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THE BIOLOGICAL IMPACT OF COMBINED METALLIC AND ORGANIC POLLUTION IN THE COEUR D'ALENE--SPOKANE RIVER DRAINAGE SYSTEM

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Project Completion Report

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ABSTRACT

An investigation was made into the biological effects of metallic and organic pollution in the Coeur d'Alene - Spokane River Lake drainage system.

Water quality data show heavy inflows of nutrients during late spring into Coeur d'Alene Lake from the St. Joe and Coeur d'Alene Rivers and Plummer Creek. Although no water devoid of dissolved oxygen have been measured, 2-4 mg/l have been measured in the southern portion of the lake. Phytoplankton productivity measurements and bottom organism identification and enumeration have shown that the lake functions at several trophic levels, meso-eutrophic to eutrophic in the southern portion, mesotrophic in the immediate area of the Coeur d'Alene River and oligotrophic in the northern portions. High metal concentrations (1000-7000 mg/kg Zn) in the bottom sediments of the middle and northern portions of the lake did not appear to substantially affect distribution of benthic chironomids or oligochaetes.

Lake sediment cores taken across the delta region of the Coeur d'Alene River penetrated through the regions of high metallic concentration and allowed an average sediment deposition rate to be calculated.

Algal toxicity tests showed the amount of Zn normally present in the Coeur d'Alene Lake and River and the Spokane River to be inhibitory to the algal test organism Selanastrum capricornutum.

The water quality of the Spokane River was shown to be of good to excellent quality in all parameters tested except for high metallic content, especially Zn. Activation and atomic absorption analysis of the metallic content in tissues of the organisms populating the Spokane River indicated that the algae were the prime concentrators of Zn, Cd, Pb, Hg, Fe, and Mn. Algae and detritus consumers such as the larvae of the caddis fly Hydropsyche and the nymphs of the may fly Baetis reflected high metallic concentrations. Most higher aquatic plants showed relatively lower concentrations.

Analysis of fish tissues showed a considerably less concentration of metals than the aquatic plants, insects, or algae. However, Zn was measured at concentrations of 80-200 mg/kg in liver tissues of several species of fishes. Fillet tissues generally contained less than one quarter of these amounts. The fish, when collected, did not appear to be under stress leading the investigators to believe that most of the metals--although present in relatively high concentration in the tissues of the organisms tested--must be in a relatively innocuous state.

FCST Category VA, VB, VC

Water quality*/Heavy metals*/Benthos*/Aquatic environment*/Food chain*/Neutron Activation Analysis/Atomic absorption spectrophotometry, Algal bioassay/ Phytoplankton/ Sediments/Concentration of heavy metals*/ Zn, Cd, Pb, Hg, Fe, Mn, Ni, Se, Cr, Rb, Co, Eu, Sb, Sc, Th, Hf, Cs/ Coeur d'Alene River/Coeur d'Alene Lake/Spokane River.

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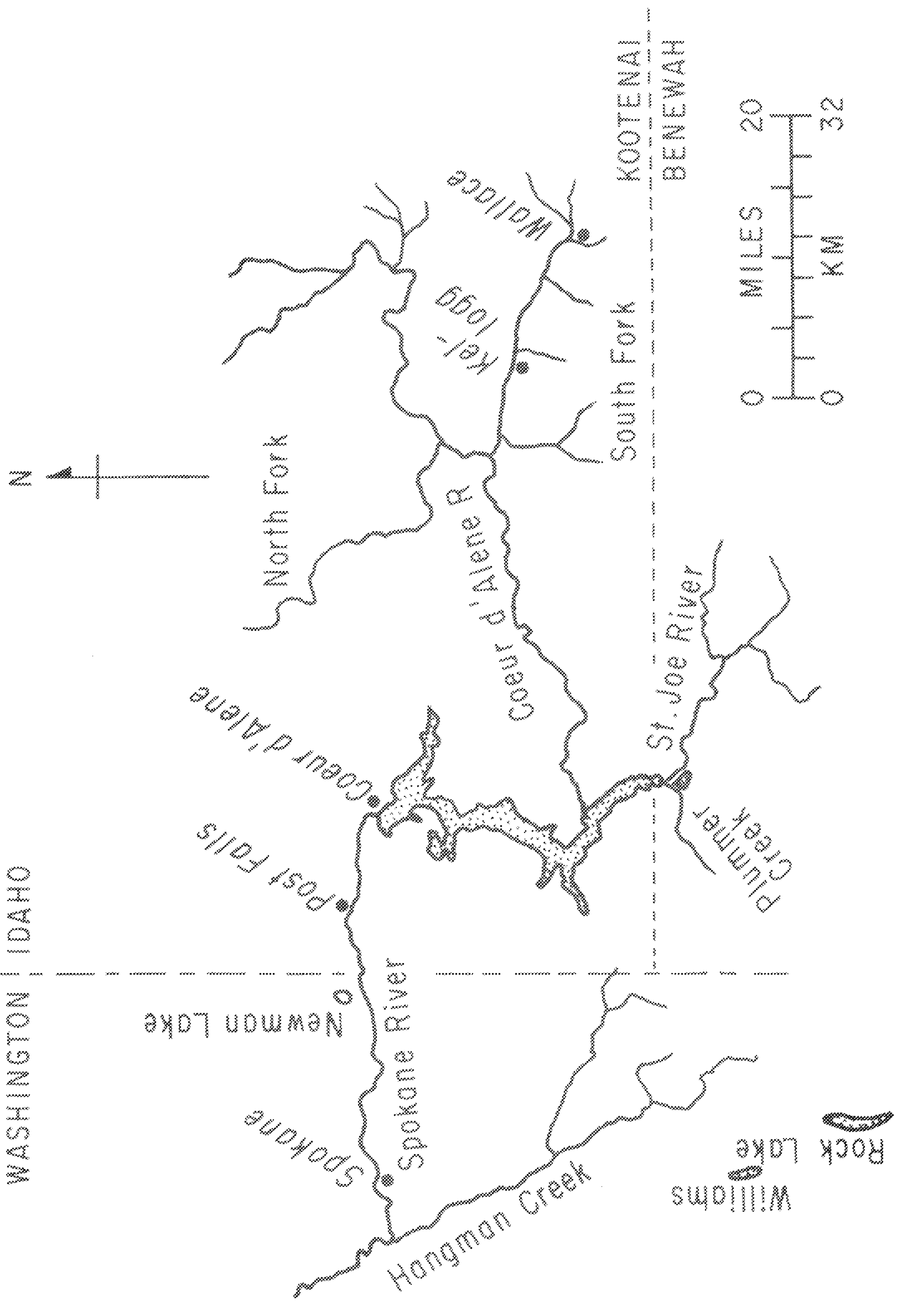


INTRODUCTION

Objectives

This research project was an attempt to bring together the expertise of two major universities, three colleges, three research centers, and four departments to focus their attention upon the effects of heavy metal and organic pollution upon the biota of two river drainage systems integrated with a lake. The specific objectives of this research were to:

1. Measure the trace metallic elements in the water and sediments of the Coeur d'Alene Lake - Spokane River drainage system.
2. Sample bottom invertebrate organisms in both rivers and in the delta and open waters of the lake to determine community composition and density as related to metal concentrations in the sediments.
3. Measure by neutron activation and atomic absorption methods the trace-metal concentration in tissues of selected aquatic organisms.
4. Measure the effects of added pollutants upon the growth of test algae, utilizing modified bioassay techniques as outlined by the Provisional Algal Assay Procedures.
5. Establish base-line data on phytoplankton composition and productivity as well as the water quality of Coeur d'Alene Lake and the upper Spokane River.

Some of these objectives had to be somewhat modified because of reduced funding available from the Office of Water Resources Research matching grants to the State of Washington Water Research Center and the University of Idaho Water Research Institute. Most, however, were carried out and exceeded in dimension by the willingness of research personnel and graduate students to freely donate much of their spare time and, in many cases, travel expenses.

Study Team Personnel

In order to assess the numerous parameters that were considered to be important in this joint investigation, several study teams were organized. Dr. Fred Rabe and his graduate students in zoology at the University of Idaho had been working in the Coeur d'Alene and St. Joe River drainage areas for several years and had also begun to measure some of the productivity factors related to Lake Coeur d'Alene. Savage (1970), Sappington (1969), Minter (1971), Wissmar (1972). For these reasons Dr. Rabe, Ms.

Savage, Mr. Winner, and Mr. Parker concerned themselves directly with the Coeur d'Alene River and Lake drainage systems. Ms. Savage aided in determining the diversity of invertebrate species in the headwaters of the Coeur d'Alene River. Mr. Winner did extensive bottom organism and sediment collection for species determination and chemical analysis throughout Coeur d'Alene Lake. Mr. Parker studied the algal production and nutrients entering the lake, measured primary productivity by the Carbon 14 method and proposed a trophic scheme for the lake. Mr. Parker also collected numerous water quality data as well as water and algae samples which were analyzed by the Sanitary Engineering laboratories at Washington State University. One of Dr. Rabe's students, Mr. Larry Bartlett, conducted algal bioassays to determine the toxicity of Zn, Cd and Cu (singly and in combination) upon the test organism Selanastrum capricornutum. The tests were made at the Sanitary Engineering laboratories under the direction of Dr.'s Funk and Rabe.

Dr. William H. Funk had been working for six years with his associates in Sanitary Engineering and with graduate students on water quality, algae problems, and trace metals in bodies of water around the Spokane region. It was jointly decided that this study group would concentrate on the water quality parameters of the Spokane River, aid in the bottom sediment work on Coeur d'Alene Lake, and complete many of the laboratory water quality analyses for both study teams. Mr. Neil Thompson studied the water quality, algal, and bacterial makeup of the upstream reaches of the Spokane River. Mr. Paul F. X. Dunigan investigated the inorganic nutrients and the trace element constituents of sediment cores taken from the bottom of Lake Coeur d'Alene. Mr. Richard Condit studied the diatom configuration of the cores, as well as completing most of the algae identification and counting for both study teams. Mr. Paul Bennett supervised the standard (wet) chemical analysis of water samples received from all study teams and also completed atomic absorption analyses of trace metal constituents of bottom organisms, fish, and algae.

Dr. Royston Filby and Dr. Richard Ragaini were interested in applying the powerful research tool of neutron activation analysis to the measurement of trace metals in biological and sediment samples. In these efforts they were assisted by Mr. Kishor Shah, Mr. Dave Baugh, and Ms. Ann Lydiard.

Mr. Fred Bennett of Walla Walla College, Mr. Leo Cunningham and Mr. Pat Syms, technicians on the Washington State University Civil Engineering staff, designed and built the hoist and retrieval mechanism for an Ewing piston corer and mounted it on Sanitary Engineering Section's pontoon barge. The latter two staff members operated the coring device and aided in many of the field sampling operations.

About a third of the sampling trips were joint ventures by the two universities with combined crews. This procedure greatly increased the in-the-field expertise as well as enhancing the utilization of sampling equipment. The WSU pontoon barge was also loaned to the U of I crews for sediment sampling on other occasions. It might be added that since the advent of this investigation there has been a constant flow of equipment and data between the two universities.

DESCRIPTION OF THE STUDY AREA

Geography

The basin containing Coeur d'Alene Lake is a submerged river valley 38.6 km (24 mi) long with an average width of 1.6 km (≈1.0 mi) located in Kootenai and Benewah Counties of northern Idaho. The present elevation of Coeur d'Alene Lake is maintained by Post Falls Dam on the Spokane River. The southern portion of the lake is divided into three shallow lakes--Chatcolet, Benewah and Round which were created in 1906 by the erection of the dam. The depth gradually increases toward the northern end of the lake to a maximum of 54.9 m (180 ft) off Three Mile Point in the northern narrows.

Two major rivers, the Coeur d'Alene and St. Joe, discharge into the southern portion of the lake. The headwaters of both rivers originate in the Bitterroot Range between Montana and Idaho. The Coeur d'Alene River drainage basin, an area of approximately 10,360 sq km (≈4,000 sq mi), consists of two subdrainages, the South Fork draining the Coeur d'Alene mining district (Figure 1) and the North Fork in the Coeur d'Alene National Forest. The South Fork joins the North Fork at Enaville to form the main stem of the Coeur d'Alene River which flows 48.2 km (30 mi) west into Coeur d'Alene Lake at Harrison, Idaho. The St. Joe River, with a watershed of about 3,880 sq km (≈1,500 sq mi), is free of mine wastes but has been affected to some extent by sewage disposal, logging, and farming activities.

The Spokane River, the only surface outlet of the lake, flows westerly from the northern end of the lake, then through the city of Spokane, Washington (pop. 200,000) to its confluence with the Columbia River 160.9 km (100 mi) to the southwest. The Spokane River above Spokane, the St. Joe River, and the North Fork of the Coeur d'Alene River support excellent sport fisheries, while the South Fork and main stem of the Coeur d'Alene River and the Spokane River below Spokane have serious pollution problems and a reduced diversity of biota.

Geology

Precambrian metasediments underlie most of the Coeur d'Alene and

St. Joe drainage basins. Faulting and subsequent mineralization in portions of this area have resulted in deposition of valuable minerals including sulfides of lead, zinc, silver, and antimony and smaller quantities of copper, cobalt, and gold. The Coeur d'Alene mining district--adjacent to the South Fork of the Coeur d'Alene River--produces most of the United State's supply of antimony and zinc and much of its silver. The lower reaches of both rivers, the lake, and the Spokane River have been eroded in Miocene basalts which overlie the basement complex; the basalts in turn are overlain by glacial alluvium or windblown loess deposits of post-glacial origin (Ross and Savage, 1967).

Sources of Pollution

Since 1885, waste from the Coeur d'Alene mining district has been carried into the lake. Tailings from ore crushing mills have been a source of large amounts of rock flour. Subaerial oxidation of heavy metal sulfides in exposed tailings ponds and subsequent leaching has contributed ions of heavy metals to streams and ground water. Effluents from lead and zinc smelters have contributed particulate matter and heavy metal ions to both air and water. A study conducted in 1911 indicated a reduced plankton population in the Coeur d'Alene River delta as compared with the open waters of the lake (Kemmerer *et al.*, 1923). An extensive survey by Ellis in 1932 showed the river to be devoid of life from the city of Wallace to its mouth, and the delta to be deficient in plankton, fish, and bottom organisms. Assay tests conducted by Ellis on native fish species indicated that lethal concentrations of zinc ions were present in the river. Sappington (1969) found a 96-hour TLm (median tolerance limit) of .09 ppm Zn for Cutthroat trout fingerlings using water from the North Fork treated with known amounts of $ZnSO_4$. Zinc concentrations as high as 2.6 ppm at the river mouth and 21 ppm in the lower reaches of the South Fork were reported by Mink *et al.* in 1971.

The river depth has been decreased by siltation (Figures 2 and 3), and large volumes of rock flour have been carried out over the lake since the beginning of mining operations in this area. Not until the construction of settling ponds in 1968 to impound ore-mill wastes has any reduction in silt load been accomplished. Evidence of mine tailings and unusually high concentrations of Zn have been detected throughout the lake by this study and by several others (O'Neal, personal communication), Sceva and Schmidt (1971).

