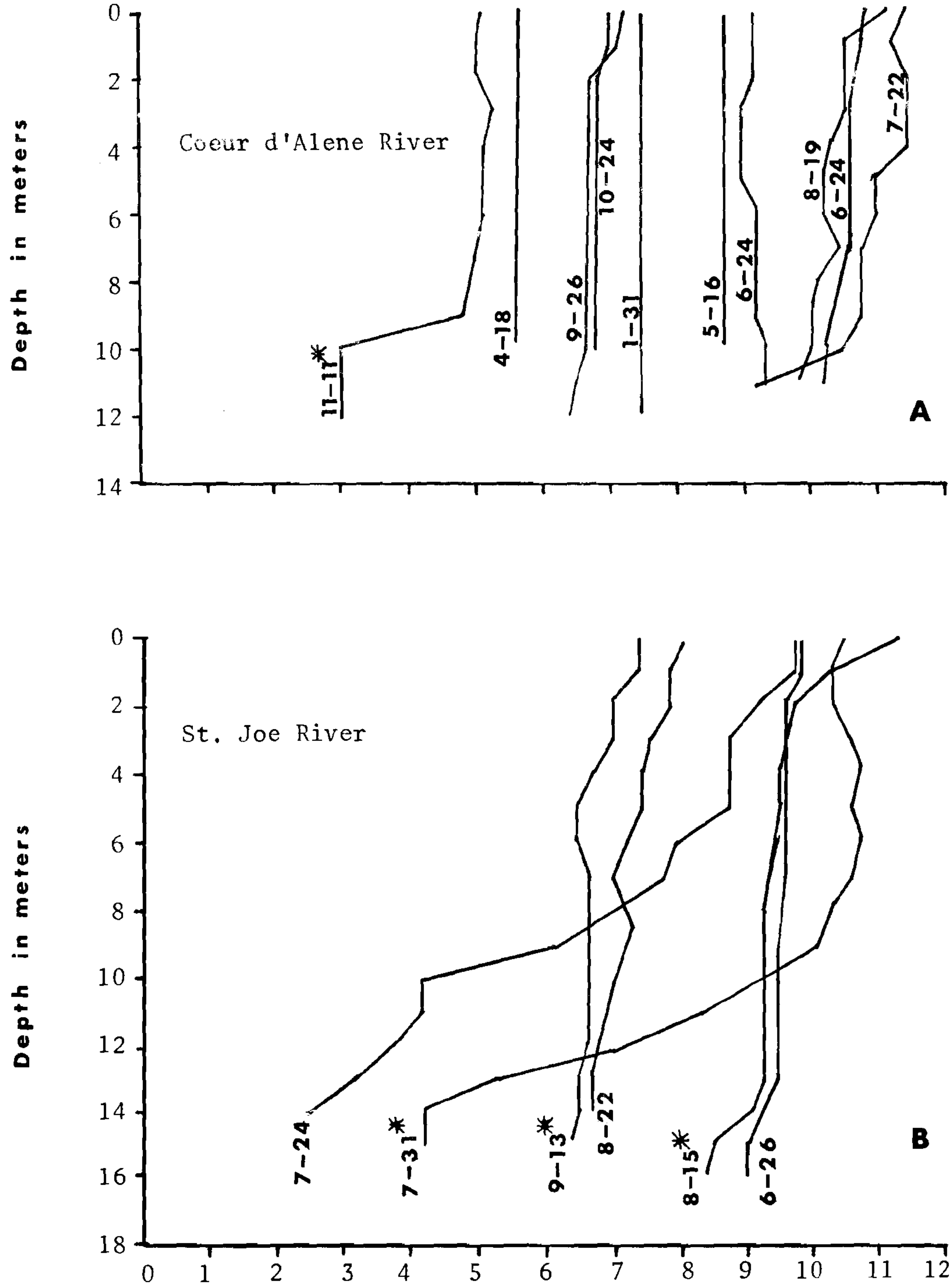


Fig. 8.--Dissolved oxygen profiles in the Coeur d'Alene River (A) and the St. Joe River (B). *Pertains to 1969 observations Numbers on each profile denote month and day.

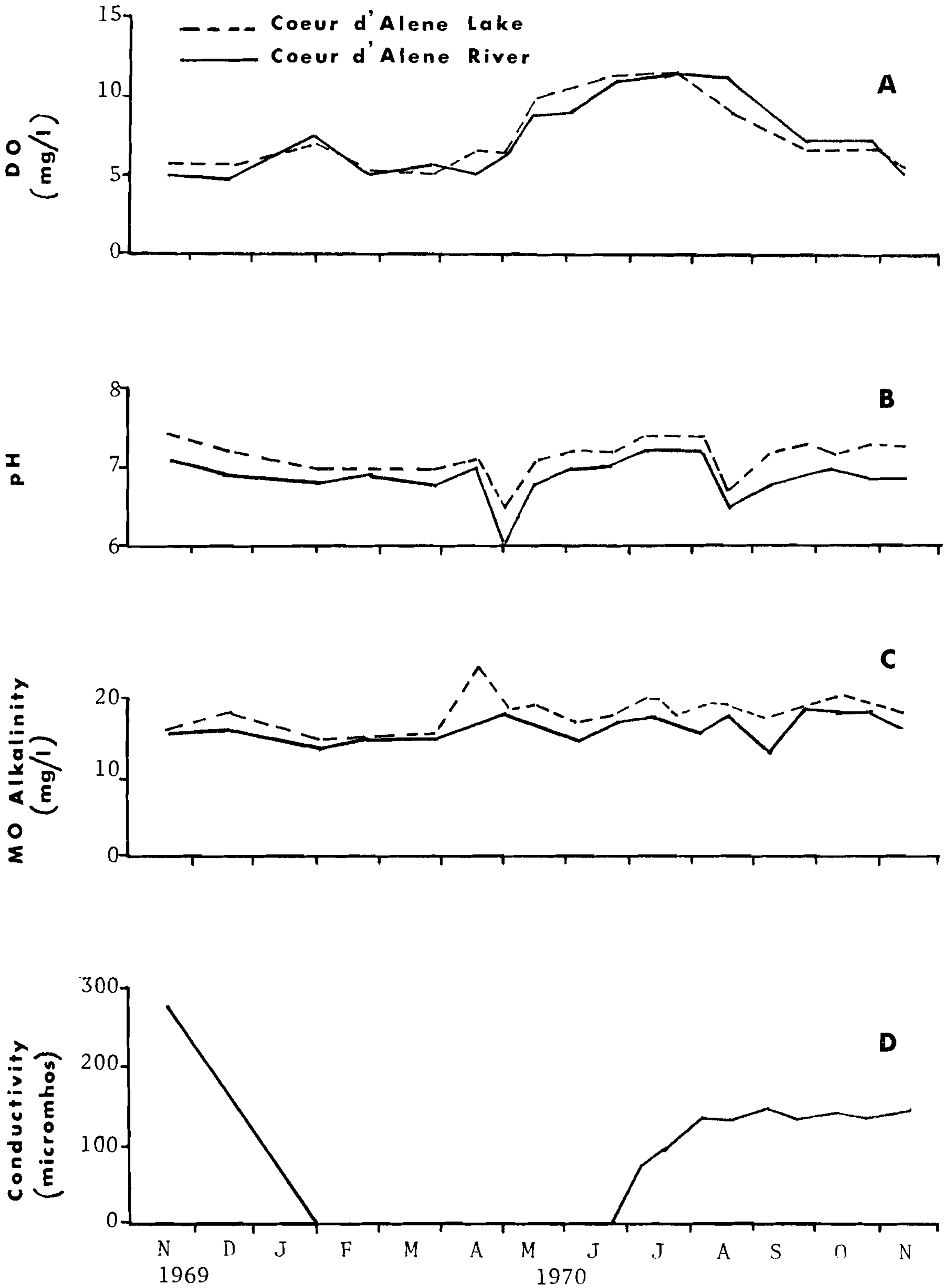


Fig. 9.--Selected chemical features in the surface waters of Coeur d'Alene Lake (station 1) and the Coeur d'Alene River (station 3). (A) D.O., (B) pH, (C) M.O. alkalinity, and (D) conductivity.

TABLE 1.--Chemical parameters at selected depths in Coeur d'Alene Lake and River, November, 1969-November 1970

Parameter	Depth (Meters)	Station		
		1 (Lake)	2 (Delta)	3 (River)
Dissolved oxygen (mg/liter)	0	5.0-11.3	4.5-11.5	4.8-11.4
	3	5.0-11.0	4.5-11.4	4.8-11.4
	9	2.1- 8.5	3.7- 9.0	4.5-10.7
	12	0.5- 8.2	0.7- 7.9	.....
pH	0	6.5-7.4	6.5-7.4	6.1-7.2
	3	6.6-7.4	6.5-7.4	6.2-7.2
	9	6.7-7.4	6.6-7.3	6.4-7.2
	12	6.7-7.3	6.5-7.2	.....
M.O. alkalinity (mg/liter)	0	15-24	15-20	13-19
	3	15-24	15-21	13-19
	9	15-21	15-21	13-18
	12	15-22	15-21	.....
Conductivity (micromhos)	0	<50	<50-240	<50-280
	3	<50	<50-220	<50-340
	9	<50	<50-280	<50-320
	12	<50	<50-280	.....

4. Alkalinity

Alkalinity was due entirely to bicarbonates which ranged from 15-24 mg/liter in the lake and 13-19 mg/liter in the Coeur d'Alene River (Table 1). Averages at all depths ranged slightly higher in the lake than in the river (Fig. 9C). The St. Joe River had a range of 18 to 41 mg/liter during the summers of 1969-70.

C. Plankton

Plankton was collected throughout an 18-month period; however, because of the great variation throughout the summers in the top 4-meter samples, only the bottom-to-surface collections were selected to demonstrate seasonal changes. The samples taken in the top 4 meters are discussed briefly.

1. Phytoplankton

a. Composition.--A total of four phyla and 59 phytoplankton genera were identified during the investigation (Appendix, Table 12). The Chrysophycophyta exhibited the largest number of genera in Coeur d'Alene Lake and the St. Joe River, whereas the Chlorophycophyta comprised the larger portion in the Coeur d'Alene River (Table 2).