Population increases and lack of adequate sewage treatment facilities in the towns along the Coeur d'Alene and St. Joe Rivers and at shore dwellings have permitted untreated and partially treated sewage to enter the lake (Leeright, 1971) (Flaherty, 1972), as indicated by the extensive growth of blue-green algae and macrophytes in shallower areas of the lake. Silt and nutrients from cultivated lands also appear to provide a substantial nutrient input into the southern portion of the lake. In Cottonwood Bay (across the lake from the Coeur d'Alene River delta) considerable silt buildup has been measured. The bay area is 6 hectares (15 acres) and the maximum estimated depth of the deposit is 3.6 m (12 ft) (Freckleton, personal communication). Near the lake outlet and along the western shoreline, large log rafts (Figure 4) await movement to sawmills. The lake bed in these areas is covered with bark and wood chips. Figure 5 shows the lake outlet and the headwaters of the Spokane River.

Figure 1. The Valley of the South Fork of the Coeur d'Alene River (March, 1972). Extensive settling ponds now reduce transport of silts to the river. River flow is toward the viewer.

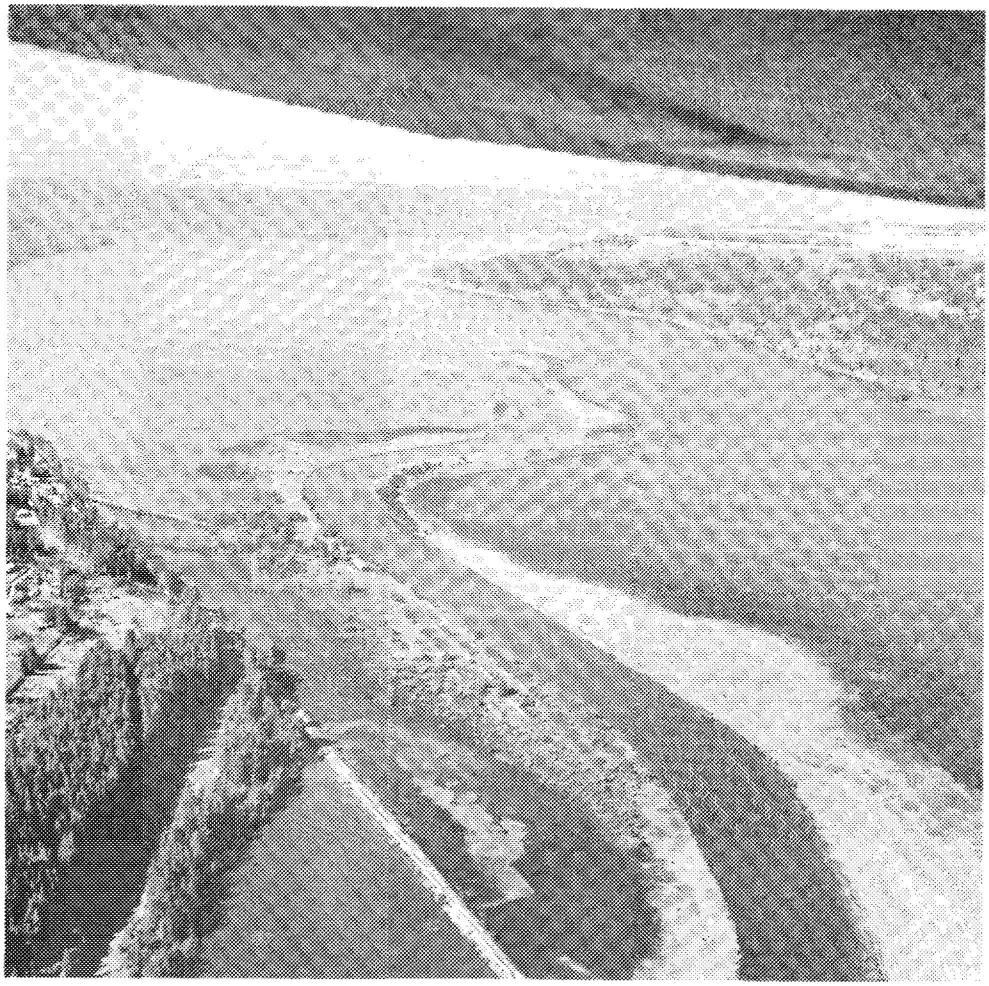


Figure 2. Coeur d'Alene River Channel and Delta. (Note that the channel has extended itself some distance into the lake by siltation.)

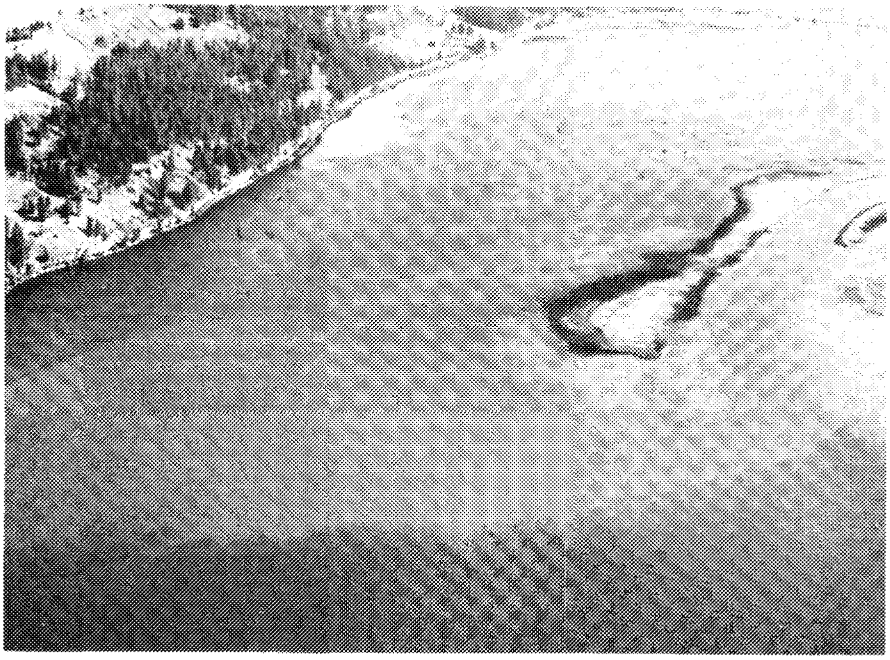


Figure 3. Upstream View of the Channel. (Note extensive silt load still carried by the river.)

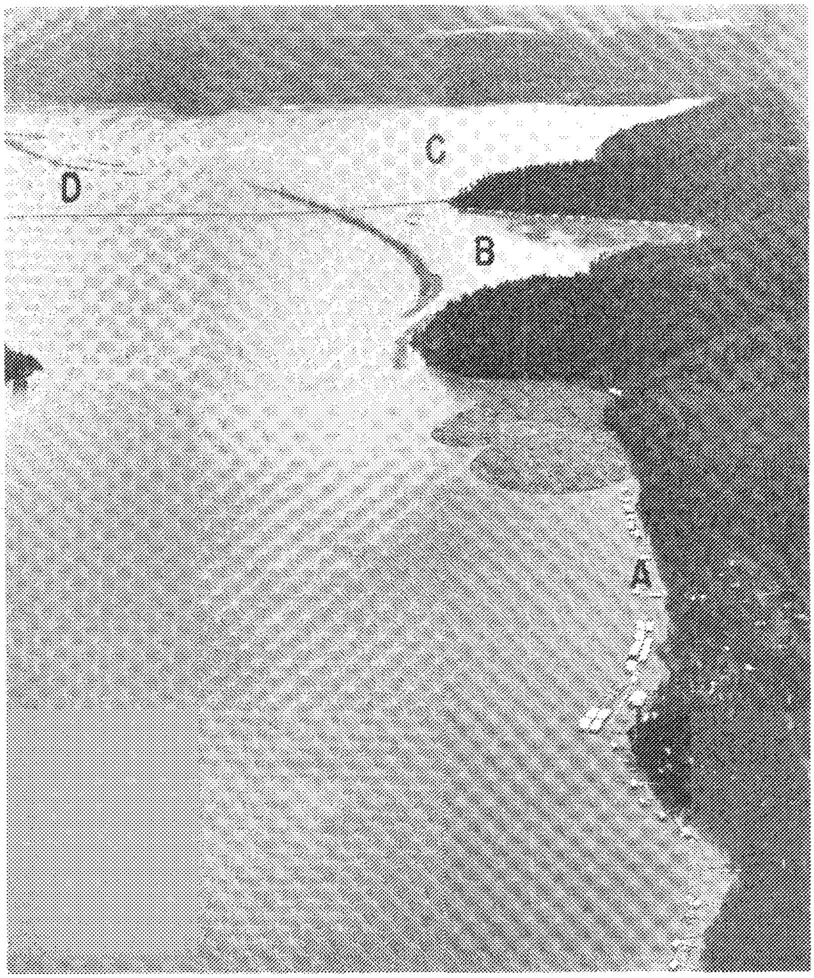


Figure 4. Log Rafts Stored Near Conkling Park, Area A. Area B is Hidden Lake, area C is Chatcolet Lake, and area D is Round Lake of the southern end of the Coeur d'Alene Lake system. (Note the extensive use of the shoreline for boat houses, summer homes and other recreational purposes.)

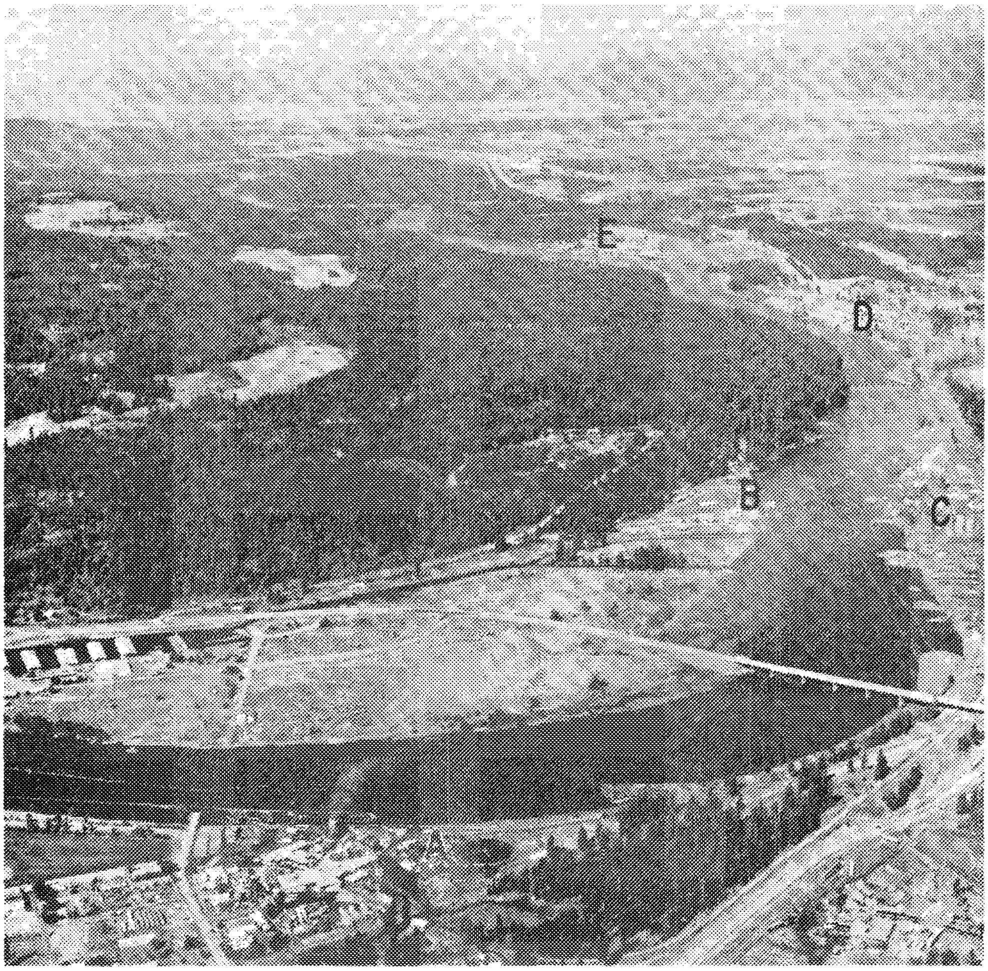


Figure 5. Coeur d'Alene Lake Outlet and the Head of the Spokane River. Letter A indicates Coeur d'Alene City Sewage Plant, B indicates the Spokane Yacht Club, and C, D, and E are industries along the Spokane River. Flow of river is away from the viewer.

MATERIALS AND METHODS

Physical Measurements

Temperature

River and lake temperature series were measured by Yellow Springs Instrument Corporation (YSI) probes (± .6 C), Whitney Thermistors Model TC-5 (± .01 C), or an Applied Research Associates' electric thermometer (± .1C).

Light

Light penetration was measured by a Secchi disc and a Gemware submarine photometer; in the latter case electrical units were recalculated to standard foot-candles. Incident solar radiation was measured with a Belfort pyrheliograph. The resulting graphs were integrated by planimetry to find a conversion factor to calculate daily production rates (Vollenweider, 1969).

Depth

Depth soundings were made with a Raytheon DE-735 Fathometer System utilizing a Raytheon DE 7041 Transducer (0-202.8 m ± .5%).

Field Chemical Measurements

Alkalinity

Alkalinity was determined by methods described in the American Public Health Association's *Standard Methods for the Analysis of Water and Waste Water*, 13th Ed. (referred to in following citations as APHA-Standard Methods) utilizing phenolphthalein and methyl orange as indicator solutions.

Dissolved Oxygen

Dissolved oxygen was determined by YSI probe (± .25 mg/l). Comparative measurements were also made using the azide modification of the Winkler Method as suggested by APHA-Standard Methods (1971). The Winkler Method was also substituted in instances of probe failure.

pH

Measurements of pH were made with Beckman Model N battery-operated pH meters (± .05 pH).

Conductivity

Conductivity measurements were made with an Industrial Instrument - RB-SOLU Bridge conductivity meter (± 5%).

Field equipment and instrumentation are shown in Figures 6, 7, and 8.

Laboratory Chemical Analysis

Water samples were collected from various depths in the rivers and lake using Van Dorn water bottles or a weighted continuous pump sampler [Figures (9a) (9b)]. In some cases grab samples were made along the rivers. In each instance, the samples were placed in 1.0 liter polypropylene bottles and cooled to 4.0 C in ice chests. Forty mg/l $HgCl_2$ added to bottles designated for Ammonia, Kjeldahl, Nitrate-Nitrogen, and Phosphorus determinations.

Standard chemical analyses (wet) were carried out at the WSU Sanitary Engineering laboratories utilizing a Beckman DU-2 spectrophotometer equipped with a photomultiplier attachment. Atomic absorption techniques were used in conjunction with a Perkin-Elmer 303 atomic absorption spectrophotometer to determine the metallic constituents of the water samples.

Analytical methods generally followed those procedures set forth by APHA-Standard Methods (1971) and the Environmental Protection Agency's Methods for Chemical Analysis of Water and Wastes (1971). The brief description which follows indicates the individual method selected.

Orthophosphate - Phosphorus

The single-reagent method (ascorbic acid) was used in which ammonium molybdate and potassium antimonyl tartrate react in an acid medium with minute amounts of phosphorus to form a blue complex. The color intensity is proportional to the amount of phosphorus present.

Figure 6. Field Sampling and Testing Equipment Aboard Washington State University's Research Boat.

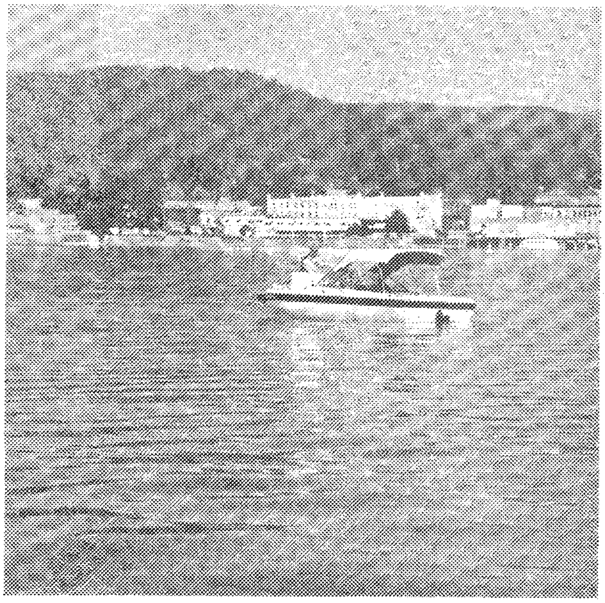


Figure 7. Collecting water samples off Coeur d'Alene, Idaho.

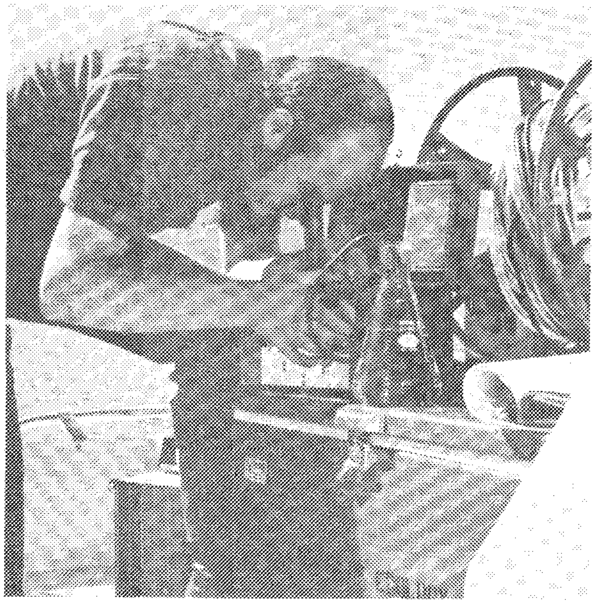


Figure 8. Immediate Analysis of a Water Sample Aboard Research Boat.

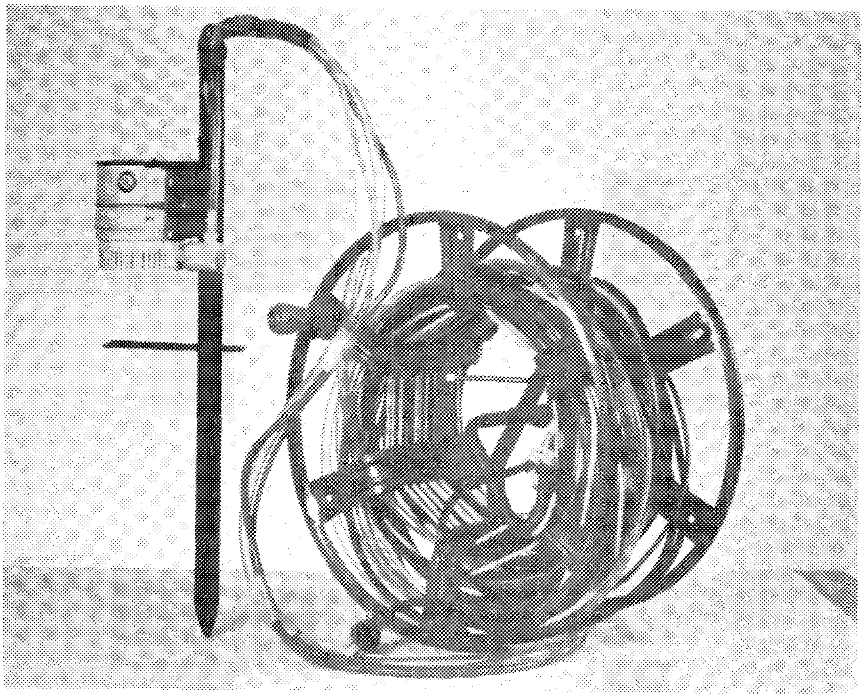


Figure 9(a). Continuous Pump Sampler Developed for Rapid Variable Depth Sampling in Lakes and Rivers of the Spokane Area.

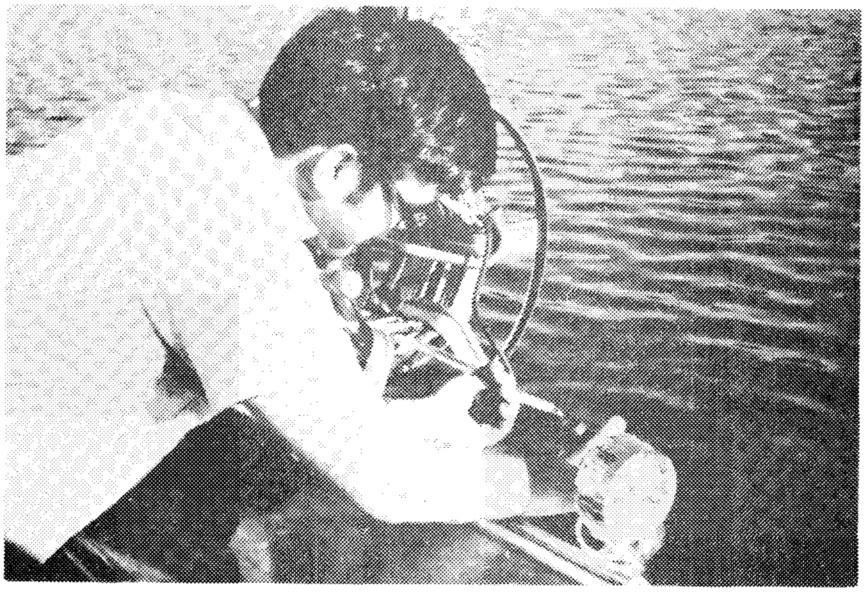


Figure 9(b). Utilizing the Continuous Pump Sampler to Collect a Water Sample (from a depth of 15 m) at the head of the Spokane River.

Total Phosphate - Phosphorous

Method II of APHA-Standard Methods (1971) was used in which H_2SO_4 and HNO_3 acids are used for preliminary digestion. The ascorbic acid method was then used to determine total phosphorus present.

Sulfate

The turbidimetric method by Rossum and Villarruz (1961) was used without adding $NaSO_4$ to the buffer (solution I). This method appears to be more sensitive at low concentrations (<10 mg/1) than the method suggested by APHA-Standard Methods (1971).

Sulfide

The reagents described by APHA-Standard Methods, 12th Ed. (1965) were utilized for the standard methylene blue method. The sample was pretreated in a BOD bottle as described in the cited reference. The floc was then suspended in 100 ml water and divided into two 50 ml portions. Two ml of 1+1 ml H_2SO_4 is added to one portion, 2.0 ml dilute amine solution is added to the other, then both mixed. Five drops $FeCl_3$ is added to each and well-mixed. After 15 minutes the sample was read in a DU-2 spectrophotometer at 670 mμ. The absorbence of the amine treated portion was measured using the other portion as reference to compensate for turbidity.

Ammonia - Nitrogen

The Phenate method was utilized (APHA-Standard Methods, 1971).

Kjeldahl - Nitrogen

Kjeldahl nitrogen was determined in accordance with methods described by APHA-Standard Methods (1971).

Biochemical Oxygen Demand

The procedures outlined by APHA-Standard Methods (1971) were followed. The bottles were submerged in 20 C water bath and incubated in a thermostatically controlled darkroom.

Chemical Oxygen Demand

These determinations were made in accordance with APHA-Standard Methods (1971) using the dichromate reflux method.

Hardness

Hardness was determined by the EDTA titrametric method outlined by APHA-Standard Methods (1971).

Iron

Procedures were followed as outlined by APHA-Standard Methods (1971) with the exception that acid pretreatment of samples was not made.

Neutron Activation Analysis

Neutron activation analysis was used to measure Fe, Co, Se, Hg, Cr, Rb, Cs, Th, Sb, Co, Zn, Sc, and Eu in sediment, water, and organism samples. The elements Al, V, and Mn were also measured in some sediment samples.

Sediments and tissues (≈1.0 gm) were freeze-dried under dust-free conditions. The samples were sealed into clean, high-purity polyethylene vials (2 drams) and irradiated with standard solutions of the elements of interest (prepared from Johnson-Matthey 'Specpure' materials). For the determination of Al, Mn, and V in sediment samples, the samples and standards were irradiated for 5 mins in the TRIGA-III type Research Reactor in a thermal neutron flux of 8×10^{12} n/cm^2 sec. For Fe, Co, Cr, Rb, Cs, Se, Hg, Th, Sb, Co, Zn, Sc, and Eu, an 8-hour irradiation in a neutron flux of 8×10^{12} n/cm^2 sec was used.

After irradiation, the samples were placed in concentrated HNO_3 for 4-8 hours to remove impurities adsorbed on the vial surfaces during immersion in the pool during irradiation. For Al, V, and Mn, the samples were counted 5-20 minutes after irradiation. For the other elements, a 4-6 week decay period was necessary. A high resolution Ge(Li) detector was used for γ-ray spectrometry of the irradiated samples. Gamma-ray spectra of samples and standards were recorded on magnetic tape and γ-ray peak areas calculated by the FOURIER program on the IBM 360/67 computer. Full details of the γ-ray spectrometry and elemental concentration calculations are given by Filby *et al.* (1970) and by Shah *et al.* (1970a, 1970b). Corrections were made for the elemental contents of the vials used in the irradiations.

Fish Tissue Analysis

Fishes were collected by personnel from Washington Water Power Company, the U.S. Bureau of Sport Fisheries and Wildlife, and Eastern Washington State College. The specimens were tagged, frozen, and delivered to the Sanitary Engineering laboratories at Washington State University. The fishes were unfrozen, weighed, measured, and then dissected with stainless steel knives under semi-sterile conditions. Portions of organs, such as the kidney, liver, fat, and fillet tissue, were freeze dried under dust-free conditions, weighed, and delivered to the Radiation Center for analysis. In certain instances, subsamples were oven dried (105 C), digested by distilled perchloric and nitric acids, and then analyzed by atomic absorption procedures.

Aquatic Invertebrates

These organisms were treated in the same manner as the fish specimens, with the exception that whole body analysis was made after a live holding period of up to 10 days--in order to clear the gut content.

Periphyton and Plant Specimen Analyses

Several aquatic plants were subjected to moderate sonification by a Branson Ultrasonic Sonifier Model LS 75 in an effort to remove adsorbed particles from their bodies. Up to 10 rinses with triple distilled water were made after each of two sonic treatments. In the case of the moss, *Amblystegium juratzkanum*, plates of artificially grown mosses (originally taken from the Spokane River) were cultured until new growth extended away from the plant body. They were clipped by stainless steel scissors and processed for neutron activation and atomic absorption analyses as previously described for tissue samples.

Sampling Sites

In order to assure proper handling in field preparation and laboratory analysis, different numbering systems were required in each operation. For example, Coeur d'Alene organisms and sediments taken by dredge were designated by a number and letter system such as 1-A, 1-B, 1-C (Chatcolet Lake stations); 2-A, 2-B, 2-C, 2-D (Harrison stations), etc. Lake water samples and productivity measurements were designated by simple consecutive numbering systems (1 to 12 and location). Coring samples were enumerated by an encircled number such as ① (off Coeur d'Alene River Delta), etc. The Spokane River samples were designated by river mile or location.

Locations of the sampling areas are shown in Figure 10(a) (Coeur d'Alene Lake benthic organisms), in Figure 10(b) (lake water and productivity sampling stations), in Figure 10(c) (lake core sampling stations), and in Figure 11 (Spokane River stations).

The Coeur d'Alene River stations were the same locations as those sampled by Mink et al. (1971). For comparative purposes Mink's station numbers are retained in this text. Figure 12 shows the stations that were sampled (9, 13, 17, 21, 23, 25, 28, and 34).

Sediment Analyses

Analysis of Sediment Core Samples

Five sediment cores were taken along an east-southwest transect across the Coeur d'Alene River Delta and the adjacent lake (Figure 10c) to obtain materials for analysis of metallic constituents.

The core samples were collected with a Ewing type piston corer (Gemware) weighing 330 kg (150 lb). The coring device was mounted on the WSU Sanitary Engineering pontoon barge shown in Figures 13, 14, 15, and 16. Cellulose acetate liners--1.83 m (6 ft) long with a 3.5 cm inner diameter--were inserted into the coring tube to retain the sediments.