The Chrysophycophyta made up nearly 100% of the phytoplankton counts during the period November, 1969, to August, 1970, in Coeur d'Alene Lake and River. The most abundant forms were the diatoms *Melosira*, *Tabellaria*, *Asterionella*, *Synedra*, and *Fragillaria*. From August through October, 1970, filamentous Chlorophycophyta and Cyanophycophyta were present in the nanoplankton counts. These were included under filamentous forms and never exceeded 32% of any one sample in the lake. The St. Joe River from June through mid-September, 1970, had as high as 54% filamentous forms. The filamentous Chlorophycophyta were dominated by *Mougeotia* and *Ulothrix* at all

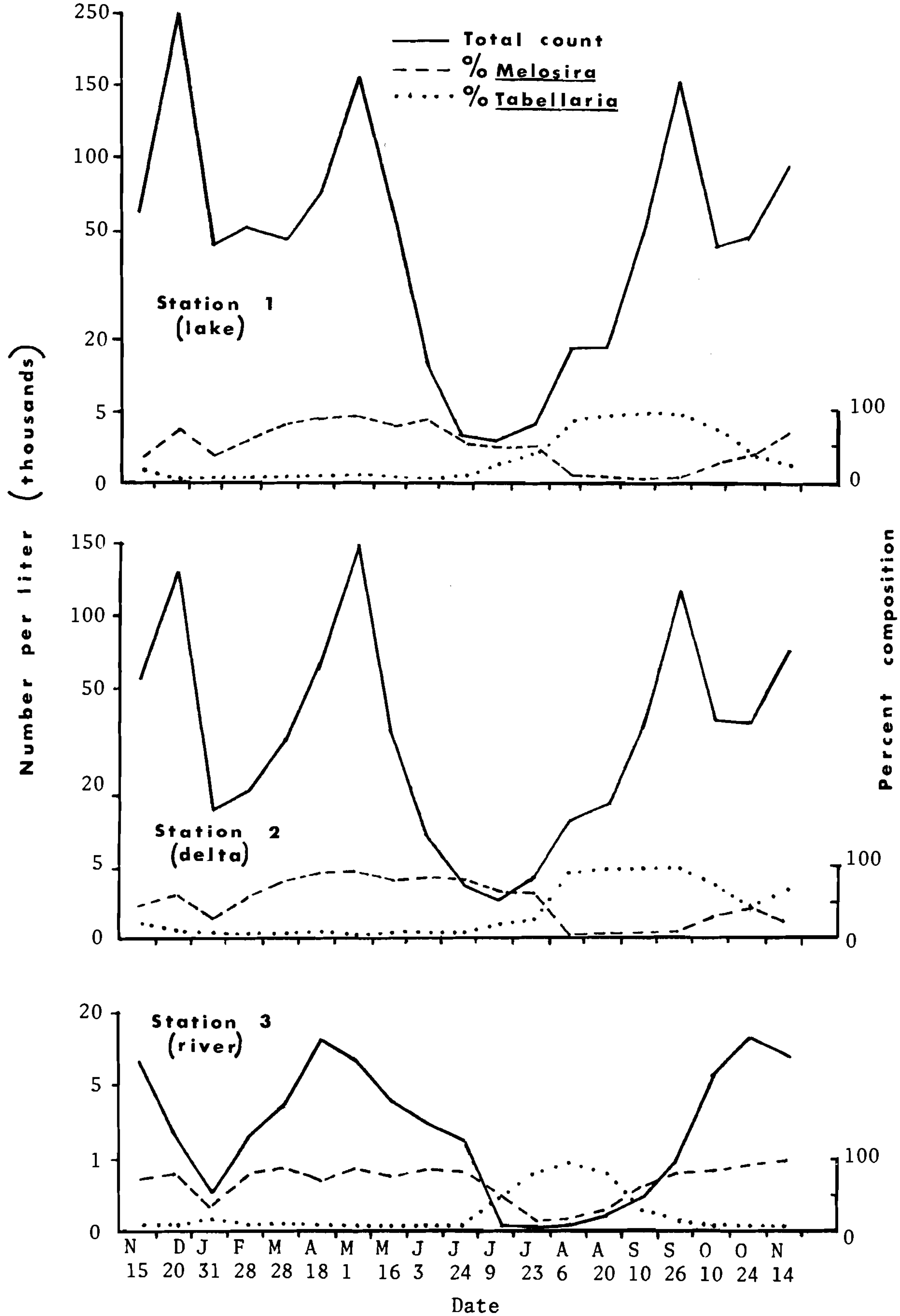
TABLE 2.--Phytoplankton composition, expressed as numbers of genera and percentage composition, in Coeur d'Alene Lake, River, and St. Joe River.

Phylum	Location		
	Coeur d'Alene Lake	Coeur d'Alene River	St. Joe River
Chlorophycophyta (green algae)	11 (36.6%)	18 (46.2%)	13 (31.0%)
Chrysophycophyta	12 (40.0%)	14 (35.8%)	25 (59.5%)
Cyanophycophyta (blue-green algae)	6 (20.0%)	6 (15.3%)	4 (9.5%)
Pyrrhophycophyta	1 (3.3%)	1 (2.6%)	0
Total	30	39	42

stations with the addition of *Spirogyra* and *Chaetophora* in the St. Joe River. The Cyanophycophyta comprised a larger portion of the counts in the rivers than in the lake.

b. *Net phytoplankton*.--There were three major peaks of net phytoplankton in Coeur d'Alene Lake during the period November, 1969, to November, 1970 (Fig. 10). The first and second peaks occurred during December and May, respectively, and were dominated by *Melosira*. The third peak, during September, was mainly *Tabellaria*. Seasonal composition for these two diatoms (Fig. 10) show that *Melosira* comprised the highest percentage of total net phytoplankton counts during the winter and spring, whereas *Tabellaria* was dominant during late summer and early fall. *Melosira* comprised as high as

Fig. 10.--Seasonal variation of total net phytoplankton, expressed as numbers per liter, in Coeur d'Alene Lake and River and percentage composition of *Melosira* and *Tabellaria*. November, 1969, to November, 1970.


Total count
% Melosira
% Tabellaria
Station 1
(lake)
Station 2
(delta)
Station 3
(river)
Number per liter (thousands)
Percent composition
250
150
100
50
20
5
1
0
100
N 15
D 20
J 31
F 28
M 28
A 18
M 1
M 16
J 3
J 24
J 9
J 23
A 6
A 20
S 10
S 26
O 10
O 24
N 14
Date

93% of the total count in early May, whereas *Tabellaria* comprised 95% of the early September count. *Asterionella* reached maximum numbers (53,000/liter) during December, at station 1, and thereafter decreased throughout the spring and summer. *Melosira* also reached a peak in December (180,000/liter) and then decreased until early May when another peak (147,000/liter) occurred, at station 1. *Tabellaria* counts showed a maximum of nearly 138,000/liter during September at station 1. Other forms with peaks were: *Synedra* (1,600/liter) during November and *Dinobryon* (600/liter) during May, at station 1.

Stations 1-A and 2-A showed similar trends in composition and abundance to the other lake stations although counts at station 1-A were somewhat higher than those at station 1, and those at 2-A were slightly higher than at station 2 (Table 3). Average net phytoplankton for the period November, 1969, to November, 1970, were approximately one and one-half times greater at station 1 than at station 2 (Table 4).

Although net phytoplankton counts were considerably lower in the Coeur d'Alene River (Fig. 10, Table 4), seasonal pulses were similar to those in the lake. *Melosira* was dominant, and *Asterionella* replaced *Tabellaria* as the second most abundant form. A pulse of *Asterionella* (2,800/liter) during November and again during April (4,300/liter) accounts for the high counts during these periods. Maximum *Melosira* (13,000/liter) occurred in late October when a maximum of *Tabellaria* (440/liter) also occurred.

Net phytoplankton in the St. Joe River averaged almost four times that in the Coeur d'Alene River during the period June through September, 1970 (Table 5). Diatoms comprised the majority of the counts in the Coeur d'Alene (94%) and St. Joe (50%) Rivers. In addition, 39% of the average total count in the St. Joe River was filamentous greens and blue greens. *Melosira* was

TABLE 3.--Average standing crop of net phytoplankton and nannoplankton, expressed as numbers per liter, at selected stations. December, 1969, to October, 1970.

Station	Net Phytoplankton	Nannoplankton
1	72,700	2,200,000
1-A	79,100	2,400,000
2	47,700	1,900,000
2-A	57,900	1,900,000

TABLE 4.--Average number of net phytoplankton, expressed as numbers per liter, in Coeur d'Alene Lake and River. November, 1969-November, 1970.

Phytoplankton	Station		
	1 (Lake)	2 (Delta)	3 (River)
Melosira	33,610	23,050	3,730
Tabellaria	18,770	14,900	110
Asterionella	10,590	8,030	690
Synedra	430	260	90
Dinobryon	60	30	10
Misc. diatoms	0	0	10
Total	63,460	46,270	4,640

TABLE 5.--Average number of net phytoplankton, expressed as numbers per liter, in the Coeur d'Alene and St. Joe Rivers. June 24, 1970-September 10, 1970.

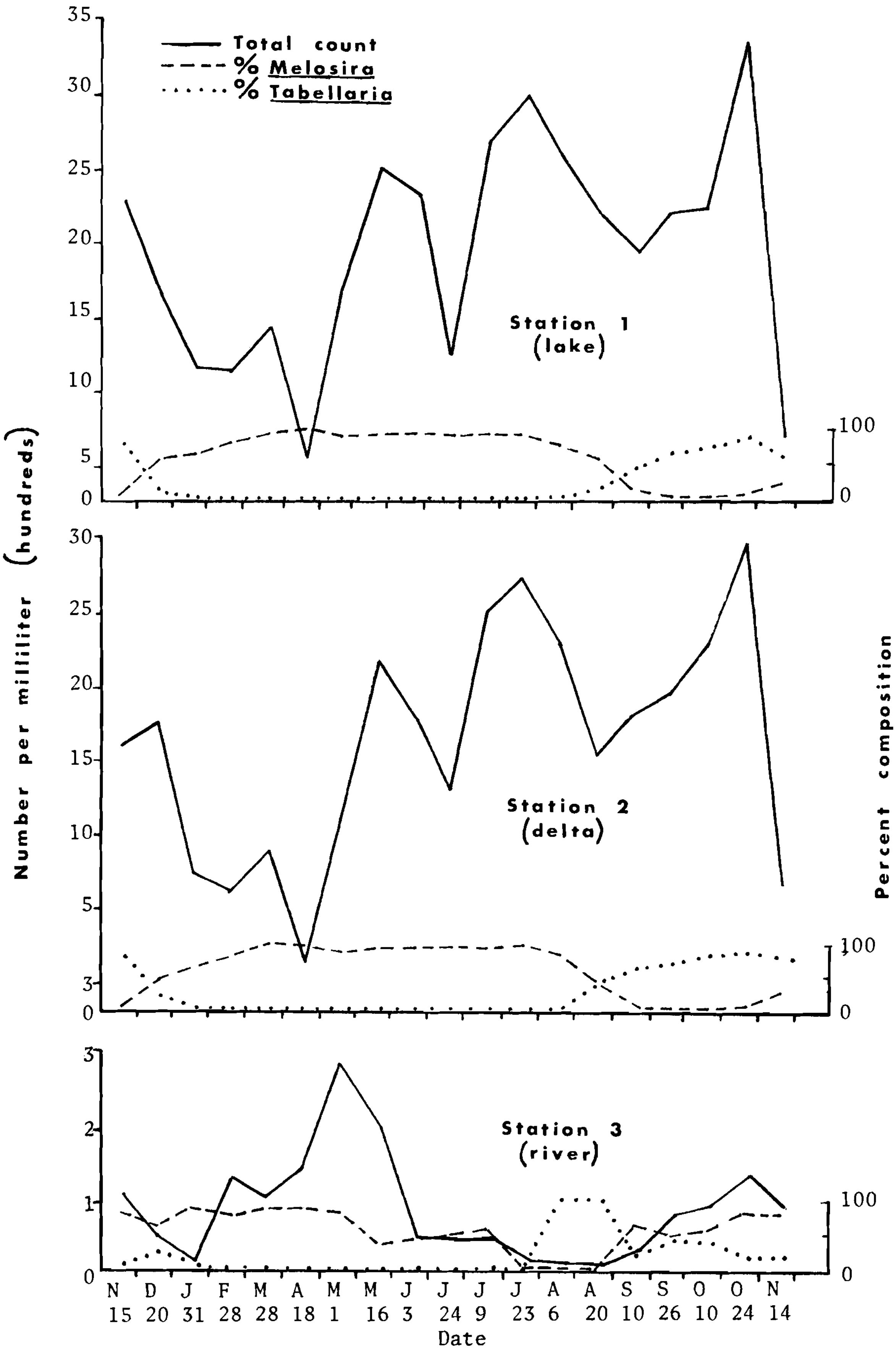
Taxon	River	
	Coeur d'Alene	St. Joe
Diatoms	450	910
Colonial greens	0	20
Filamentous forms	0	710
Flagellated forms	20	130
Total	470	1770