After the cores were obtained, the cored samples and plastic liners were cut into 10 cm lengths and stored at 4 C until analyzed. All samples except those portions used for pH and neutron activation were dried for

MACROBENTHIC SAMPLING STATIONS

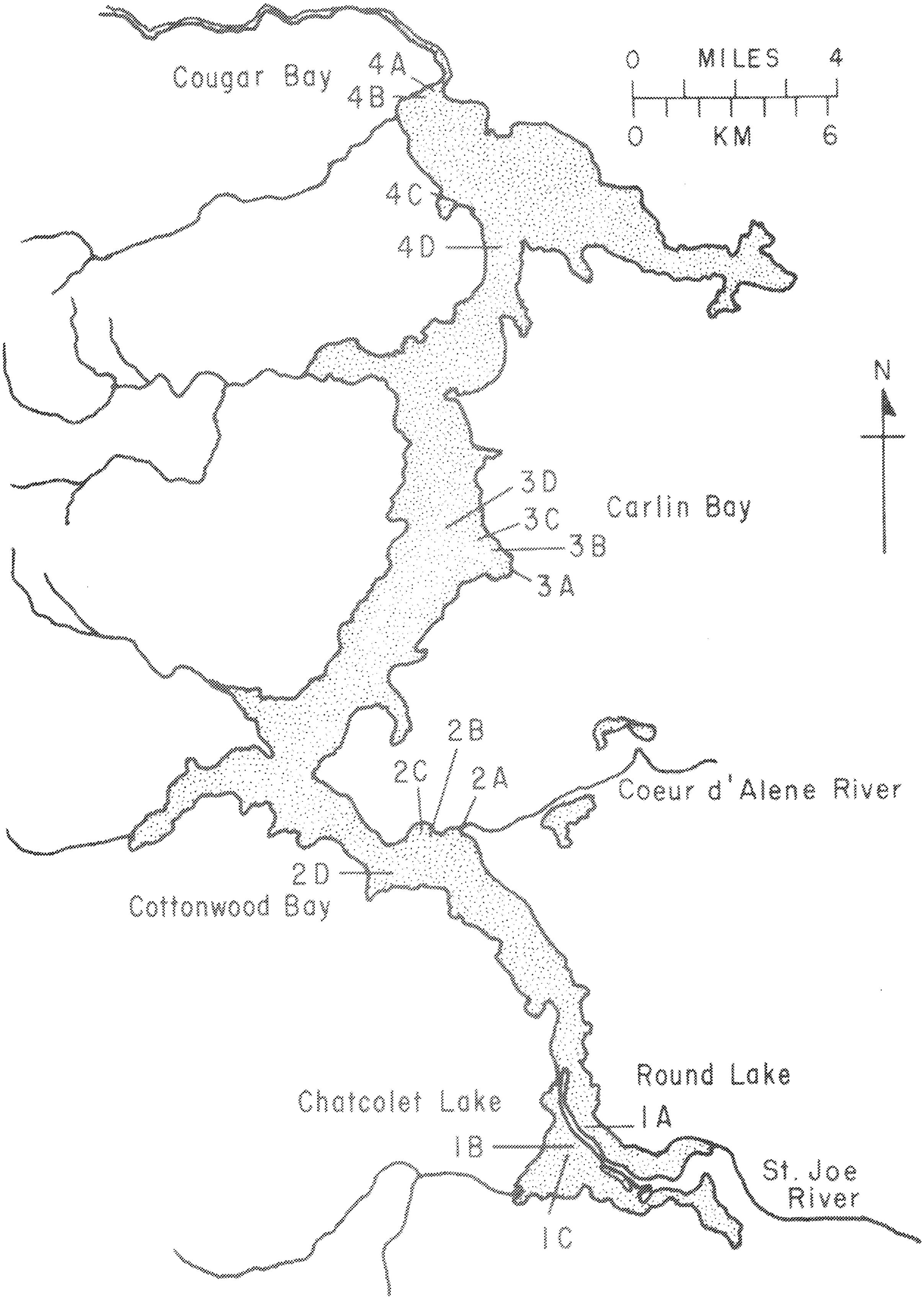


Figure 10(a) Coeur d'Alene Lake and Station Locations (Winner, 1972.)

WATER QUALITY AND PRODUCTIVITY STATIONS

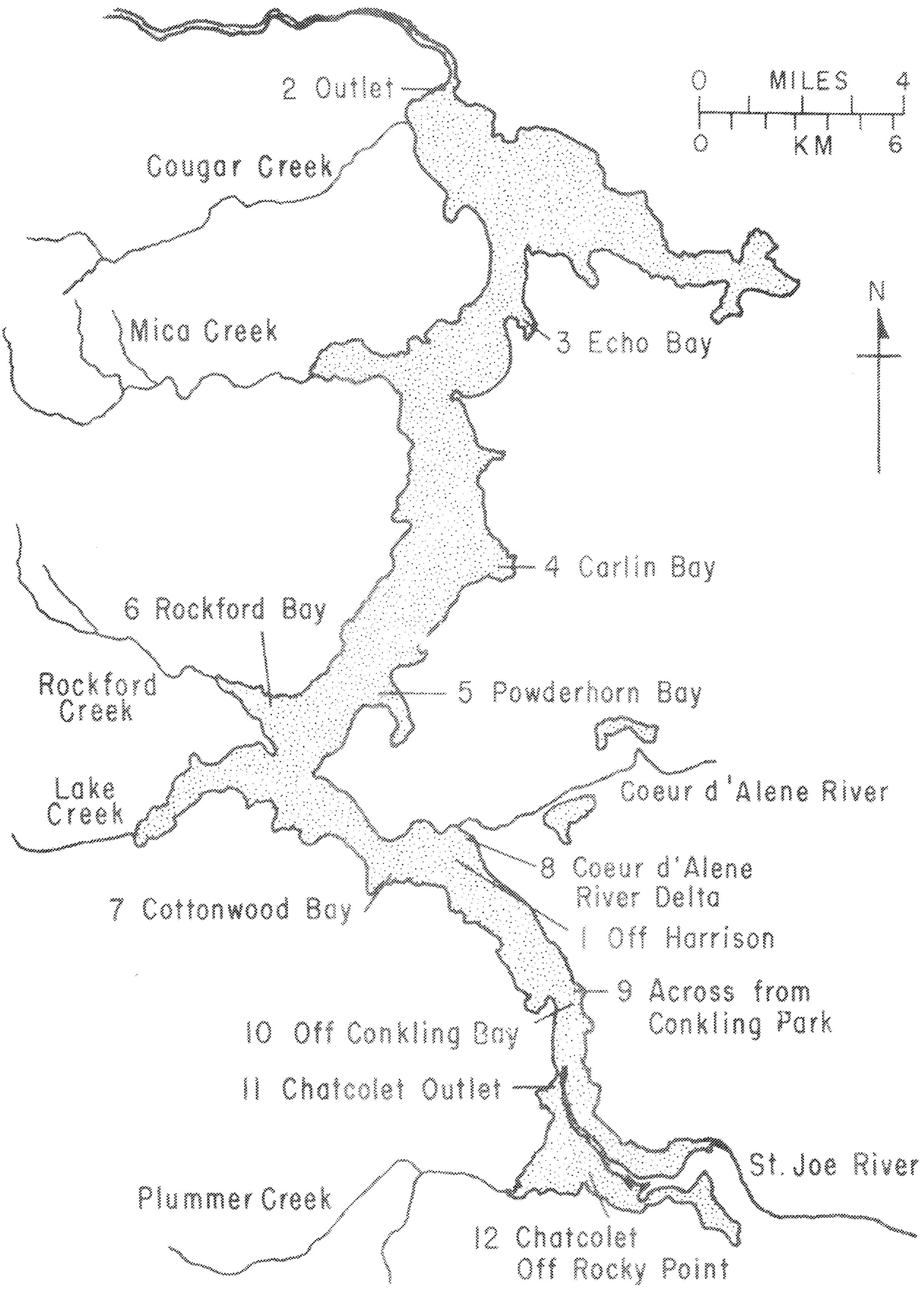


Figure 10(b) Coeur d'Alene Lake and Station Locations (Parker, 1972.)

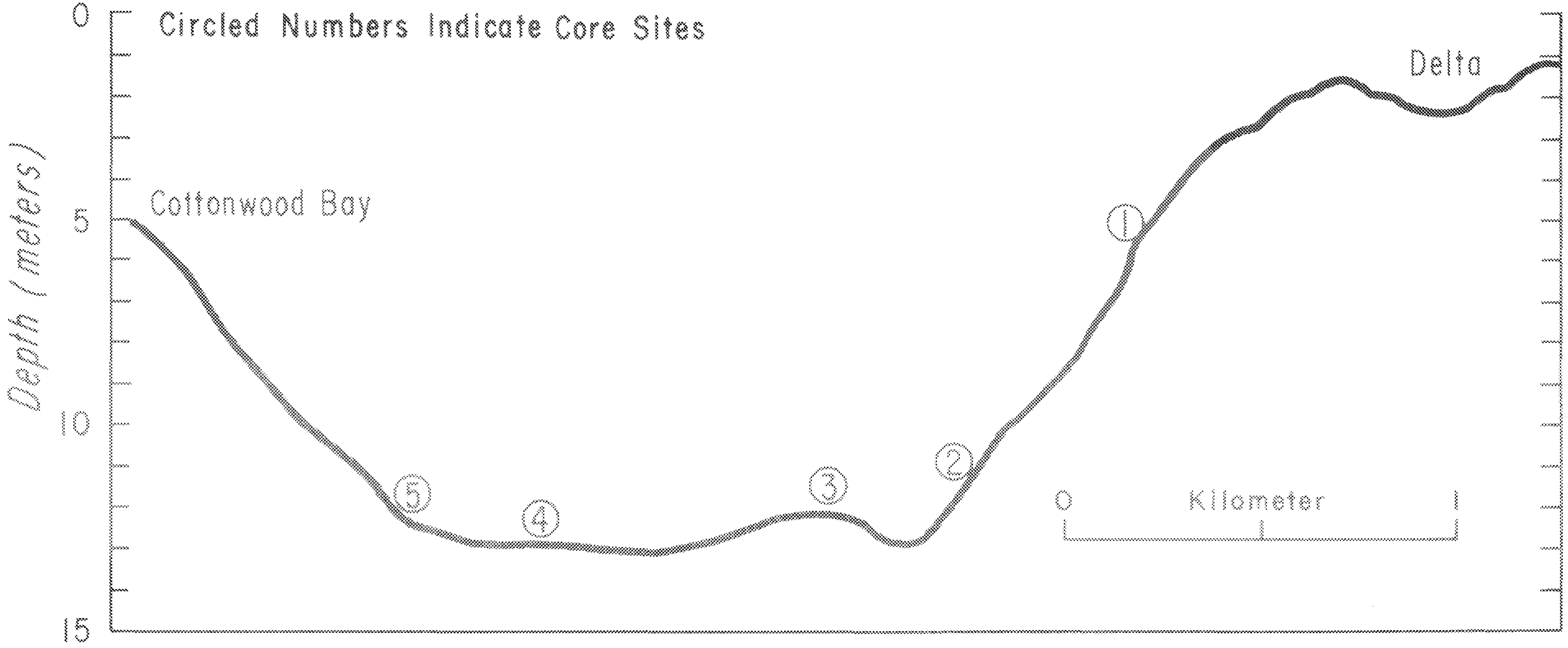


Figure 10(c). Core Sampling Stations from Coeur d'Alene River Delta to Cottonwood Bay. (Dunigan, 1972.)