the dominant in the St. Joe, reaching a maximum of nearly 1,100/liter during June and comprising between 23 and 60% of the counts throughout the summer. Other diatoms in decreasing order of abundance were: Tabellaria, Synedra, Ceratoneis, and Frustulia. Dinobryon, present throughout the summer, reached a maximum (300/liter) during September. Colonial greens (Volvox, Eudorina) occurred in maximum numbers (25/liter) during late July, whereas filamentous forms (Ulothrix, Mougeotia, Spirogyra) reached a maximum (1,160/liter) in late August.

c. Nannoplankton.--Nannoplankton comprised between 90 and 97% of the total phytoplankton standing crop throughout the investigation. Composition was similar to net phytoplankton, with Melosira and Tabellaria making up the highest percentage of the counts.

Three distinct pulses of nannoplankton occurred in the lake (Fig. 11). The largest pulse occurred during October, 1970. Smaller pulses were

Fig. 11.--Seasonal variation of total nannoplankton, expressed as thousands per milliliter, in Coeur d'Alene Lake and River and percentage composition of *Melosira* and *Tabellaria*. November, 1969, to November, 1970.


Total count
% Melosira
% Tabellaria
Station 1
(lake)
Station 2
(delta)
Station 3
(river)
Number per milliliter (hundreds)
Percent composition
35
30
25
20
15
10
5
0
100
0
3
2
1
N 15
D 20
J 31
F 28
M 28
A 18
M 1
M 16
J 3
J 24
J 9
J 23
A 6
A 20
S 10
S 26
O 10
O 24
N 14
Date

observed in mid-May and late July. Seasonal trends at stations 1 and 2 were almost identical (Fig. 11). October counts (3,400/ml) at station 1 comprised 65% Tabellaria. Melosira maximum (2,900/ml) occurred during late July, at station 1, comprising 95% of the total count. Asterionella was most abundant during early winter, reaching 470/ml during December. Other diatoms (Synedra, Fragillaria) never comprised more than 4% of the total counts. Filamentous forms (Mougeotia, Ulothrix) reached maximum numbers during September.

Stations 1-A and 2-A followed similar trends in composition and abundance as stations 1 and 2. Average nannoplankton counts were slightly higher at 1-A and 1 than off the river's mouth, stations 2 and 2-A (Table 3).

Nannoplankton in the Coeur d'Alene River (Fig. 11, Table 6) were considerably lower than in the lake. One major pulse (293/ml) occurred during early May and a smaller one (130/ml) during late October. The general seasonal trend of percentage composition of Melosira and Tabellaria showed similar trends as in the lake. Melosira maximum (236/ml) occurred during early May, whereas Tabellaria, almost non-existent from January to August, reached 32/ml during October. Asterionella and miscellaneous diatoms comprised the rest of the total counts (Table 6). Diatoms comprised 100% of the total nannoplankton counts in the Coeur d'Alene River compared to 80% in the St. Joe River during the summer of 1970 (Table 7). Average counts were higher in the St. Joe River, with two blooms occurring during late June and early August. The June population was 30% Melosira and 38% filamentous forms. The August maximum consisted of 61% Tabellaria and 14% filamentous forms. Other taxa in decreasing order of abundance were: Synedra, Ceratoneis, and Frustulia. Miscellaneous diatoms never exceeded 13% of the total count. The filamentous forms comprised between 13 and 38% of the average total count in

TABLE 6.--Average number of nannoplankton, expressed as numbers per milliliter, in Coeur d'Alene Lake and River. November, 1969-November, 1970.

Phytoplankton	Station		
	1 (Lake)	2 (Delta)	3 (River)
Melosira	1147	920	59
Tabellaria	550	514	7
Fragillaria	10	3	0
Asterionella	100	72	11
Synedra	19	18	0
Misc. diatoms	18	10	6
Filamentous forms	111	97	0
Total	1955	1634	83

TABLE 7.--Average number of nannoplankton, expressed as numbers per milliliter, in the Coeur d'Alene and St. Joe Rivers. June 24 to September 10, 1970.

Taxon	River	
	Coeur d'Alene	St. Joe
Diatoms	24	55
Filamentous forms	0	14
Total	24	69

the St. Joe River, whereas in the Coeur d'Alene River they were virtually non-existent in the nannoplankton.

2. Zooplankton

a. Rotifera.--Two distinct groups of Rotifera were present in both the lake and rivers, the "seasonal" forms represented mostly by species of Notholca, Conochiloides, Trichocerca, and Monostyla and the "permanent" forms by Polyarthra and Keratella. Other forms present in the St. Joe River during the summer of 1970 were: Conochilus, Branchionus, Filina, and Asplancha. Seasonal variation was not pronounced in the open waters of the lake although major pulses occurred in June (19/liter) and October (14/liter) at station 3 (Fig. 12) in the river. Polyarthra comprised the highest average counts at all stations throughout the study (Tables 8 and 9) and was more prominent in both rivers than in the lake. Conochiloides, almost absent in the open waters of the lake, occurred in maximum numbers (114 and 76 per liter) in the top 4 meters during early June at stations 4 and 5, respectively. Individual rotifer counts for selected stations are listed in the Appendix.

b. Cladocera.--The Cladocerans comprised a major portion of the total Crustacea during the late summer and early fall, with the single exception when they occurred in highest numbers during late June in the Coeur d'Alene River (Fig. 13). Bosmina longirostris was the dominant form in the Coeur d'Alene River, whereas Diaphanosoma brachyurum was dominant in the lake (Table 8). Daphnia longispina comprised the largest portion of the Cladocera in the St. Joe River (Table 9). Other species present in decreasing order of abundance were: Leptodora kindtii, Ceriodaphnia sp., Chydorus sphaericus, Polyphemus pendiculus, and Moina sp. Leptodora occurred only in the lake and was more abundant in the bays. Maximum numbers of Cladocera occurred during

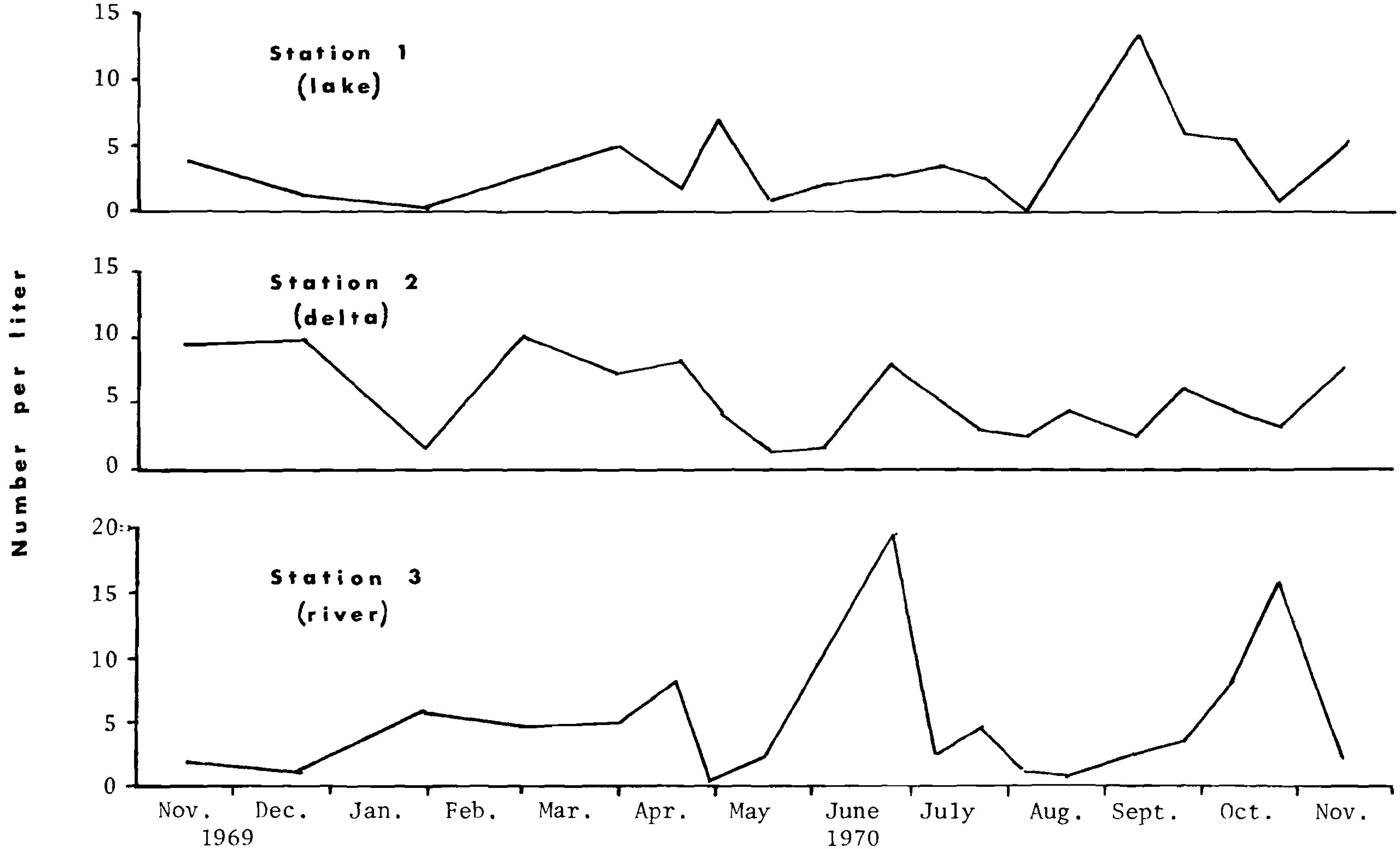


Fig. 12.--Seasonal variation of total Rotifera, expressed as numbers per liter, in Coeur d'Alene Lake and River. November, 1969, to November, 1970.