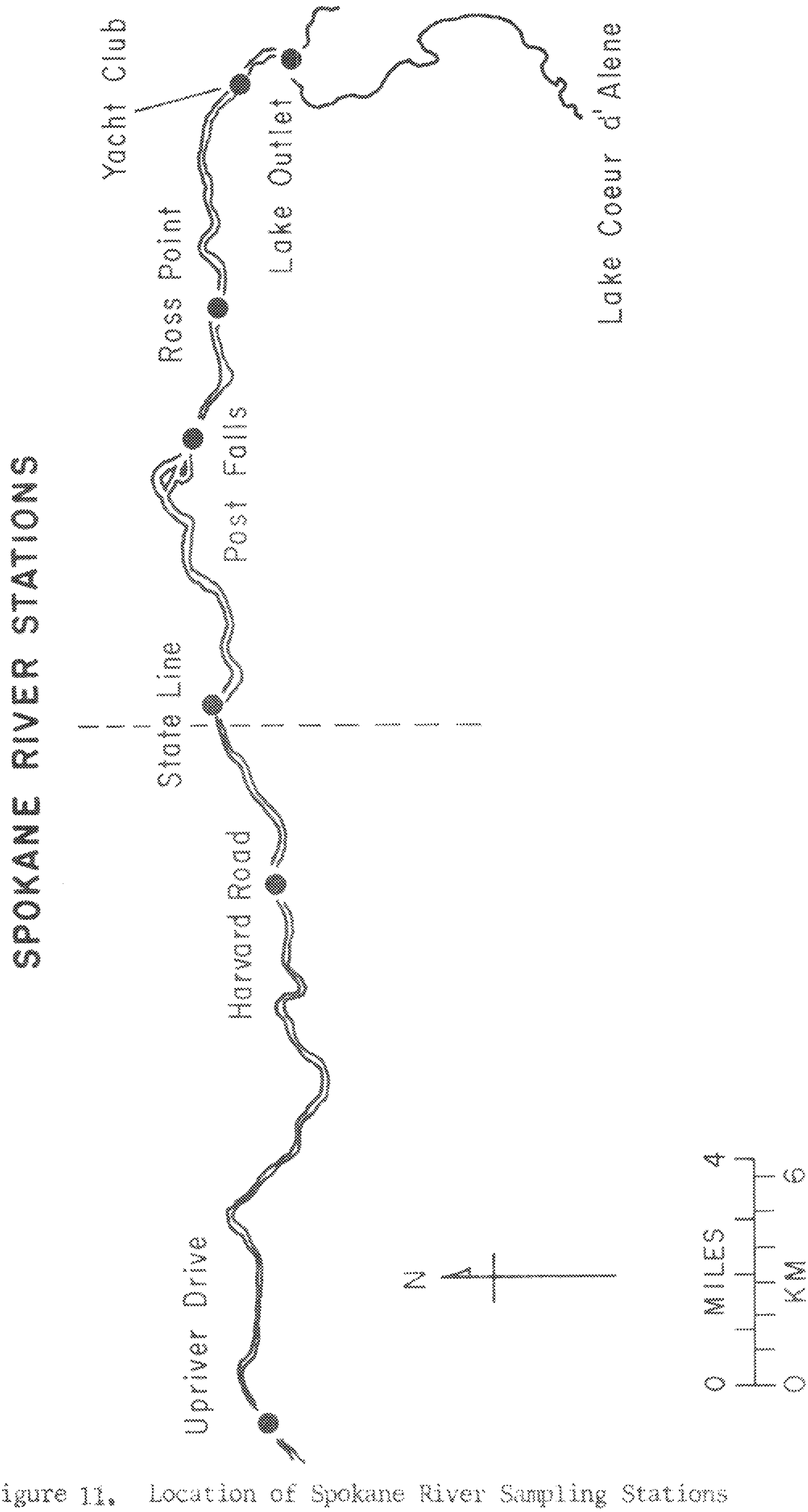


Figure 11. Location of Spokane River Sampling Stations

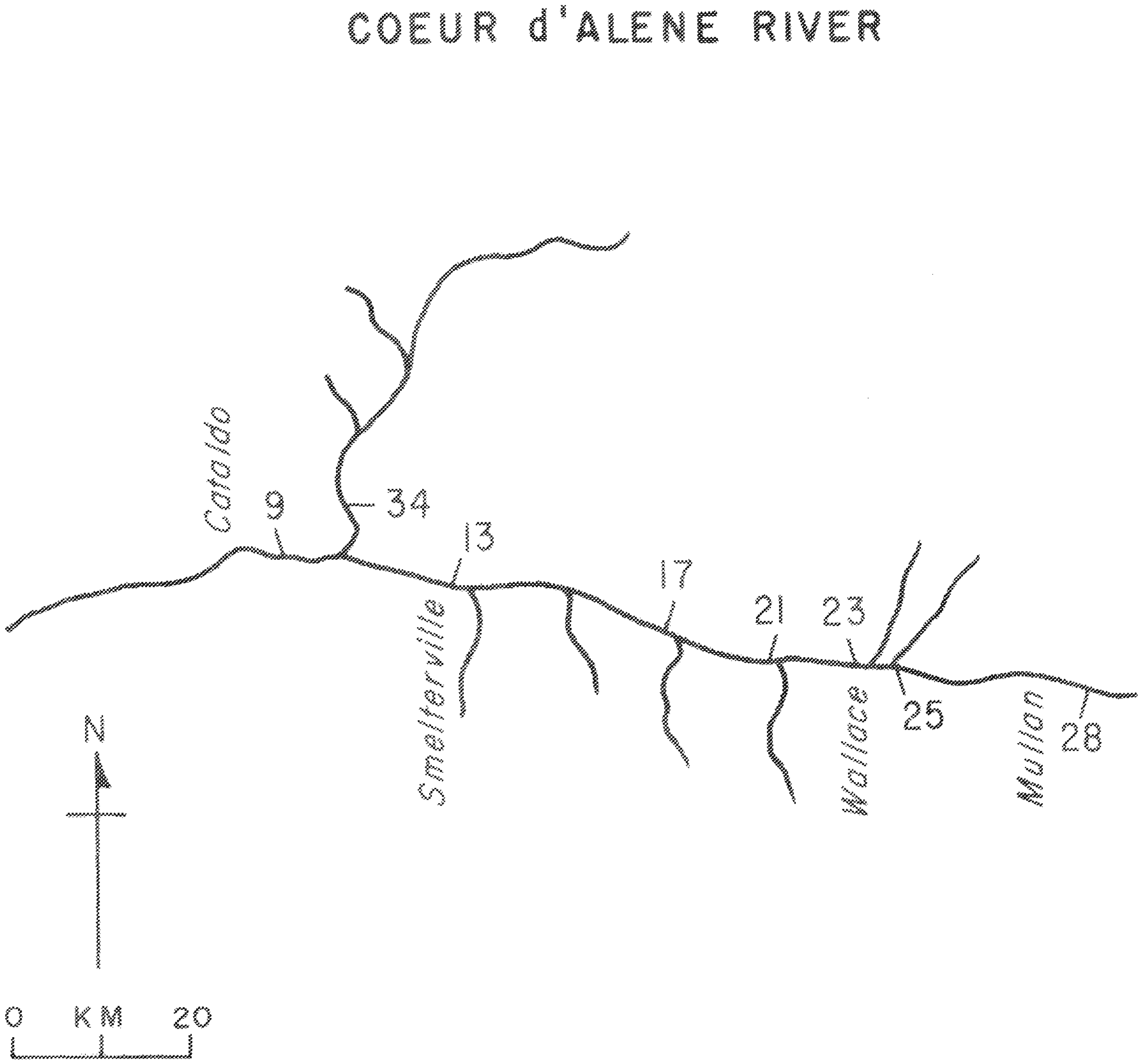


Figure 12. Coeur d'Alene River Stations Where Benthic Samples were Gathered. (Numbering system corresponds with that of Mink, 1971, for comparative purposes.)

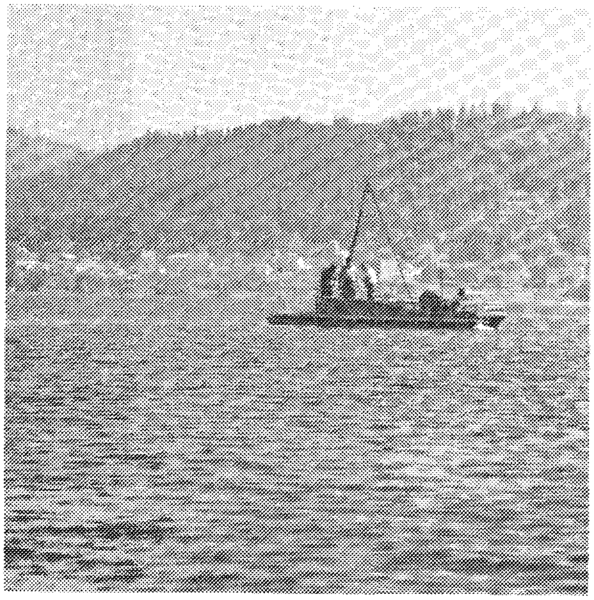


Figure 13. Assemblying the Coring Derrick.

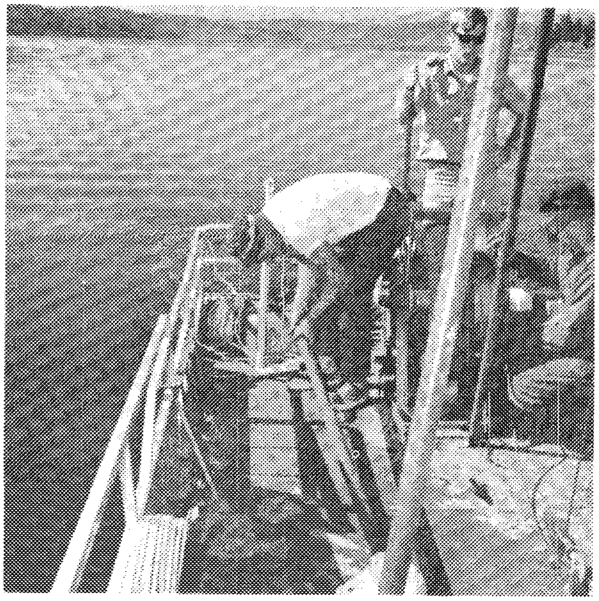


Figure 14. Assembly of the Coring Tube and Cutting Bit. Arrow Indicates Trap Door Through Which Piston Corer is Dropped.

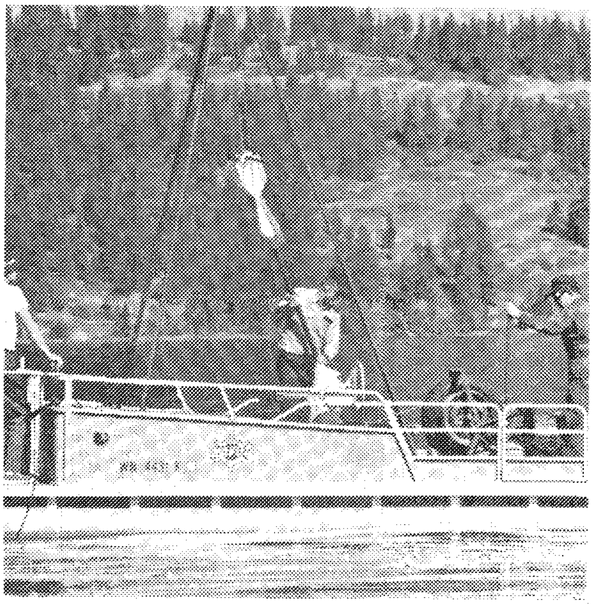


Figure 15. Raising the Coring Assembly Before Dropping Through the Trap Door.

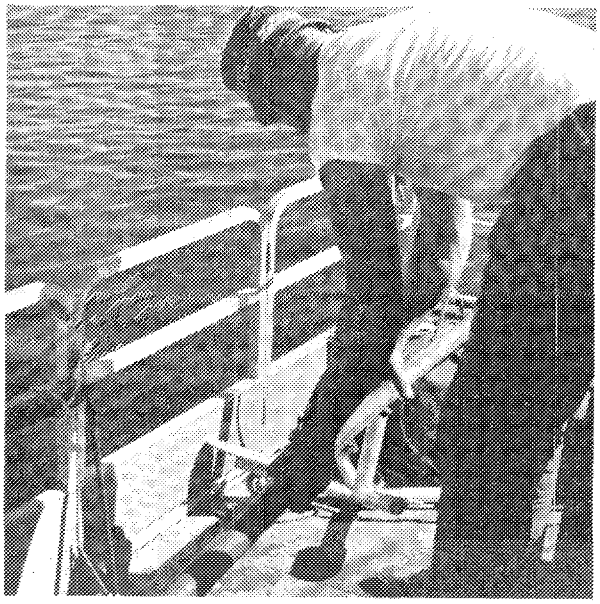


Figure 16. Extracting Sediment Core from Coring Tube.

24 hours in a 105 C oven. The samples used in neutron activation analysis were dried in a 35 C oven or freeze-dried. The pH was determined on undried samples at water saturation percentage. Prepared samples were analyzed with a Beckman Model 76 pH meter. Percent water content was determined by weighing before and after drying in a 105 C oven for 24 hours.

Dried core sediment samples (.5 gm) were digested according to procedures outlined in APHA-Standard Methods (1971) and the resulting extract analyzed for total phosphorous as orthophosphate, and for arsenate. Orthophosphates were analyzed by the Vanadomolybdophosphoric Yellow Color Method described by Jackson (1958). This method was chosen as the least sensitive to high metal concentrations. Subsamples from the total phosphorous digestion were analyzed for arsenate using a modification of the ascorbic acid reduced molybdate blue phosphate procedure described in Standard Methods (1971) and the reducing technique developed by Johnson (1971). A Beckman Model B spectrophotometer was used to determine absorbence of each prepared sample and the concentration in mg/kg of sediment was calculated.

Total carbon was determined using a LECO 521 - 300 high-temperature induction furnace with a preweighed CO_2 absorption bulb as in Allison *et al.* (1965). Total carbon was calculated from the increase in the weight of the CO_2 absorption bulb.

Neutron activation analysis was used to search for the following elements: aluminum (Al), antimony (Sb), cesium (Cs), cobalt (Co), chromium (Cr), iron (Fe), manganese (Mn), nickel (Mi), rubidium (Rb), scandium (Sc), selenium (Se), silver (Ag), vanadium (V), and zinc (Zn). A Perkin-Elmer Model 303 atomic absorption spectrophotometer was used to detect copper (Cu), cadmium (Cd), lead (Pb), magnesium (Mg), molybdenum (Mo), nickel (Ni), and zinc (Zn).

Sediment samples were prepared for determination of clay mineralogy following the procedure of Kittrick and Hope (1963) and were analyzed at the Washington State University Soils Mineralogy Laboratory by X-ray diffraction.

Diatom Analysis of Sediment Cores

Portions of two of the core sediment samples previously taken were also selected for diatom analysis; one from a mid-delta core (2) and the other from a point 328 m (300 yds) off the west shore of the lake, core (5). Both cores were taken from a water depth of 18.3 m (60 ft). Subsamples were taken vertically from the nonsmeared inner portion of the core. A 7 mm diameter cork borer was used to obtain 1.0 cm long plugs at the surface, at 2 cm, at 5 cm, and at every 10 cm thereafter for the remaining length of the core.

Each sample (approximately 1 gm wet weight) was prepared by boiling in a 1:1 solution of distilled water and nitric acid in a 50 ml beaker. When the solution reached half volume, a small amount of potassium dichromate was added for final oxidation and the solution allowed to cool. The beaker was repeatedly decanted, rinsed in distilled water, and allowed to resettle until the orange dichromate color disappeared and all traces of the acid were removed.

The cleared sample was resuspended in 80 mls of distilled water from which two drops were removed with a dropper and placed on a 22 x 60 mm coverslip. The diatoms were dispersed by flooding the coverslip with distilled water. After drying under a lamp and desiccation over a hot plate, the coverslip was permanently mounted on a glass slide using Hydrax mounting medium (refractive index, 1.65).

Two slides were prepared for each sample. Random transects were taken under high power (600X) and oil immersion (1,000X) until approximately 500-1,000 valves (250-500 diatoms) had been counted. Species identification was based on Wolle (1890), Patrick and Reimer (1966), Hustedt (1930), and Vanlandingham (1970).

Sediment Samples for Lake Benthos Study

Samples for organic content and heavy metal analysis were carefully collected with an Eckman dredge to minimize disturbance of the substrate surface. Sediment from the top 3 cm was placed in sample bottles and stored under ice. Upon return to the laboratory at the University of Idaho, samples were homogenized by stirring with a glass rod before subsamples were extracted for analysis. The organic carbon content was estimated by drying approximately 12 g of wet sediment to a constant weight and measuring the weight loss after ashing at 550 C.

The metal analysis on the sediments collected in September was performed by neutron activation techniques at the Radiation Center at Washington State University. Analysis of the samples collected in March 1972, was performed by atomic absorption in the Sanitary Engineering laboratory at WSU.

Biological Analyses

Lake Phytoplankton

Phytoplankton determinations were made by collecting a 500 ml sample of mixed test water from the top 4 m at each station. Each sample was then centrifuged at 15,000 rpm, the concentrate was diluted to 10 ml, and a 1 ml subsample was pipetted into a Sedgwick-Rafter cell for counting and identification under a microscope equipped with a Whipple disc. This method is similar to that described by APHA-Standard Methods (1971). Calibration was made by the methods of Jackson and Williams (1962). Counts were expressed as cells/ml. Standard five-cell lenghts of filamentous algal forms were counted as 1 unit/ml.

In situ ^{14}C phytoplankton production measurements were made at station 1 (Figure 17 shows ^{14}C field equipment). Replicate light and dark bottles were filled with water from depths of 0.5, 1, 2, 3, 5, 7, 9 and 12 meters. Each bottle was injected with 1 ml of a standardized 3-5 microcurie/ml (μCi/ml) solution of $NaH^{14}CO_3$, suspended from buoys by the apparatus shown in Figure 17 at the selected depths, and incubated for 4 hours from 10:00 to 14:00 hours. A 200 ml subsample from each bottle was prepared and counts/min determined using a Packard liquid scintillation spectrometer. Corrections were made for instrument efficiency and background radiation. Carbon fixation mgC/m^3) was calculated as described in APHA-Standard Methods (1971). Areal production estimates were calculated and corrected to whole day production rates.