TABLE 8.--Average standing crop of plankton Crustacea and Rotifera, expressed as numbers per liter, in Coeur d'Alene Lake and River. November, 1969-November, 1970.

Zooplankton	Station		
	1 (Lake)	2 (Delta)	3 (River)
Cladocera			
Leptodora	.08	.08	0
Daphnia	.03	.14	.13
Bosmina	2.03	1.30	1.70
Diaphanosoma	8.62	8.94	.06
Miscellaneous	0	0	.13
Total	10.76	10.46	2.04
Copepoda			
Cyclops	9.35	7.77	1.34
Nauplii	47.01	38.26	10.56
Total	56.36	46.03	11.90
Rotifera			
Polyarthra	1.84	2.75	3.44
Keratella	.78	1.95	.57
Notholca	0	.05	.28
Conochiloides	0	0	.55
Trichocerca	0	0	.07
Monostyla	1.14	.64	.37
Total	3.37	5.41	5.30

TABLE 9.--Average standing crop of plankton Crustacea and Rotifera, expressed as numbers per liter, in the St. Joe and Coeur d'Alene Rivers, June 24 to September 10, 1970.

Zooplankton	River	
	St. Joe	Coeur d'Alene
Cladocera		
Daphnia	1.57	0.38
Bosmina	1.18	4.72
Diaphanosoma	0.30	0.15
Ceriodaphnia	0.32	....
Miscellaneous	0	0.35
Total	3.37	5.60
Copepoda		
Cyclops	1.34	0.61
Nauplii	13.82	9.04
Total	15.16	9.65
Rotifera		
Polyarthra	6.68	3.09
Keratella	0.19	0.93
Notholca	1.13	0.06
Conochilus	3.01	....
Conochiloides	....	0.87
Branchionus	1.96	....
Filina	0.20	....
Asplancha	1.76	....
Monostyla	....	0.25
Total	14.93	5.20

August when 63 and 47/liter were collected at stations 2 and 1, respectively. A maximum of 27/liter, comprised of 90% Bosmina, occurred during June in the Coeur d'Alene River. Total Cladocera averaged slightly higher in the Coeur d'Alene River than in the St. Joe River during the summer of 1970 due to this one large pulse (Table 9). Moina and Chydorus were found only in the Coeur d'Alene River and were included under miscellaneous forms due to their

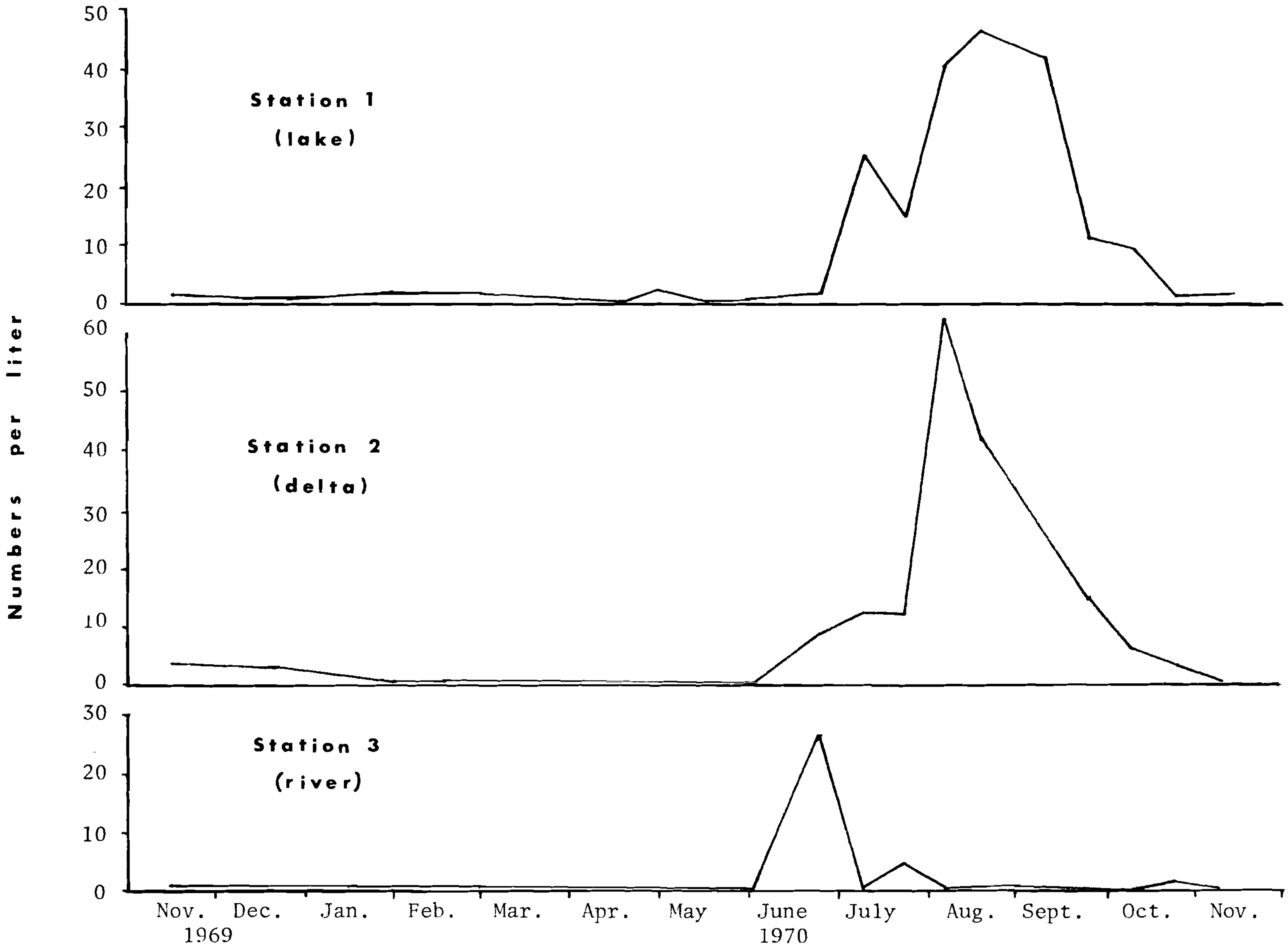


Fig. 13.--Seasonal variation of total Cladocera, expressed as numbers per liter, in Coeur d'Alene Lake and River. November, 1969, to November, 1970.

periodic occurrence and low numbers. Cladoceran counts were lower in the rivers than in the lake; however, the seasonal trends in the St. Joe River were similar to those in the lake. Cladocera in the top 4 meters were consistently higher in the bay stations throughout both summers. A pulse of 100/liter was recorded in Clealand Bay, during late July, 1969, when *Diaphanosoma* comprised nearly 100% of the total count. *Polyphemus* occurred only in the Coeur d'Alene River and the bays in the lake and was included under miscellaneous counts. *Ceriodaphnia* occurred in both rivers with a maximum of 1/liter during August in the St. Joe River. *Daphnia* comprised approximately 73% of the August maxima in the St. Joe River. Individual cladoceran counts for selected stations are given in the Appendix.

c. *Copepoda*.--The Copepoda comprised the dominant group of zooplankton throughout the study. *Cyclops bicuspidatus thomasi* and its nauplii were the only forms present in sufficient numbers to count. Other forms present during the investigation in the lake and Coeur d'Alene River were: *Diaptomus ashlandi* and *Epischura nevadensis*.

Large pulses of copepods occurred during April, June, and October in the lake and Coeur d'Alene River (Fig. 14) and during August in the St. Joe River (Fig. 15). Maximum numbers of *Cyclops* were found at station 1 (28/liter) and station 2 (23/liter). Average counts were higher at station 1 than nearer the delta at station 2 throughout the study (Table 8). The seasonal trend of total Copepoda was an increase during the spring with a maximum during July. A smaller pulse also occurred during October. *Cyclops* averaged twice as high in the St. Joe River as in the Coeur d'Alene River during the summer of 1970 (Table 9). Maximum in the St. Joe was 7/liter during August, whereas less than 4/liter were recorded in the Coeur d'Alene.

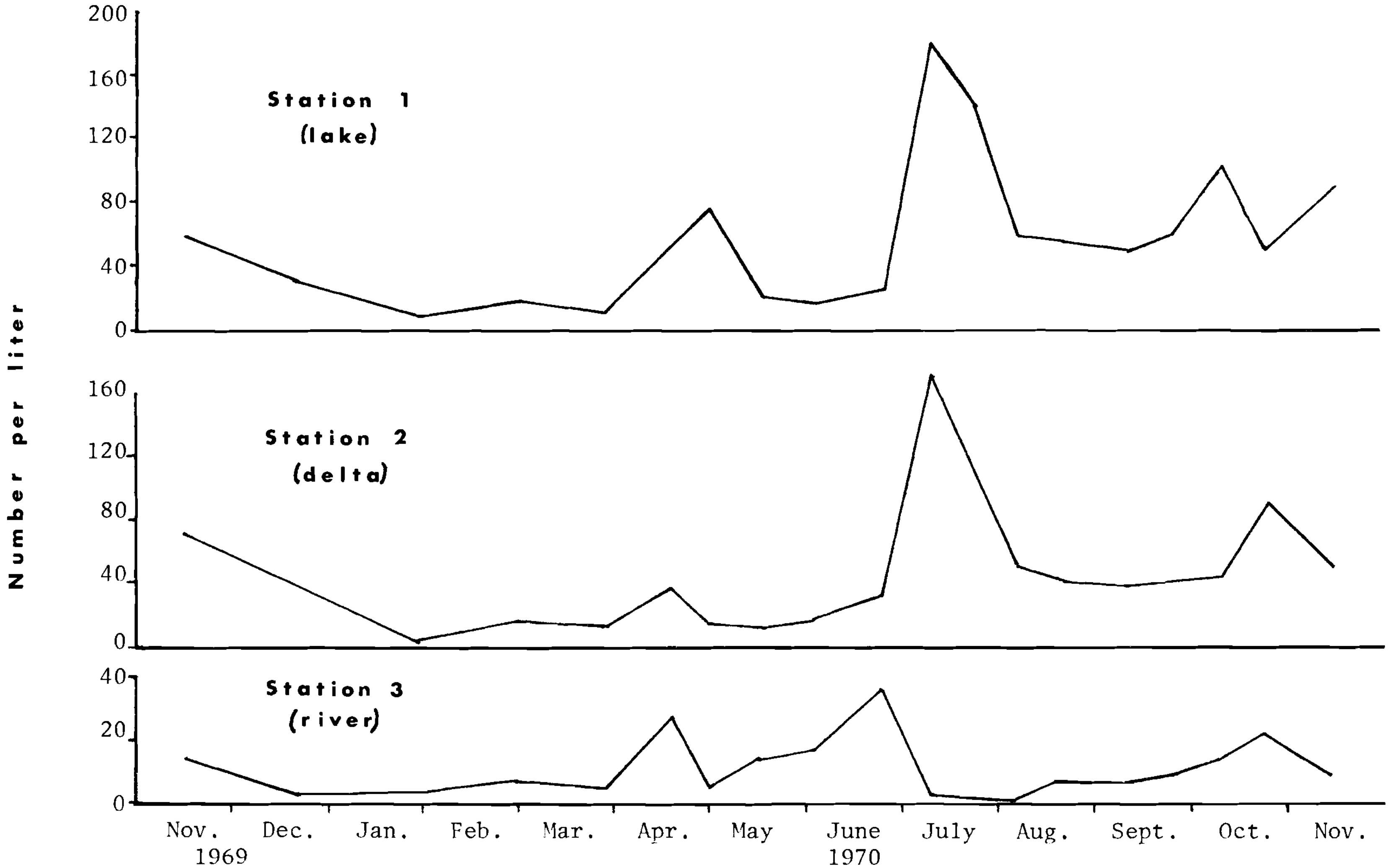


Fig. 14.--Seasonal variation of total Copepoda (nauplii included), expressed as numbers per liter, in Coeur d'Alene Lake and River. November, 1969, to November, 1970.

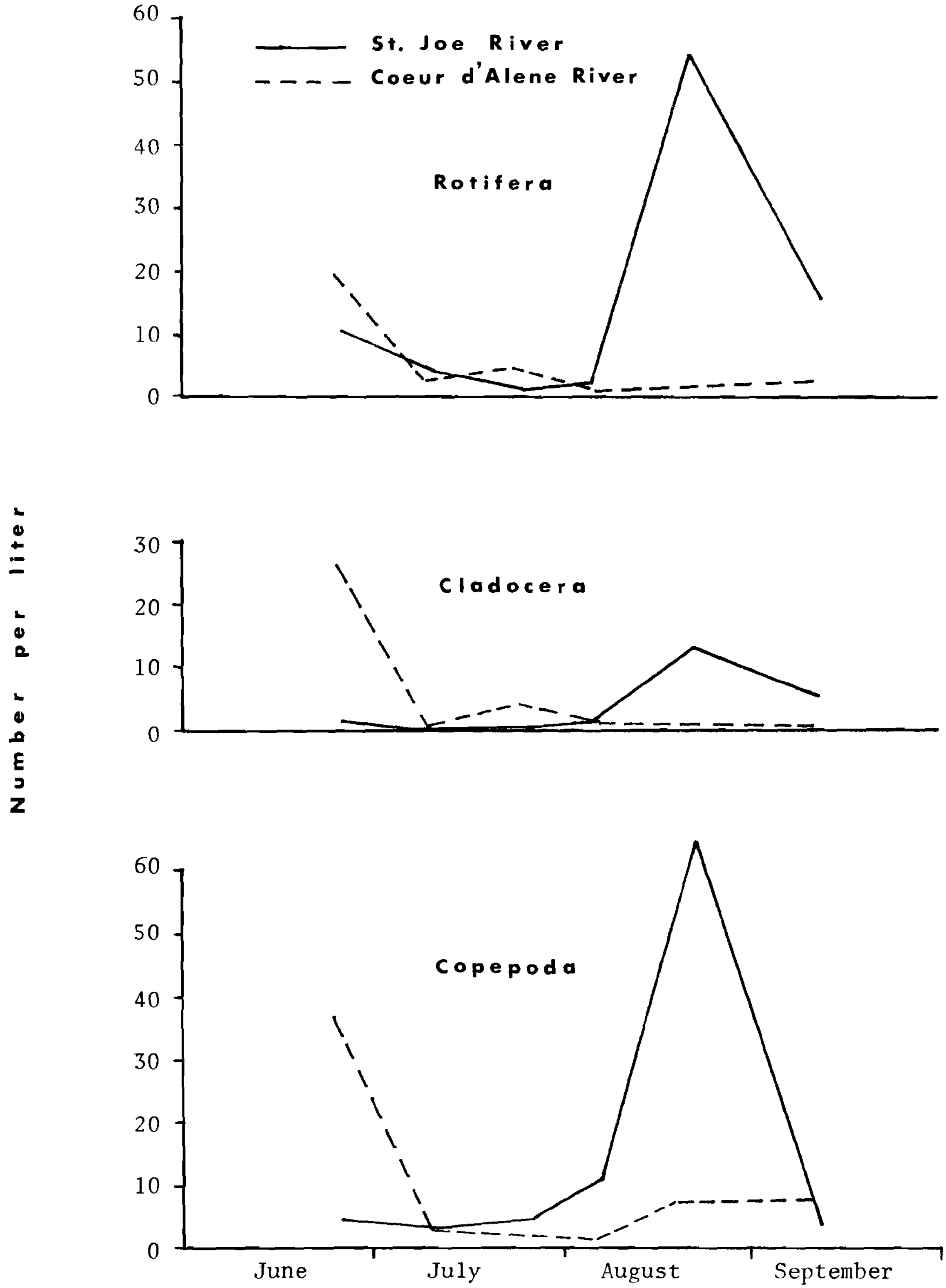


Fig. 15.--Seasonal variation of plankton Crustacea and Rotifera, expressed as numbers per liter, in the St. Joe and Coeur d'Alene Rivers. June to September, 1970.

Nauplii comprised the majority of the copepod counts throughout the investigation (Tables 8 and 9). Average counts in the St. Joe River were one and one-half times those in the Coeur d'Alene River. The open lake waters had a higher average count than the delta region (Table 8). A maximum pulse of 167/liter occurred at both stations 1 and 2 during July, 1970. A maximum 57/liter was recorded in the Coeur d'Alene River during late June.

Average copepod counts in the top 4 meters were generally higher in the bays. A maximum of 81/liter occurred in Clealand Bay during late June, 1969, and a similar pulse of 71/liter in early July, 1970. Copepod counts for selected stations are listed in the Appendix.

3. Inter-Station Difference in Quantity of Zooplankton

An attempt was made to determine whether stations in one portion of the delta contained a greater abundance of zooplankton than those in another portion of the delta. The comparison was made during the period December 20, 1969, to October 24, 1970 (eight samples). Station 2-A appeared to be less productive than the other stations, and stations 1 and 2 showed similar production (Table 10). Similarities in composition existed at all stations, within each group of zooplankton, and it is apparent that stations 1 and 2 represent the typical open waters of the delta region. However, the greater average number at station 2 near the mouth of the river appeared to be influenced more by the open waters than by the river's influx throughout most of the year.

TABLE 10.--Average standing crop of zooplankton, expressed as numbers per liter, at selected stations. December, 1969-October, 1970.

Organism	Station			
	1	1-A	2	2-A
Cladocera	9.6	11.0	10.6	8.5
Copepoda	47.5	62.0	46.3	34.6
Rotifera	3.0	3.5	5.9	4.9
Total	60.1	76.5	62.8	48.0

DISCUSSION

My study includes the open waters and bays in the delta region of the Coeur d'Alene River which typifies the aquatic habitat comprising the southern arm of Coeur d'Alene Lake. This portion of the water body is relatively shallow and occurs in a sinuous valley where the two major inlets flow into the lake.

Two stations were sampled in these inlets to understand better what influence they might have on the lake environment. Both the St. Joe and Coeur d'Alene Rivers originate in the same general mountainous area and similarly flow in a westwardly direction separated only by a gentle rise in topography.

Specific observations in the backwaters of both rivers demonstrate that they more closely resemble lotic than lentic environments. With the exception of a small thermocline near the surface in the Coeur d'Alene River during July, 1970, both rivers remained nearly homothermous throughout the investigation period.

Coeur d'Alene Lake may be classed as dimictic, since there is a spring and fall overturn typical of lakes in the temperate zone (Reid, 1961). A thermocline did not form during the summer of 1969 until late August, indicative of the colder spring and winter which occurred during 1968-69 when the entire lake froze over. A similar oxygen and temperature stratification as existed during the summer of 1969 was also reported by Kemmerer *et al.* (1923) and Ellis (1932). However, during 1970, a thermocline formed in early June and was present throughout the summer, reaching a maximum depth of 13 meters in September. With the increased temperature stratification, lower oxygen readings were observed in the deeper waters during the summer of 1970.

Bicarbonate alkalinity, dissolved oxygen, and pH were essentially the same in both rivers and were considered within the range of normal biotic production. Specific conductivity was higher in the Coeur d'Alene River, most likely due to heavy metal pollution from mine wastes. Conductivity measurements recorded during this survey were similar to those found by Ellis (1932) and were considered low as compared to sea water and other bodies of fresh water.

Reduced transparency in the Coeur d'Alene River is due to silt which is presently being discharged into the South Fork of the Coeur d'Alene River and from sediments deposited along the South Fork and main river from past mining operations.

Reid (1961) states that no true or distinctive plankton community exists in rivers, although they frequently contain an abundant tychoplankton (organisms dislodged from the bottom or submerged objects). River plankton is also subject to extreme fluctuations in quantity and species composition; therefore, data concerning plankton production in different rivers are comparable only when observations are made over a long period of time.

Several lateral lakes adjacent and tributary to the lower reaches of the Coeur d'Alene River apparently contribute a considerable amount of allochthonous matter, including plankton, to the river at various times during the year. The degree to which the standing crop is affected from these lateral lakes is difficult to assess but may be substantial during and shortly after spring run-off and the fall rainy period.

Ellis (1932) found ample (sic) plankton fauna in some of the tributary lakes and a sparse plankton population in Coeur d'Alene Lake. He also noted a particularly poor (sic) plankton fauna in the southern end of the lake and none near the mouth or in that portion of the Coeur d'Alene River carrying mine wastes. Kemmerer et al. (1923) found similar results in their study of the lake and river during 1911 and noted that plankton counts in the vicinity of the river mouth near Harrison were lower than elsewhere in the lake. At that time, Kemmerer et al. reported that the suspended matter carried by the waters of the Coeur d'Alene River could be traced well out into the lake. The higher plankton counts recorded during this investigation are believed to be partially brought about by the decrease in silt load carried by the Coeur d'Alene River since the installation of settling ponds.