On the second day of each lake sampling trip, water was collected from each of the 12 stations for the experimental assessment of carbon fixation measured under controlled conditions in a culturing tank. A mixed haul of water from the top 4 meters at each station was used to fill replicate light and dark bottles. After injection with the same standardized ^{14}C

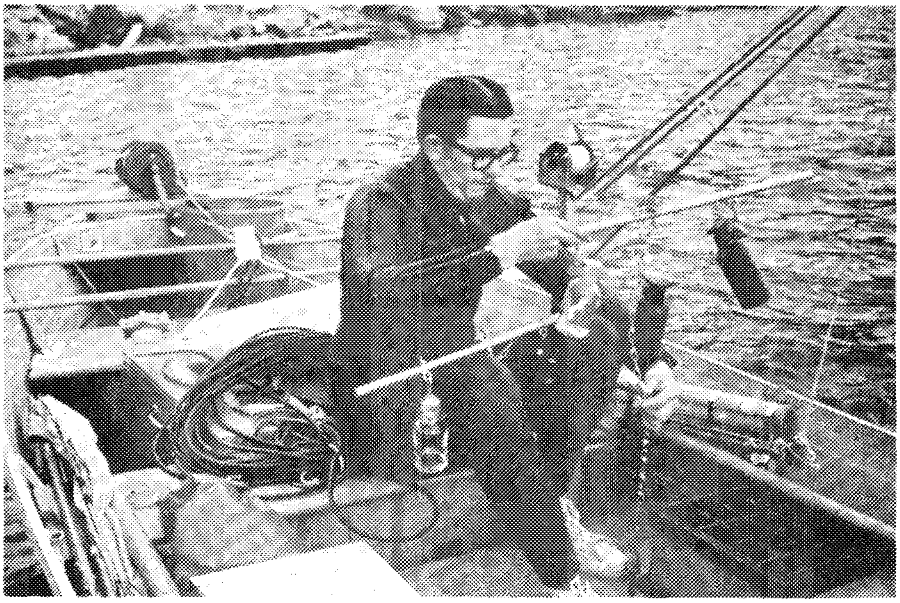


Figure 17. University of Idaho Researcher Setting Out Light and Dark Bottles for Carbon 14 Productivity Studies.

solution as used for in situ experiments, the bottles were incubated underwater in a 300 gallon tank at a light intensity of 4305 Lux (≈400 fc) at 18 C ± 1 C for 4 hours. After 4 hours, a 200 ml subsample from each bottle was prepared, counted, and corrected. Carbon fixation data are presented as mgC/m^3/4-hr incubation period.

Spokane River Phytoplankton

River algae were collected, identified, and counted in the same manner as that described for the lake phytoplankton.

Benthos

Benthic samples were collected in the lake with a 15.24 by 15.24 cm standard Eckman dredge at all stations, except 4A and 4B in Cougar Bay, where a Peterson dredge was used. Samples were not accepted unless a complete square at least 3 cm deep was obtained. To prevent loss of organisms, a standard 30-mesh sieve was placed under the dredge before lifting it from the water. The samples were strained through the sieve and preserved in 70% isopropyl alcohol. The collection and sieving equipment is shown in Figure 18. Organisms were separated from the debris under a dissecting microscope at the University of Idaho laboratories. Counts were multiplied by 43 and reported as numbers/m^2.

Chironomid larvae were soaked for 24 hours in 9% KOH, rinsed for 2 hours in distilled water, transferred to absolute alcohol for 1 hour, and mounted on a slide, ventral side up, in Euparal (GBI Labs Limited, Dendon, England). Light pressure on the coverslip helped expose parts necessary for microscopic identification. Keys by Mason (1968) and Johannsen (1937) were used to identify Chironomidae and Ceratopagonidae; by Usinger (1968) for Trichoptera, Ephemeroptera, Odonata, and Coleoptera; and by Pennak (1953) for Hirundinea and miscellaneous organisms.

A Surber square-foot sampler (Figure 19) was used to collect benthic organisms in the Coeur d'Alene River, which were then placed in isopropyl alcohol and later identified and enumerated with the aid of a binocular microscope. The Shannon index of diversity was used to summarize species and total counts (Margalef, 1957):

$$\bar{d} = - \Sigma n_i/N \log_2 n_i/N$$

where n_i is the number of individuals of each species in a sample and N is the total number of organisms in the sample.

Benthic organisms were collected by collection nets and screens from the two Spokane River stations (shown in Figure 11 Ross Point and Upriver Drive). Random sites of 1 sq m were dislodged to a depth of 3 cm, the organisms collected, and immediately transported to the WSU laboratory. In the laboratory, the organisms were held in trays filled with filtered river water at river water temperatures for up to 10 days in order to clear the gut contents. This procedure was carried out prior to whole body neutron and atomic absorption analysis. Selected individuals were preserved in isopropyl alcohol for later identification.

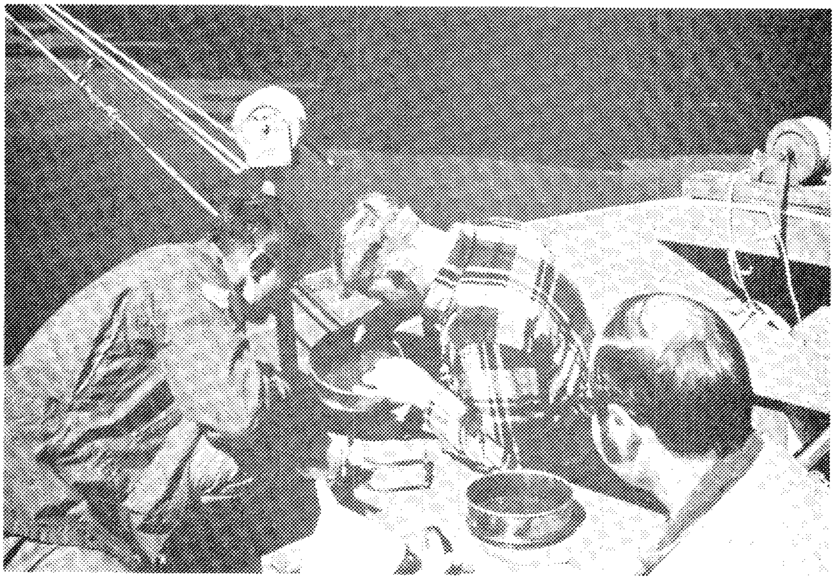


Figure 18. Combined Crews from the University of Idaho and Washington State University Collecting and Sieving Benthos Organisms at Coeur d'Alene Lake.

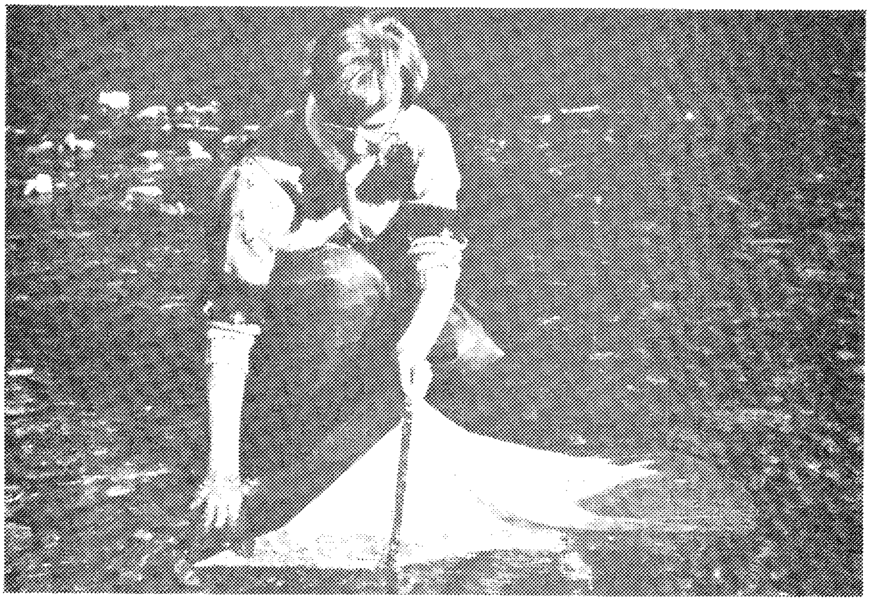


Figure 19. University of Idaho Researcher Gathers Benthos Organisms from the Coeur d'Alene River with a Surber Sampler.

Bacteriological Methods

Indicator bacteria of water quality significance were monitored at the stations along the Spokane River. The procedures for total coliforms, fecal coliforms, and fecal streptococci were carried out in accordance with procedures outlined in APHA-Standard Methods (1971).

Laboratory Algal Culture for Toxicity Studies

The growth and maintenance of algal cultures followed the procedures outlined in the EPA Algal Assay Procedures; Bottle Test (1971). The chemical, physical, and biological parameters were slightly modified, as described below, to attain two objectives: (1) to test the toxicity to algae of several of the more abundant heavy metals in the Coeur d'Alene drainage system and (2) to check the adaptability of the AAP test organism, Selenastrum capricornutum, for heavy metal toxicity tests.

The alkalinity and pH of the synthetic medium were monitored. The pH of day-old medium was 7.1-7.2; heavy metal additions up to 700 μg/l did not lower the pH below 6.8. The alkalinity was 8.2 mg/l, and the total hardness was 14.97 mg/l as $CaCO_3$.

Waters of the Coeur d'Alene River system were filtered through HA 0.45 μ Millipore filters and stored at 4 C in polyethylene bottles. Macronutrient additions were made to this water from stock solutions. Analyses were made for Cu, Zn, and Cd, using a Perkin-Elmer Model 303 atomic absorption spectrophotometer.

Stock cultures of Selenastrum capricornutum obtained from the National Environmental Research Center, Corvallis, Oregon, were maintained at 20 C under "Cool White" fluorescent light. Inoculum cultures were prepared from stock cultures and incubated four to five days at 24 C (± 0.2 C).

The method of algicidal concentration determination suggested by Fitzgerald and Faust (1963) was used. Triplicate flasks containing 50 ml of medium spiked with heavy metals as $ZnCl_2$, $CuCl_2$, or $CdCl_2 \cdot 2\frac{1}{2}H_2O$ were inoculated with 1 ml of inoculum culture and incubated seven days. The cells were then centrifuged, washed, and reinoculated into stock medium. If growth was measured at the end of the seven day incubation period, a positive test was indicated. The concentrations of Cu, Zn, and Cd were increased in 50 μg increments until negative results were observed. A control medium was simultaneously incubated.

RESULTS AND DISCUSSION

I. Coeur d'Alene Lake

A. Algae Production and Lake Trophy

Physicochemical Conditions

Important variations among the specific physicochemical parameters examined were observed at the 12 lake sampling stations. [Figure 10(b)]

Temperatures were relatively uniform for the deep water stations during most of the year. The shallower waters in the southern end of the lake appeared to warm earlier, however. As a result, a shift from diatom to blue-green algal forms appeared during July in the southern end but did not occur until August in the northern portions of the lake. [Patrick (1971) has demonstrated a similar shift by artificially raising water temperatures.] Thermal stratification was observed from lake June until mid-October when overturn took place, producing homothermous conditions.

Standard Secchi Disc transparency values ranged from 2-4.5 m. At no time during the study period did transparency severely limit production. The southern end of the lake, however, did exhibit lower transparency values and frequently appeared to be more turbid than the northern portions of the lake. Stream runoff caused extremely turbid conditions in Chatcolet Lake during a high-flow period late in February 1972.

Photometer readings of light intensity were used to calculate foot-candles of intensity at the various depths. The surface radiation was reduced to 1% at approximately 10 m. This depth closely approximated the depth of the euphotic zone where light bottle carbon fixation equaled dark bottle fixation.

The mean and range of selected chemical parameters for each station are presented in Table 1. Highest conductivity measurements were recorded at the mouth of the Coeur d'Alene River and were generally in excess of 100 μ mhos. Dissolved oxygen ranged from 4-10 mg/l during the study period. In July 1970, however, Minter (1971) recorded a value of less than 1 mg/l off

Table 1. Mean and range of specific conductance, dissolved oxygen, available carbon, and range of pH for each station (July-November, 1971). (Parker, 1972.)

Station	Specific Conductance (Micromhos)	Dissolved Oxygen (mg/l)	Available Carbon (mg/l)	pH
1	50 (<50- 75)	7.5 (4 -10)	8.2 (7.3- 9)	(6.8-7.4)
2	50 (<50- 75)	7.5 (6 - 9)	7.0 (6 - 8.4)	(6.7-7.5)
3	50 (<50- 75)	8.0 (6.5- 9)	6.6 (5.9- 7.4)	(6.9-7.7)
4	50 (<50- 75)	8.0 (6.5-10)	7.2 (6.2- 8.4)	(6.9-7.5)
5	55 (<50- 95)	8.0 (6.5-10)	7.2 (6.2- 8)	(6.9-7.4)
6	60 (<50-100)	7.5 (4 -10)	7.6 (6.1- 9.3)	(6.9-7.5)
7	60 (<50-100)	8.0 (6.5-10)	6.8 (6 - 7.5)	(7.0-7.5)
8	65 (<50-100)	7.0 (4 - 9)	7.8 (6.7- 8.7)	(7.0-7.7)
9	55 (<50- 75)	8.0 (5 -10)	8.8 (8.2- 9.9)	(6.8-7.8)
10	55 (<50- 75)	8.5 (4 -10)	8.8 (7 - 9.3)	(6.9-7.5)
11	60 (<50- 95)	8.0 (4 - 9)	9.3 (7.5-10)	(6.8-7.8)
12	60 (<50-100)	7.5 (5.5- 9)	9.0 (6.7-10)	(6.8-7.9)

the Coeur d'Alene River delta (near station 8) in 12 m of water, indicating that DO depletion can occur. On occasion, other shallow areas such as Chatcolet Lake also exhibited low DO content (2-4 mg/l) during late summer periods (Funk and Bennett, 1972).

Station averages of methyl orange alkalinity, orthophosphate-phosphorus (O-PO_4), and nitrate-nitrogen (NO_3-N) are presented in Figure 20. It is important to observe the NO_3-N and O-PO_4 data in relation to general averages for these two nutrients in unpolluted fresh water systems. Reid (1961) lists world averages of NO_3-N for fresh water as .30 mg/l and .01-.03 mg/l O-PO_4 for most lakes. The overall averages for Coeur d'Alene Lake were .177 mg/l NO_3-N and .01 mg/l O-PO_4 which are slightly lower than those presented above. However, averages calculated for the southern portions of the lake were .21 mg/l NO_3-N and .51 mg/l O-PO_4; 25 times the average PO_4 levels given by Reid. The shallower depths and smaller volume of the southern area of the lake appears to allow more rapid turnover of the PO_4 than the deeper and larger volume of water in the northern sections--which may act as a semi-permanent sink for available dissolved PO_4 (Odum, 1971).

Community Structure

Dense communities of Potamogeton, Meriophyllum, and Anacharis grow annually in the shallow areas (less than 4 m) of Chatcolet, Round, and Benewah Lakes. A combination of high nutrient levels, deep light penetration, and silted substrate provides a very suitable habitat for the growth of these rooted aquatic plants. The lowest concentrations of planktonic algae were observed within this area. Kofoid (1903), Pond (1905), and Hasler and Jones (1949) have suggested that macrophytes are either better competitors for nutrients than phytoplankton or that some antagonistic mechanism or substance tends to limit phytoplankton development in waters abundantly inhabited by them.