Highest phytoplankton and zooplankton counts in the Coeur d'Alene River were during May and June and again during early fall. Phytoplankton density was low, but diversity was relatively high when compared with that of the St. Joe River. This strongly suggests that the lateral lakes influence the plankton community in the Coeur d'Alene River since few if any reaches of the river below the mining operations are suitable habitat for plankton production.

The installation of settling ponds during 1968-69 along the South Fork of the Coeur d'Alene River has greatly increased the transparency of the river waters by reduction of suspended solids and showed a definite beneficial effect on the water quality (Mink, Williams, and Wallace, 1971). However, certain heavy metals, mainly zinc and cadmium, remain a major limiting factor to much of the biota (Ellis, 1932).

Bioassay static tests by Sappington (1969), using North Fork water, found native cutthroat trout 24-, 48-, and 96-hour median tolenerance limit values of 0.62, 0.27, and 0.09 mg/liter zinc, respectively. Mink et al. (1971) reports as high as 21 mg/liter zinc in the South Fork of the river and nearly 3 mg/liter in the lower slackwaters during low flow. Savage (1970) performed a species diversity study on benthic macroinvertebrates in the North Fork, South Fork, and main stem of the Coeur d'Alene River before and after the settling ponds were established. Her findings suggest that siltation was a major factor in preventing the colonization of riffles in the South Fork and main stem of the river. Observations in 1969 indicated a slight trend toward insect recolonization of the Coeur d'Alene River system. Rabe (personal communication) believes that the greater transparency of the river water together with optimum nutrient influx from sewage has been responsible for the high biomass of algae on the rocks in the South Fork and near the confluence. These algae provide nourishment and a habitat for colonization of some insects capable of tolerating high heavy metal concentrations.

Several investigators have observed that plankton in rivers is dependent mainly on current velocity and age of the water (Hutchinson, 1967; Cushing, 1964). Hynes (1966) states that algae communities of rivers are essentially sessile although those forms that are planktonic are not indigenous and cannot maintain themselves as can lake plankton. Current is related to plankton production in both the Coeur d'Alene and St. Joe Rivers by restricting the length of time for plankton development. Rapidly moving waters hinder plankton development by decreasing the length of time that organisms can remain in their lotic habitat. As mentioned previously, the lateral lakes adjacent to the lower reaches of the Coeur d'Alene River may influence the plankton community. Few lakes and ponds are associated with the lower reaches of the St. Joe River above station 7.

Maximum numbers of plankton in the St. Joe River occurred in August during this investigation. However, the period during peak discharge was not sampled and could not be compared with that of the Coeur d'Alene River. Davis (1961) reported a June phytoplankton peak occurred in the lower reaches of the St. Joe River and attributed this to the overflow of plankton-rich waters from ponds and lakes associated with the backwaters. This peak occurred where the lakes at the southern end of Coeur d'Alene Lake affect the St. Joe River during flood stage. In addition, raw sewage from the town of St. Maries is dumped into the St. Joe River slackwater. The fertilizing effect of this sewage should favor zooplankton and phytoplankton production in the lower slackwater.

The higher plankton counts recorded during this investigation in the lower St. Joe River as compared to the lower Coeur d'Alene River may also be attributed to the more vegetated shoreline which exists along the St. Joe River and serves an allochthonous source of energy.

Davis (1961) attributed the low plankton numbers in the St. Joe River to soft water, current, water age, lack of associated lentic environments, and fluctuations of hydrographic conditions. As all of these factors also act on the lower Coeur d'Alene River, with the exception of the lack of associated lentic environments, it is understandable why river plankton are subject to extreme fluctuations. In the case of the Coeur d'Alene River, the added toxic effects of heavy metals on plankton and fish as found by Ellis (1932) may remain the major limiting factor on the biota of that portion of the river carrying mine wastes.

Measurements of physical, chemical, and biological features indicate a change from oligotrophic to mesotrophic conditions in some bay areas. The extreme southern portion of the lake is eutrophic due to the shallow conditions and increased human activity. This is substantiated by various plankton indicators (Rawson, 1956; Teiling, 1955), lake depth, relatively high temperatures during the summer, decreasing oxygen content near the bottom, and a quantitatively high population of phytoplankton comprised mostly of diatoms. The lake apparently has a higher population of phytoplankton in comparison to other large lakes in the northwest studied by Kemmerer *et al.* (1923).

Since the phytoplankton in Coeur d'Alene are mainly diatoms, the abundance of the population will depend largely on factors influencing diatom production (Ricker, 1938). It has been shown by Chandler (1940) in Lake Erie, however, that other algal groups may become abundant when diatoms are limited. This was evident in Coeur d'Alene Lake when filamentous greens (*Ulothrix*, *Mougeotia*) and blue greens (*Anabaena*, *Oscillatoria*) became abundant during late summer when water temperatures were optimum for these forms.

The inhibiting effect of a large influx of warm turbid waters from the Coeur d'Alene River on phytoplankton production apparently was demonstrated by the decline in phytoplankton standing crop in the delta region during June, 1970. Another factor which may have influenced this decrease was the large volume of plankton-poor river waters displacing or diluting the delta waters. Similar conditions were reported by Stross (1954) during spring discharge of the Clark Fork River into Lake Pend Oreille, Idaho, and by Verduin (1951) in western Lake Erie.

The open waters of the delta region are affected by the increase of spring winds during and after the spring overturn. It is believed that open waters of the lake and delta are enriched with plankton from the more productive bays near the west shore during windy periods. During windy periods, a distinct color from the river waters could be observed to flow along the east shore, north of the river mouth. The formation of a well-defined thermocline did not occur until late August during 1969 due to a cooler spring and windy conditions throughout the first 2 months of summer. Ruttner (1964) points out that spring winds may inhibit stratification until the entire lake is warmed.

Rotifers are generally low in numbers, although plankton Crustacea are abundant during the summer months. The size of the standing crop of phytoplankton varies greatly with season. Spring and fall pulses which occur in Coeur d'Alene Lake are quite common in lakes dominated by diatoms (Chandler, 1940; Welch, 1952). A comparison of the standing crop in Coeur d'Alene Lake with that of other lakes is difficult, however, due to the annual variability of the plankton populations (Ricker, 1938; Verduin, 1951). The comparison of plankton populations among lakes is also affected by different collecting methods employed (Rawson, 1942; Anderson, 1971).

Zooplankton abundance in Coeur d'Alene Lake may not depend entirely on the net phytoplankton. Nannoplankton constitute a large portion of the primary productivity in lakes and are the major food for various zooplankton (Ruttner, 1964; Pennington, 1941). Hutchinson (1967) believes that the removal of part of the phytoplankton is an obvious possible cause of phytoplankton pulses, but that in most cases both the plant and animal parts of the community are so diversified and complicated that it is difficult to determine what the effects of zooplankton grazing are. The large number of Cyclops nauplii, which are phytophagous feeders, in Coeur d'Alene Lake may indeed have a large grazing effect on the nannoplankton community.

The relatively small number of species of plankton Crustacea may be indicative of the rather unproductive environment which exists in Coeur d'Alene Lake. Carl (1940) and Anderson (1971) found comparatively few species of Crustacea in a number of alpine and sub-alpine lakes in western Canada. Carl observed that temperature, food types, and lake depth and area are important in determining what species would be present in a lake and that usually only one species of each genus is represented in any one body of water. Kemmerer et al. (1923) found similar results in their study of northwestern lakes of the United States. Their investigation shows lower numbers of plankton Crustacea in 1911 than those recorded in this study; however, their counts were made only during July and therefore may not be comparable on an annual basis. They report that both rivers were carrying high silt loads, and plankton samples taken near the mouth of the rivers were not countable for this reason. Their counts may have also been lower because samples were collected from the deeper, more oligotraphic part of the lake.

At the time of the study by Kemmerer et al., Cyclops bicolor was the dominant copepod in the lake although Cyclops bicuspidatus thomasi was reported in Lake Chatcolet at the southern end of Coeur d'Alene Lake. During this investigation, C. bicuspidatus thomasi was the only Cyclopoid copepod present in large numbers. Hutchinson (1967) reported that C. bicuspidatus thomasi often replaces C. bicolor as a body of water becomes more eutrophic.

In comparison with the Copepoda and Rotifera, the Cladocera fluctuations corresponded more with temperature changes with one large pulse occurring during August. Leptodora occurred more often in the bays than in the open waters of the delta. Its large size may have brought about selective grazing by plankton-feeding fish and therefore reduced the numbers which normally would have been taken in the net hauls. Stross (1954) reports such selection by the kokanee (Oncorhynchus nerka kennerlyi) in Lake Pend Oreille during July and August when Leptodora is most abundant. The kokanee is generally considered to be a plankton feeder and is the major fish taken in Coeur d'Alene Lake.

A comparison of zooplankton Crustacea and total phytoplankton was made between the St. Joe and Coeur d'Alene Rivers and various rivers throughout the United States (Table 11). The average zooplankton density of the St. Joe River and Coeur d'Alene River was slightly higher than the yearly average in the Missouri and about one-half that in the Illinois and Mississippi Rivers. Counts from the Yellowstone and Snake Rivers, however, were considerably lower than the St. Joe and Coeur d'Alene Rivers.

Average densities of phytoplankton for the summer are considerably lower in the Coeur d'Alene and St. Joe Rivers in comparison to the other rivers. The phytoplankton densities indicate low productivity in both rivers; however, the phytoplankton counts indicate that the St. Joe River is three times more productive than the Coeur d'Alene drainage.

TABLE 11.--Average density of zooplankton Crustacea and total phytoplankton, expressed as numbers per liter, in various rivers in the United States.

River	Zooplankton	Phytoplankton[a]
Coeur d'Alene	15.2[b]	24,300
St. Joe	18.5[b]	70,500
Snake[c]	0.5[d]	5,498,000
Yellowstone[c]	0.2[d]	6,093,000
Illinois[c]	34.0[d]	9,489,000
Missouri[c]	12.4[d]	2,230,000
Mississippi[c]	34.0[d]	15,615,000

[a]Phytoplankton average during June-September.

[b]Zooplankton average during June-September.

[c]From Louis G. Williams, 1963, Plankton population dynamics, Public Health Service Publication 663 (Suppl. 2).

[d]Zooplankton average during July, 1960, to July, 1961.

SUMMARY

1. A limnological survey of the Coeur d'Alene River delta and adjacent lake waters and the lower St. Joe River was begun in May, 1969, and continued through November, 1970. The project was undertaken to measure seasonal variation in physical and chemical features, to determine the plankton composition and seasonal changes in abundance of the various forms, and to attempt to relate the factors influencing plankton populations in the delta region.
2. Seven sampling stations were established within the open waters and bays of the delta region and one station within the channels of the Coeur d'Alene and St. Joe Rivers. The following limnological data were collected at each station: physical measurements of transparency and air and water temperatures; chemical factors including dissolved oxygen, hydrogen-ion concentration, methyl orange alkalinity, and electrical conductivity; biological measures of net phytoplankton, nannoplankton, and zooplankton.
3. Net phytoplankton was more abundant in the bays and open waters of the lake than near the mouth of the Coeur d'Alene River, with major peaks occurring during May and October. Nannoplankton standing crops were highest from May through October. Both net phytoplankton and nannoplankton were dominated by the diatoms *Melosira*, *Tabellaria*, *Asterionella*, and *Synedra*.