As one proceeds north in the lake, deeper water with rocky shores, and presumably less suitable substrate, preclude the growth of macrophytes. In these areas, well-developed communities of algae replace the macrophytes. Another phenomenon also occurs in the area north of the mouth of the Coeur d'Alene River. In this region high concentrations of nitrates and phosphates

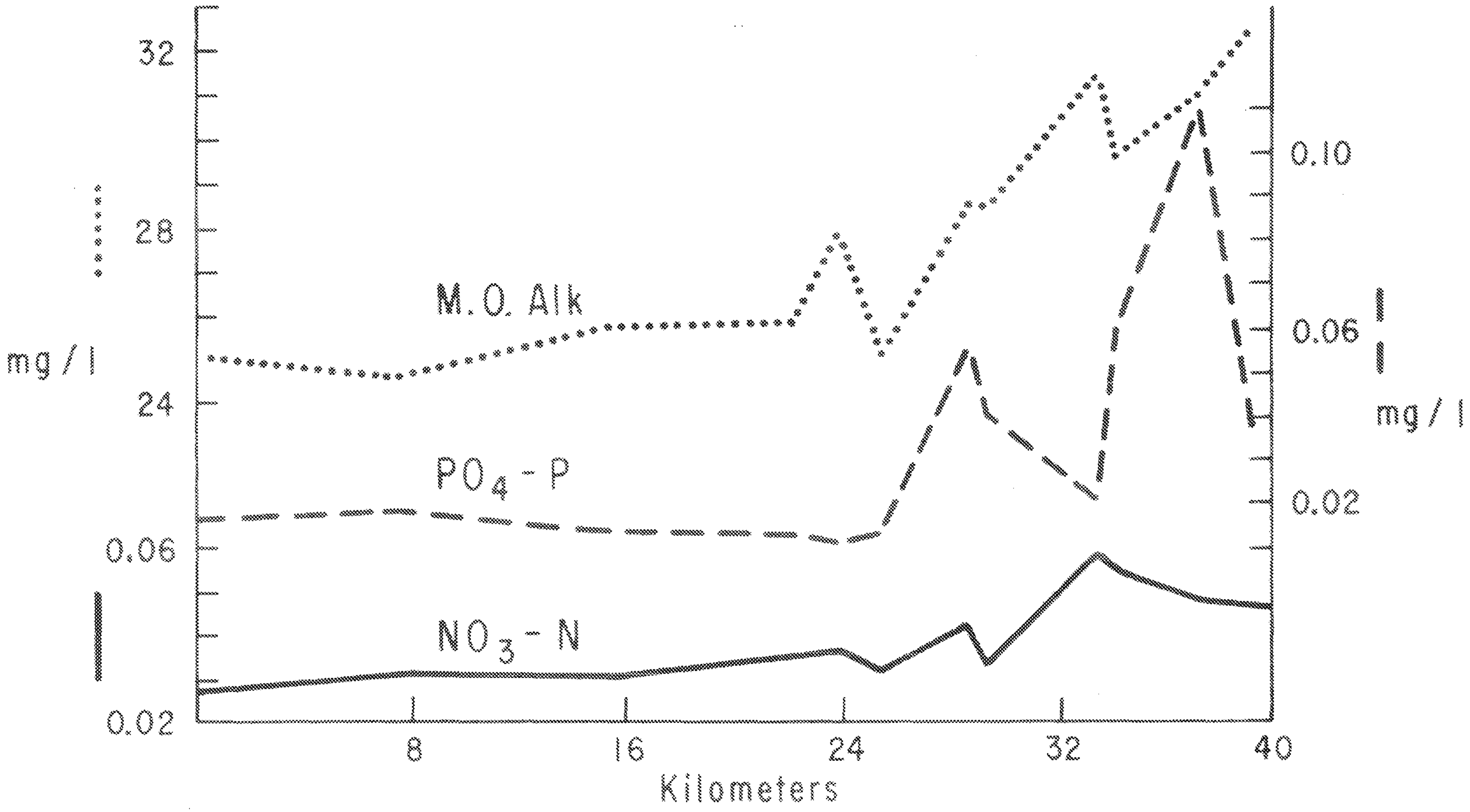


Figure 20. Station Means of Methyl Orange Alkalinity, PO_4-P, and NO_3-N. July-November, 1971. Distance Measured From North End of Coeur d'Alene Lake. (Parker, 1972.)

rapidly decline, along with the simultaneous reduction in phytoplankton abundance and carbon fixation rates. The exact location of this region is not known and probably varies with river flow, silt load, and other physicochemical factors. Reduced nutrient conditions prevail for all stations from this point to the Spokane River outlet.

Numerically, the most abundant phytoplankton in the lake were the yellow-green algae (Chrysophyta), which made up 80% of the cells counted. Of these cells, the most abundant subgroup were the Bacillariophyceae or true diatoms: Melosira accounted for 42%; Tabellaria with 33%; and Asterionella with 13% of the total number of cells counted from July-November. Other Chrysophta frequently observed were Tribonema and Dinobryon. These species made up 15% of the community. Maximum numbers of diatoms were reached at station 10 in November when Melosira was present at 1,154 cells/ml.

Least squares analysis of variance was used to test for differences in distribution of diatoms. Sampling dates were found to be significantly different at the 1% probability level. Tukey's mean separation procedure (Mendenhall, 1968) revealed that diatom counts were significantly lower in August and significantly higher in November. Although variations in counts among individual stations were found not significant, differences were observed when groups of stations were considered. The northern and southernmost group of stations had lower diatom concentrations, while the group of stations in the middle portion of the lake had the highest concentrations (Figure 21).

Green algae (Division-Chlorophyta) made up 10% of all the algae samples evaluated. Open water genera were the nonfilamentous varieties and included Phacotus, Chlamydomonas, Ankistrodesmus, Genicullaria, Chlorella, and assorted desmids. Many filamentous varieties were observed as periphyton in the littoral zone. Mean and standard error counts of planktonic green algae cells/ml are presented in Figure 22, which illustrates variations between stations.

The numbers of most genera were significantly reduced during colder water conditions in November. An October maximum showed a total of 256 cells/ml. Green algae cell counts were very low in August when the

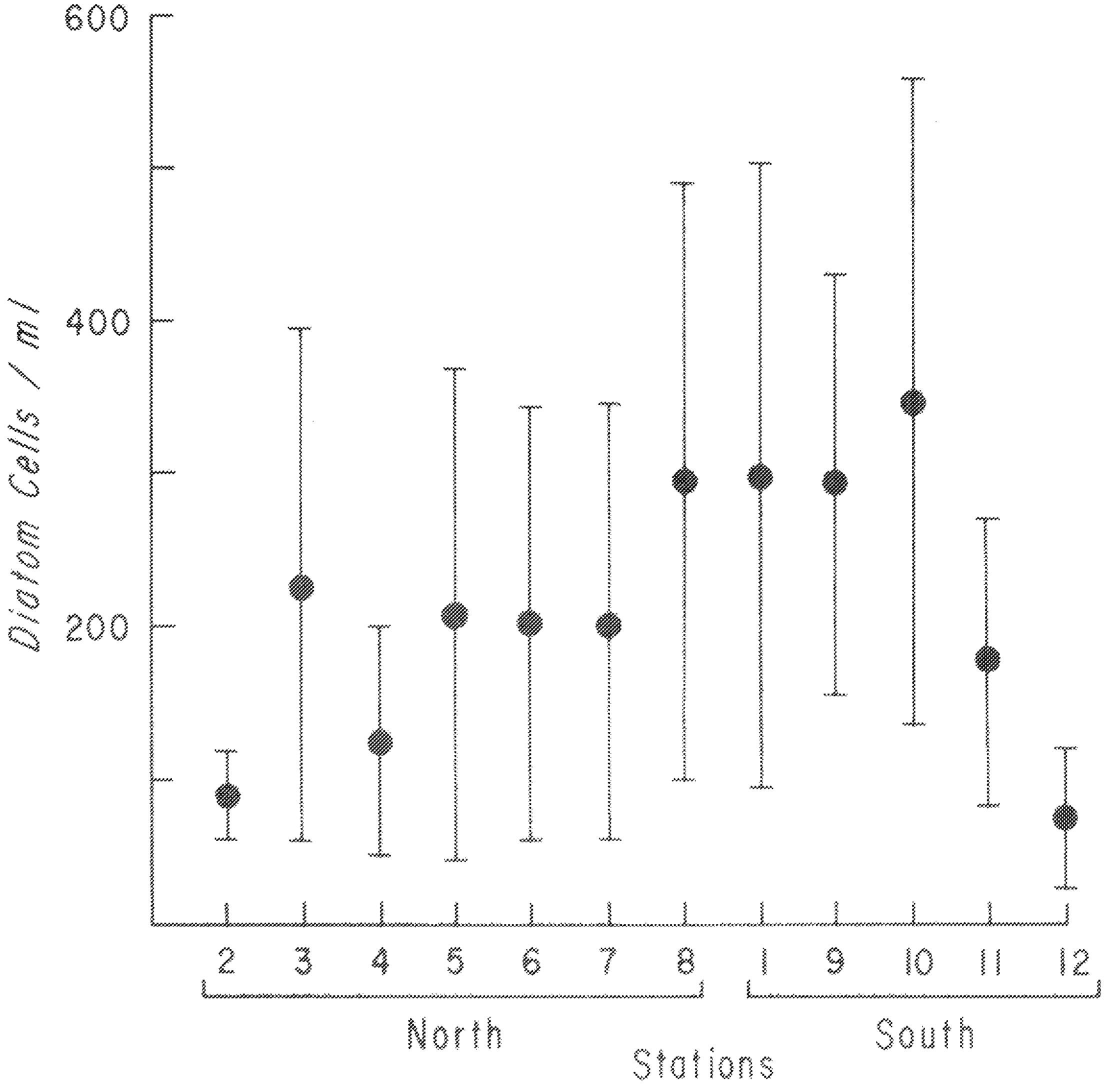


Figure 21. Mean and Standard Error of Diatom cells/ml for each Station. Shown on a North-South Gradient. July-November, 1971. (Parker, 1972.)

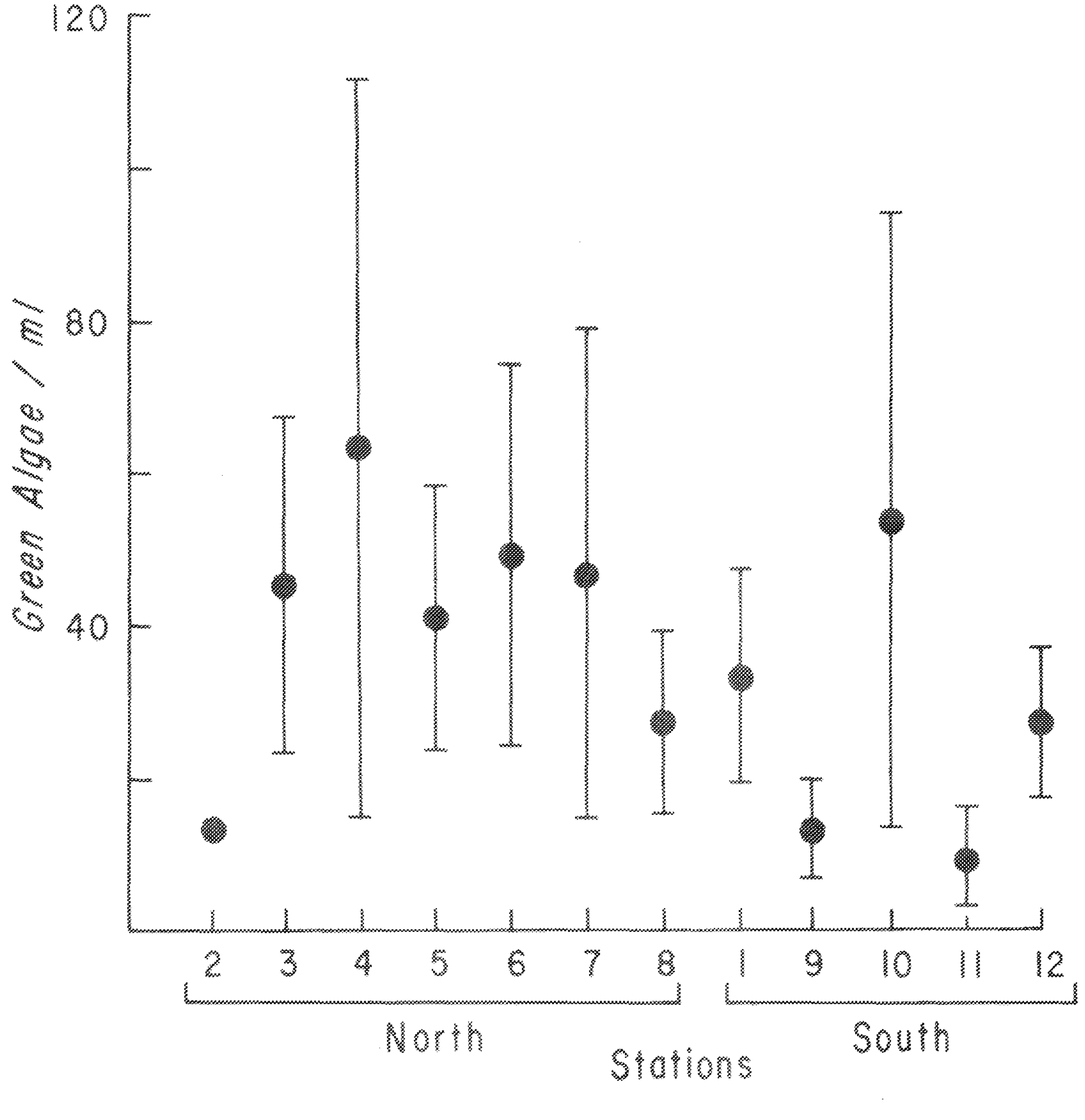


Figure 22. Mean and Standard Error of Green Algae cells/ml for Each Station. Shown on a North-South Gradient. July-November, 1971.(Parker, 1972.)

phytoplankton community was dominated by blue-green algae. Blue-green algae (Division-Cyanophyta) made up 10% of all cells collected. Planktonic blue-green algae included mostly *Aphanizomenon* with some *Nostoc* and *Anabaena* filaments present. A maximum concentration of 488 standard units/ml of *Aphanizomenon flos-aquae* occurred in August at station 5. Blue-green algae dominated the phytoplankton community throughout the August period of higher water temperatures. (Few blue-green algae were observed during the fall or winter months.)

Primary Productivity

Primary productivity measurements and estimates of carbon fixation were chosen as the basic tools to assess variations in productivity among the stations. *In situ* productivity measurements were used to construct production-depth profiles at station 1 during the sampling period. All sampling dates showed a similar type curve with a distinct maximum in the upper strata of the euphotic zone, followed by a rapid reduction in productivity rates at the lower depths. Productivity appeared to be very light-dependent, as shown by Figure 23. Findenegg (1964) describes curves of this type as being characteristic of lakes rich in phytoplankton and nutrients.

Seasonal variations in productivity measured *in situ* were observed, and seasonal changes in the phytoplankton community structure account for some of this variability (Table 2). Analysis revealed that carbon available for photosynthesis was not limiting, that the euphotic zone extended downward to 12 m and that the depths of maximum phytoplankton density also yielded the maximum production.

Later observations revealed station 1 to be more productive than other similar habitats of the lake and may be atypical of the open water situation. Productivity values for this station fall within a strong mesotrophic range as described by Winberg (1963), while the waters of the northern portions of the lake tend to fall more in an oligotrophic classification.