4. Zooplankton abundance was directly related to water temperatures, with all taxonomic groups (Copepoda, Cladocera, and Rotifera) having peaks during the summer and early fall.
5. Plankton organisms present in the Coeur d'Alene River followed similar seasonal cycles as those in the delta and open waters of the lake but were considerably lower in numbers.
6. Plankton were more diversified and appeared in greater numbers in the St. Joe River in comparison with the Coeur d'Alene River. A greater contribution of allochthonous materials and lack of mining activity in the St. Joe drainage partially account for these differences.
7. Dissolved oxygen, alkalinity, and pH were not considered limiting to plankton communities in any of the waters.
8. Several lateral lakes adjacent and tributary to the lower reaches of the Coeur d'Alene River are thought to contribute to plankton abundance and composition in the river during the spring and early fall.
9. Measurements of physical, chemical, and biological features in the bay areas of the delta indicate a change from oligotrophic to mesotrophic conditions.

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APPENDIX

TABLE 12.--List of phytoplankton genera in the Coeur d'Alene Lake (1), River (2), and the lower St. Joe River (3).

Genus	1	2	3	Genus	1	2	3
Chlorophycophyta							
Ankistrodesmus	X		X	*Mougeotia*	X	X	X
Cerasterias			X	*Palmodictyon*		X	
Chaetophora			X	*Pediastrum*		X	X
Cladophora		X		*Rhizoclonium*		X	
Closterium	X	X	X	*Spirogyra*	X	X	X
Cosmarium		X		*Spondylosium*			X
Desmidium			X	*Staurastrum*	X	X	
Docidium	X	X		*Stigeoclonium*	X	X	
Eudorina	X	X	X	*Ulothrix*	X	X	X
Gleocystis		X		*Volvox*	X	X	X
Hydrodictyon		X		*Zygnema*	X	X	
Micrasterias		X	X				
Chrysophycophyta							
Amphora		X	X	*Gomphonema*			X
Asterionella	X	X	X	*Gyrosigma*		X	X
Bumilleria			X	*Mastogloia*			X
Camplodiscus			X	*Melosira*	X	X	X
Ceratoneis	X	X	X	*Navicula*	X	X	X
Chrysosphaerella			X	*Opephora*	X		
Cocconeis			X	*Rhopalodia*			X
Coscinodiscus		X	X	*Stauroneis*			X
Cyclotella	X			*Surirella*			X
Denticula			X	*Synedra*	X	X	X
Diatoma			X	*Synura*		X	X
Dinobryon	X	X	X	*Tabellaria*	X	X	X
Fragillaria	X	X	X	*Tribonema*	X	X	X
Frustulia	X	X	X				
Cyanophycophyta							
Anabaena	X	X	X	*Marssoniella*	X		
Aphanizomenon	X	X	X	*Oscillatoria*	X	X	X
Calothrix		X		*Phormidium*		X	
Coelospharium	X			*Spirulina*	X	X	X
Pyrrhophycophyta							
Ceratium	X	X					

TABLE 13.--Abundance of net phytoplankton, expressed as units per liter, at stations 1, 2, and 3 during the period November, 1969, to November, 1970 (bottom to surface hauls).

Station	Taxon	1969		1970							
		11-15	12-20	1-31	2-28	3/28	4/18	5/1	5/16	6/3	6/24
1	Melosira	23375	180123	17361	31645	37264	68605	147143	49658	12404	2003
	Tabellaria	9930	8781	926	1365	819	702	585	487	266	340
	Asterionella	30029	53471	27804	20407	9364	8741	10342	13755	1021	699
	Synedra	1655	585	195	273	234	156	195	195	113	28
	Dinobryon	0	0	0	0	0	0	0	585	340	132
	Misc. diatoms	0	0	0	0	0	0	0	0	0	0
	Total	64989	242960	46241	53690	47681	78204	158265	64680	14104	3202
2	Melosira	21626	72528	4381	11544	27056	59065	137385	28988	8715	3088
	Tabellaria	8700	5854	819	357	325	260	130	283	346	236
	Asterionella	27111	48460	12308	9203	8195	7415	10538	8417	1245	472
	Synedra	882	325	31	130	130	130	130	47	15	15
	Dinobryon	0	0	0	0	0	0	0	331	220	126
	Misc. diatoms	0	0	0	0	0	0	0	0	0	0
	Total	58319	127167	17539	21234	35706	66870	148183	38066	10541	3937
3	Melosira	6778	1860	163	1718	3213	9815	8668	3088	2616	1624
	Tabellaria	157	97	81	63	63	65	63	63	31	31
	Asterionella	2837	179	211	173	415	4290	1229	914	283	189
	Synedra	299	416	116	315	94	162	31	0	0	0
	Dinobryon	0	0	0	0	0	0	0	31	63	94
	Misc. diatoms	0	0	0	63	31	32	63	31	31	0
	Total	10071	2552	571	2332	3816	14364	10054	4127	3024	1938

TABLE 13.--Continued.

Station	Taxon	1970								
		7/9	7/23	8/6	8/20	9/10	9/26	10/10	10/24	11/14
1	*Melosira*	1560	2004	1465	1182	1654	12485	12389	17638	18820
	Tabellaria	756	1739	15700	16646	46580	137817	31116	17071	65071
	Asterionella	709	359	1087	425	567	1135	709	11633	8937
	Synedra	0	0	0	0	236	1563	993	1418	283
	Dinobryon	15	0	0	0	0	0	0	0	0
	Misc. diatoms	0	0	0	0	0	0	0	0	0
	Total	3040	4102	18252	18253	49037	153000	45207	47760	93111
2	*Melosira*	1859	2860	827	768	1225	10289	11918	14568	19392
	Tabellaria	346	1111	13635	15838	39719	103722	26986	14118	50372
	Asterionella	598	378	788	295	709	946	630	10079	4808
	Synedra	0	0	0	29	193	946	882	945	157
	Dinobryon	0	0	0	0	0	0	0	0	0
	Misc. diatoms	0	0	0	0	0	0	0	0	0
	Total	2803	4349	15250	16930	41846	115903	40416	39710	74729
3	*Melosira*	32	9	8	46	281	812	5988	13557	10595
	Tabellaria	29	48	89	136	124	113	204	441	173
	Asterionella	0	0	0	0	51	100	661	1324	252
	Synedra	0	0	0	0	0	15	63	126	110
	Dinobryon	0	0	0	0	15	31	63	0	0
	Misc. diatoms	0	0	0	0	0	0	0	0	0
	Total	61	57	97	182	471	1071	6979	15448	11130

TABLE 14.--Abundance of nannoplankton, expressed as units per milliliter, at stations 1, 2, and 3 during the period November, 1969, to November, 1970 (bottom to surface column mix).

Station	Taxon	1969		1970							
		11/15	12/20	1/31	2/28	3/28	4/18	5/1	5/16	6/3	6/24
1	*Melosira*	250	914	770	911	1318	504	1431	2261	2219	1125
	Tabellaria	1815	247	75	10	16	1	3	65	57	16
	Fragillaria	52	32	0	0	0	0	0	39	6	0
	Asterionella	136	468	282	233	65	18	227	107	26	32
	Synedra	39	6	16	5	0	0	3	13	0	0
	Misc. diatoms	0	0	0	10	28	8	22	39	13	13
	Filamentous	0	0	0	0	0	0	0	0	0	0
	Total	2292	1667	1143	1169	1427	531	1686	2524	2321	1186
2	*Melosira*	143	886	456	483	862	337	1005	1998	1767	1184
	Tabellaria	1308	443	43	5	4	8	13	33	16	12
	Fragillaria	13	0	0	0	0	0	0	13	0	0
	Asterionella	114	390	201	103	16	2	104	117	20	33
	Synedra	29	10	0	0	0	0	0	6	0	0
	Misc. diatoms	0	3	5	16	28	9	29	42	16	20
	Filamentous	0	0	0	0	0	0	0	0	0	0
	Total	1607	1712	705	607	910	356	1151	2209	1819	1249
3	*Melosira*	96	29	10	100	95	130	236	88	21	24
	Tabellaria	13	15	0	0	0	0	0	2	2	0
	Fragillaria	0	0	0	0	0	0	0	0	0	0
	Asterionella	0	0	0	0	0	0	51	93	18	16
	Synedra	0	0	0	0	0	0	0	0	0	0
	Misc. diatoms	1	2	1	33	9	12	6	20	3	5
	Filamentous	0	0	0	0	0	0	0	0	0	0
	Total	110	45	11	133	104	142	293	203	44	45

TABLE 14.--Continued.

Station	Taxon	1970								
		7/9	7/22	8/6	8/19	9/10	9/25	10/10	10/24	11/14
1	*Melosira*	2633	2890	2164	1280	352	184	151	341	219
	Tabellaria	10	10	135	564	932	1556	1686	2766	422
	Fragillaria	0	21	16	0	0	0	0	11	13
	Asterionella	16	113	92	37	10	5	16	54	24
	Synedra	0	5	27	54	5	27	65	86	12
	Misc. diatoms	5	5	0	0	0	0	0	0	0
	Filamentous	0	0	162	287	623	520	358	168	0
	Total	2664	3044	2596	2223	1922	2292	2276	3426	690
2	*Melosira*	2403	2598	1801	662	288	119	65	315	204
	Tabellaria	27	22	190	613	1074	1275	1779	2479	439
	Fragillaria	0	0	33	0	0	0	0	0	0
	Asterionella	43	92	43	27	0	0	22	43	13
	Synedra	0	5	38	43	11	33	76	92	14
	Misc. diatoms	16	11	0	0	0	0	0	0	0
	Filamentous	0	0	163	184	520	499	379	103	0
	Total	2489	2728	2268	1529	1833	1926	2321	3032	670
3	*Melosira*	30	0	0	0	14	37	51	108	65
	Tabellaria	0	0	9	7	4	29	32	18	13
	Fragillaria	0	0	0	0	0	0	0	0	0
	Asterionella	17	9	0	0	0	5	0	0	0
	Synedra	0	0	0	0	0	0	0	0	0
	Misc. diatoms	3	4	0	0	3	3	4	5	3
	Filamentous	0	0	0	0	0	0	0	0	0
	Total	50	13	9	7	21	74	87	131	81

TABLE 15.--Abundance of net phytoplankton, expressed as units per liter, at station 7, during the period June to September, 1970 (bottom to surface hauls).

Taxon	Date					
	6/26	7/10	7/24	8/7	8/21	9/11
Melosira	1059	410	340	599	690	984
Tabellaria	104	44	126	151	284	378
Synedra	28	107	13	13	9	38
Ceratoneis	38	13	13	0	0	0
Frustulia	9	6	0	0	0	0
Dinobryon	114	32	139	50	113	303
Colonial greens	19	19	25	13	19	19
Misc. diatoms	142	50	32	19	28	19
Filamentous	246	378	826	372	1163	681
Total	1759	1059	1514	1217	2306	2422

TABLE 16.--Abundance of nannoplankton, expressed as units per milliliter, at station 7 during the period June to September, 1970 (bottom to surface column mix).

Taxon	Date					
	6/26	7/10	7/24	8/7	8/21	9/11
Melosira	28	23	13	11	16	29
Tabellaria	0	0	4	59	16	11
Synedra	2	20	4	3	1	1
Ceratoneis	11	10	2	2	3	1
Frustulia	6	3	3	1	1	1
Misc. diatoms	12	12	3	6	7	6
Filamentous	36	18	4	15	5	7
Total	95	86	33	97	49	56

TABLE 17.--Abundance of zooplankton, expressed as units per liter, at station 1 during the period November, 1969, to November, 1970 (bottom to surface hauls).

Taxon	1969		1970							
	11/15	12/20	1/31	2/28	3/28	4/18	5/1	5/16	6/3	6/24
Cladocera										
Leptodora	0	0	0	0	0	0	0	0	0	0
Daphnia	0	0	0	0	0	0	.12	0	0	.12
Bosmina	.48	.12	1.76	1.54	.77	0	1.53	0	.44	1.28
Diaphanosoma	.80	0	0	0	0	0	.76	.25	0	.57
Total	1.28	.12	1.76	1.54	.77	0	2.41	.25	.44	1.97
Copepoda										
Cyclops	18.32	8.09	2.00	10.54	1.47	14.65	15.55	3.14	1.02	1.47
Nauplii	36.39	19.28	2.32	4.69	7.32	35.42	59.02	15.49	14.46	21.46
Total	54.71	27.37	4.32	15.23	8.79	50.07	79.57	18.63	15.48	22.93
Rotifera										
Polyarthra	2.48	.63	.15	1.92	4.88	1.02	6.29	.57	1.02	1.66
Keratella	3.93	.77	.15	.57	.12	.38	.77	0	.70	1.21
Monostyla	0	0	0	0	0	0	0	0	0	0
Total	6.41	1.40	.30	2.49	5.00	1.40	7.06	.57	1.72	2.87

TABLE 17.--Continued.

Taxon	1970								
	7/9	7/22	8/6	8/19	9/10	9/25	10/10	10/24	11/14
Cladocera									
Leptodora	0	0	1.02	.37	0	.25	0	0	0
Daphnia	0	.12	0	0	.12	0	0	0	.12
Bosmania	23.01	5.01	.51	.12	.38	1.15	.38	.12	0
Diaphanosoma	2.30	10.28	38.69	46.15	41.65	10.28	8.87	1.41	1.79
Total	25.31	15.41	40.22	46.64	42.15	11.68	9.25	1.53	1.91
Copepoda									
Cyclops	11.69	13.88	5.40	5.26	27.89	16.84	10.92	3.87	5.77
Nauplii	167.29	124.21	51.94	49.88	20.95	40.62	91.29	47.70	83.44
Total	178.98	138.09	57.34	55.14	48.84	57.46	102.21	51.56	89.24
Rotifera									
Polyarthra	2.31	1.15	0	.12	2.43	3.85	1.79	0	2.82
Keratella	1.28	1.53	0	0	.37	0	.12	.38	2.56
Monostyla	0	0	0	4.62	10.92	2.18	3.59	.51	0
Total	3.59	2.68	0	4.74	13.72	6.03	5.50	.89	5.38

TABLE 18.--Abundance of zooplankton, expressed as units per liter, at station 2 during the period November, 1969, to November, 1970 (bottom to surface hauls).

Taxon	1969		1970							
	11/15	12/20	1/31	2/28	3/28	4/18	5/1	5/16	6/3	6/24
Cladocera										
Leptodora	0	0	0	0	0	0	0	0	0	0
Daphnia	0	0	0	0	0	0	0	0	0	1.71
Bosmina	.74	2.99	.85	.54	.31	.21	0	0	.32	6.85
Diaphanosoma	2.56	0	0	0	0	0	0	.23	.10	.10
Total	3.30	2.99	.85	.54	.31	.21	0	.23	.42	8.56
Copepoda										
Cyclops	25.39	18.63	2.89	7.81	2.13	6.21	2.89	1.44	2.42	2.56
Nauplii	44.46	21.42	1.81	7.17	8.56	29.68	10.49	10.12	14.35	27.75
Total	69.85	40.05	4.70	14.98	10.69	35.89	13.38	11.56	16.77	30.41
Rotifera										
Polyarthra	3.10	0	.85	7.60	6.10	7.70	3.85	.72	.95	6.63
Keratella	6.42	10.27	.74	2.78	1.06	0	.42	.47	.42	1.49
Notholca	0	0	0	0	0	.53	.32	.07	.10	.10
Monostyla	0	0	0	0	0	0	0	0	0	0
Total	9.52	10.27	1.59	10.38	7.16	8.23	4.59	1.26	1.47	8.22

TABLE 18.--Continued.

Taxon	1970								
	7/9	7/22	8/6	8/19	9/10	9/25	10/10	10/24	11/14
Cladocera									
Leptodora	0	.07	.63	.31	.34	.15	.10	0	0
Daphnia	.85	.15	0	0	0	0	0	0	0
Bosmina	8.03	2.88	0	.15	.34	.48	0	0	0
Diaphanosoma	3.53	9.23	61.72	41.94	26.46	14.45	6.31	3.32	0
Total	12.41	12.23	62.35	42.40	27.14	15.08	6.41	3.32	0
Copepoda									
Cyclops	1.60	8.11	2.13	.79	23.14	14.30	10.17	10.06	5.13
Nauplii	167.70	99.81	48.64	39.37	14.72	26.03	31.39	79.29	44.35
Total	169.30	107.92	50.77	40.16	37.86	40.33	41.56	89.35	49.48
Rotifera									
Polyarthra	2.46	.88	1.27	.96	.51	1.76	1.81	.74	4.49
Keratella	2.56	2.32	1.27	.31	.52	.63	.21	1.38	3.85
Notholca	0	0	0	0	0	0	0	0	0
Monostyla	0	0	0	3.20	1.22	3.85	2.56	1.49	0
Total	5.02	3.20	2.54	4.47	2.25	6.24	4.58	3.61	8.34

TABLE 19.--Abundance of zooplankton, expressed as units per liter, at station 3 during the period November, 1969, to November, 1970 (bottom to surface hauls).

Taxon	1969		1970							
	11/15	12/20	1/31	2/28	3/28	4/18	5/1	5/16	6/3	6/24
Cladocera										
Daphnia	0	0	0	0	0	0	0	0	0	2.24
Bosmina	.71	.26	.44	.42	.21	0	0	0	1.06	24.42
Diaphanosoma	0	0	0	0	0	0	0	0	.10	.10
Misc. forms	0	0	0	0	0	0	0	0	0	.10
Total	.71	.26	.44	.42	.21	0	0	0	1.16	26.86
Copepoda										
Cyclops	3.21	1.97	1.11	3.85	1.17	2.56	.53	1.92	.63	1.49
Nauplii	11.05	1.54	2.91	9.74	10.38	25.07	4.71	12.96	17.25	35.24
Total	14.26	3.51	4.02	13.59	11.55	27.63	5.24	14.88	17.88	36.73
Rotifera										
Polyarthra	1.54	.79	3.14	2.78	2.78	6.52	.74	2.67	4.28	12.31
Keratella	.37	.31	.59	.85	.85	.53	0	.21	1.49	1.49
Notholca	.13	0	.07	1.28	1.17	1.06	0	0	0	0
Conochiloides	0	0	2.16	0	0	0	0	0	3.00	5.24
Trichocerca	0	0	0	0	0	0	0	0	0	0
Monostyla	0	0	0	0	0	0	0	0	1.17	.21
Total	2.04	1.10	5.96	4.91	4.80	8.11	.74	2.88	9.94	19.25

TABLE 19.--Continued.

Taxon	1970								
	7/9	7/22	8/6	8/19	9/10	9/25	10/10	10/24	11/14
Cladocera									
Daphnia	0	0	0	0	0	0	0	0	0
Bosmina	.31	2.50	.57	.15	.37	0	.10	.95	0
Diaphanosoma	0	.64	.12	.05	0	.04	.05	.21	0
Misc. forms	.18	1.28	.25	.31	0	0	0	.42	0
Total	.49	4.48	.94	.51	.37	.04	.15	1.58	0
Copepoda									
Cyclops	0	.12	.06	.96	1.01	.89	1.49	1.38	1.17
Nauplii	3.01	2.43	1.28	6.21	6.10	8.99	12.96	21.10	7.71
Total	3.01	2.55	1.34	7.17	7.11	9.88	14.45	22.48	8.88
Rotifera									
Polyarthra	.89	3.27	.63	.21	1.22	2.13	5.72	10.92	2.89
Keratella	1.60	1.47	.57	0	.47	.04	0	0	0
Notholca	0	0	0	.05	.31	.16	1.01	.42	0
Conochiloides	0	0	0	0	0	0	0	0	0
Trichocerca	0	0	0	0	0	.30	.53	.53	0
Monostyla	.06	0	0	.59	.64	1.02	1.39	2.03	0
Total	2.55	4.74	1.20	.85	2.64	3.65	8.65	13.90	2.89

TABLE 20.--Abundance of zooplankton, expressed as units per liter, at station 7 during the period June to September, 1970 (bottom to surface hauls).

Taxon	6/26	7/10	7/24	8/6	8/21	9/11
Cladocera						
Daphnia	0	0	.06	.07	9.25	0
Bosmina	.56	0	0	.96	1.92	3.62
Diaphanosoma	0	0	0	0	.38	1.46
Ceriodaphnia	.48	0	0	.36	1.02	0
Total	1.04	0	.06	1.49	12.57	5.08
Copepoda						
Cyclops	.15	.06	.70	.29	6.81	.08
Nauplii	4.65	3.53	4.24	9.79	57.21	3.46
Total	4.80	3.59	4.94	10.08	64.02	3.54
Rotifera						
Polyarthra	.80	2.76	1.02	.73	27.77	7.01
Keratella	.48	.06	.38	0	.25	0
Notholca	0	0	0	0	5.39	1.40
Conochilus	.23	0	0	0	15.17	2.70
Brachionus	9.39	.45	.13	1.18	.64	0
Filina	0	1.15	.06	0	0	0
Asplancha	0	0	0	0	5.01	5.55
Total	10.90	4.42	1.59	1.91	54.23	16.66