In vitro Primary Productivity

In vitro experiments were used to test for station variability in productivity. Results are expressed as counts per minute and $mgC/m^3/4$-hr

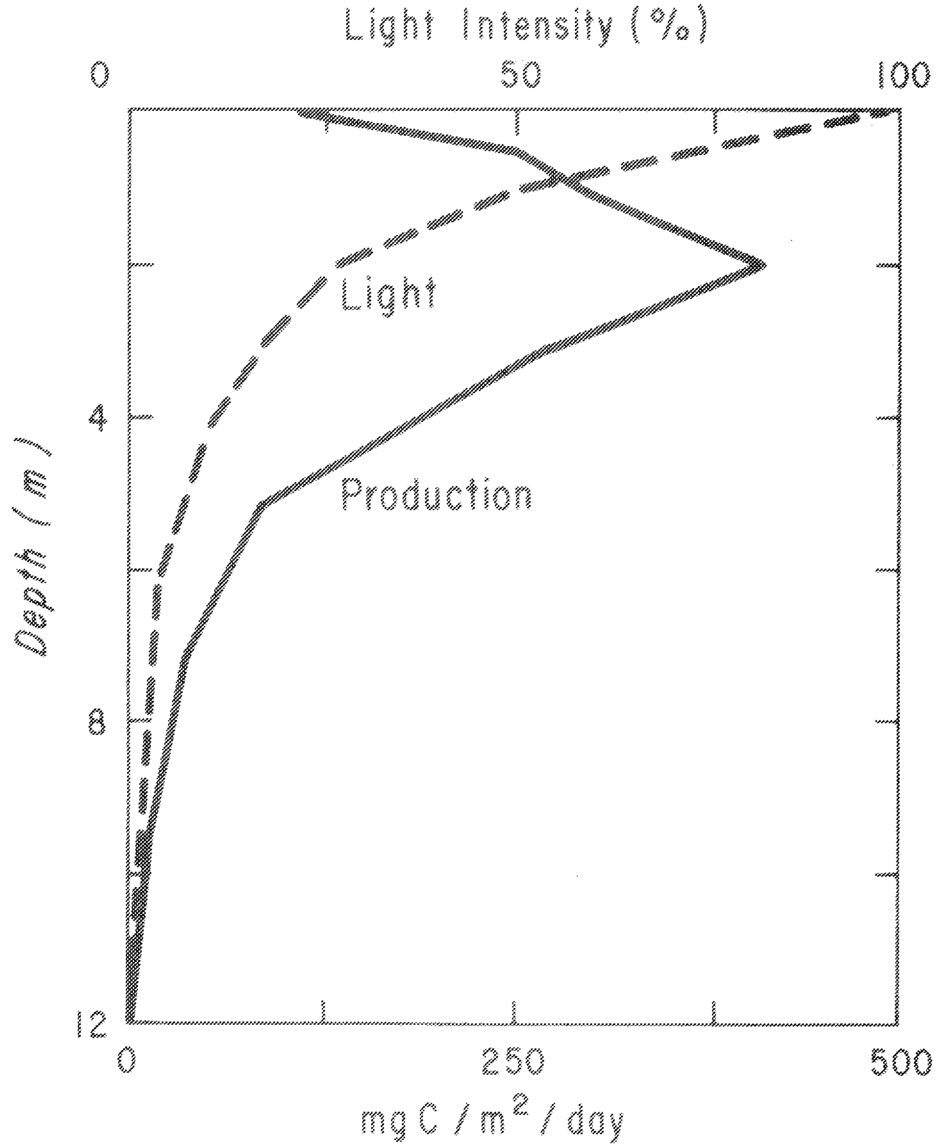


Figure 23. Primary Production and Light Attenuation-Depth Profile. Station 1 on August 19, 1971. (Parker, 1972.)

Table 2. Areal primary production rate and community structure for station 1. July-November, 1971. (Parker, 1972.)

Month	$mgC/m^2/day$	Community Structure
July	3744	Green algae and diatoms
Aug.	2793	Blue-green algae
Sept.	607	Few diatoms
Oct.	811	Few diatoms
Nov.	6610	Very abundant diatoms

Table 3. Comparison of *in situ* and *in vitro* counts per minute from station 1. July-November, 1971. (Parker, 1972.)

Date	*In Situ* CPM	*In Vitro*[a] CPM	*In Situ* Depth[b] (m)	*In Situ* Temp.[b] (°C)	*In Situ* Ft-cd[b]
July	22,700	17,300	2	21	450
Aug.	36,820	33,375	2	21	331
Sept.	7,560	7,050	2	16	270
Oct.	9,560	10,740	2	10	250
Nov.	90,100	120,920	Surface	7	200

[a] *In vitro*: Temp. = 18 C ± 1 C; 400 ft-cd.

[b] Physical parameters used to select *in situ* values.

incubation period. First four moments analysis indicated that $\log_{10}$ transformations would yield a normal distribution. The initial step in this analysis required a close correspondence between carbon fixation rates measured *in situ* and *in vitro* obtained under similar conditions of light and temperature. Counts per minute and the respective physical conditions used to select the *in situ* values are shown in Table 3. The results show a close agreement.

Additional investigation indicated that station 11 was significantly lower in carbon fixation that the other stations, while stations 1, 6, and 10 were consistently higher in carbon uptake. The production estimates obtained by culturing water samples from each station and for each sampling date were used to calculate the monthly and station averages presented in Table 4. The relation between diatoms and carbon fixation is illustrated in Figure 24.

From the results of this work, three distinct areas of the lake were recognized. These areas are described in the following section and are geographically illustrated in Figure 25. Stations are shown in Figure 10(b).

Classification of Coeur d'Alene Lake Based on Productivity

Area I includes that northern section of Coeur d'Alene Lake from the city of Coeur d'Alene south to East Point (stations 2, 3, 4, and 5). In this area the open water is deep, averaging greater than 20 m, with Secchi transparency measurements not less than 3 m. Nutrient levels are moderately low, and the plankton community structure consists of low concentrations of diatoms. Carbon fixation rates for the period of study averaged approximately 400 mgC/m^3/4-hr incubation period. Water in this section would be considered closer to oligotrophic with the exception that certain bay areas are somewhat eutrophied.

Area II includes that section of the lake from Rockford Bay south to Conkling Park (stations 6, 7, 8, 1, 9 and 10). This area is deep, averaging greater than 15 m, is rich in nutrients, and supports a very dense diatom community with seasonal development of blue-green algae populations in August. Carbon fixation levels averaged 520 mgC/m^3/4-hr incubation period. The data support the conclusion that this area is enriched and can be

Table 4. Carbon fixation measured *in vitro* at all lake stations. July-November, 1971. Expressed as mgC/m^3/4-hr incubation period. (Parker, 1972.)

Station	Carbon Fixation (mgC/m^3/4-hr incubation period)					
	July	Aug.	Sept.	Oct.	Nov.	Avg.
1	150	435	73	114	1956	546
2	119	166	18	40	1880	445
3	73	205	20	48	1845	438
4	85	206	22	96	1292	340
5	48	215	28	98	1763	430
6	245	234	17	51	2249	559
7	122	259	25	108	1994	502
8	169	360	78	69	1642	464
9	136	612	68	83	1146	409
10	168	699	109	215	1378	514
11	10	45	59	106	610	166
12	49	44	68	227	907	259
Avg.	115	290	49	105	1555	

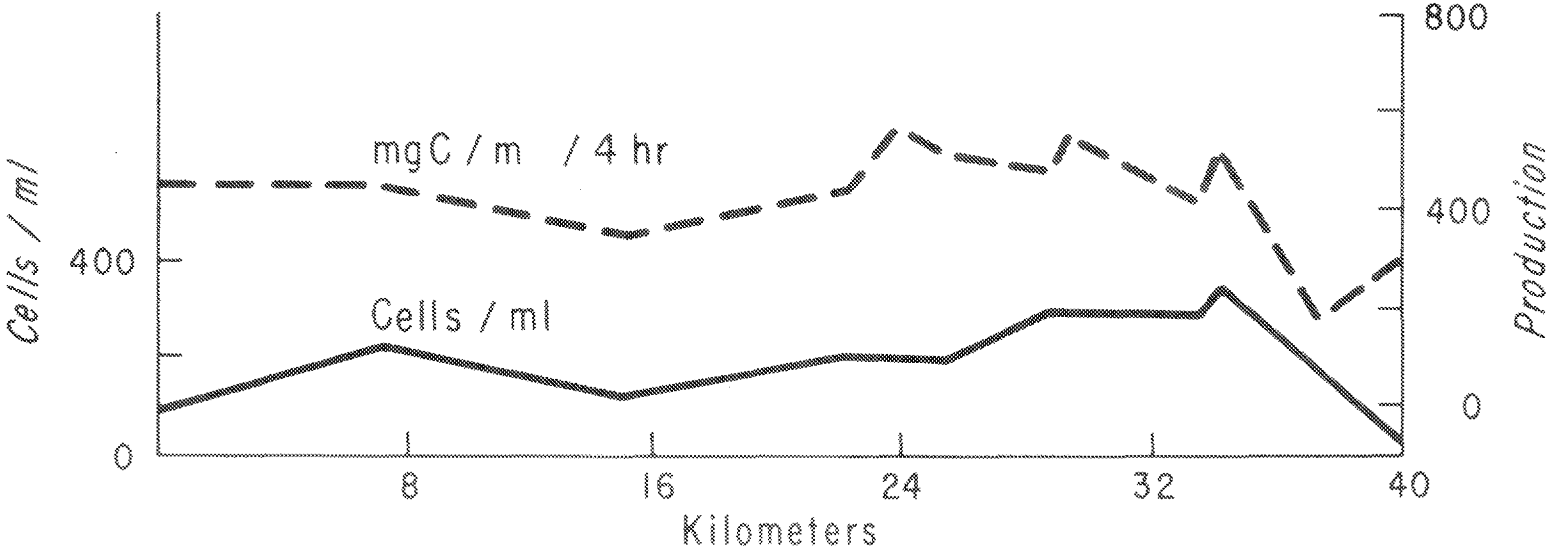


Figure 24. Mean of Carbon Fixation and Diatom Concentrations for Each Station. July-November, 1971. Kilometers Measured from North End of Lake. (Parker, 1972.)

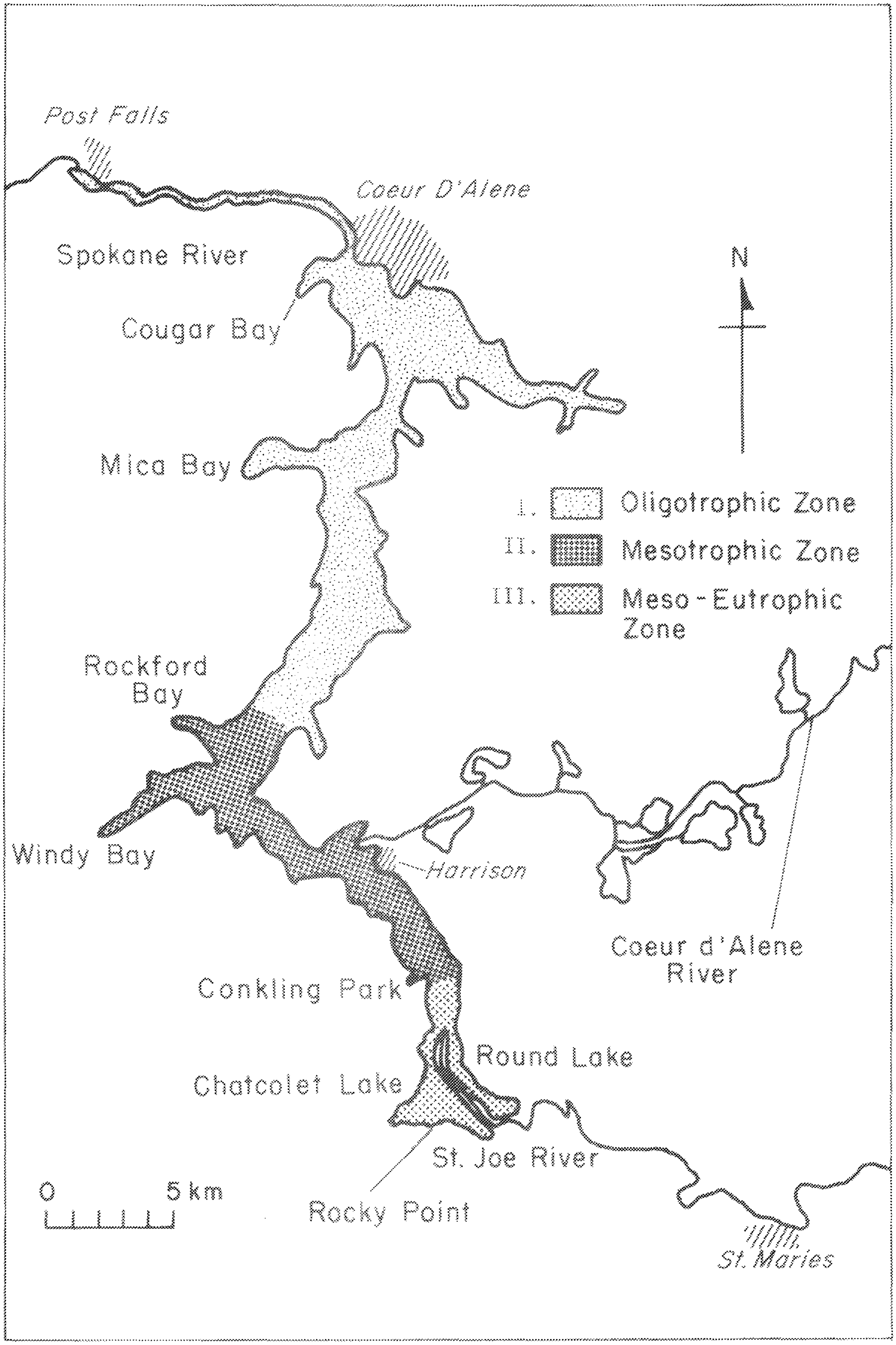


Figure 25. Trophic Areas (I--oligotrophic; II--mesotrophic; III--strongly mesotrophic) of Coeur d'Alene Lake. (Parker, 1972.)

classified as strongly mesotrophic. However, station 9 is somewhat different than the other stations. It has lower diatom concentrations and thereby lower phytoplankton productivity. There is abundant macrophyte growth in the area, and these plants may account for a considerable part of the autotrophic production at station 9 as well as reduced phytoplankton production. This station is also considered the dividing zone between Areas II and III as it reflects the north-south gradient in production and nutrient levels.

Area III includes the southernmost portion of the lake--from Shingle Bay south to Rocky Point in Chatcolet Lake (stations 11 and 12). This water is quite shallow with measured depths averaging less than 7 m. Dense growths of macrophytes persist from late July to early October. Nutrient supplies are abundant. Weak thermal stratification does occur but it is easily dissipated and the waters are usually well mixed. Carbon fixation rates by phytoplankton averaged 275 mgC/m^3/4-hr incubation period, the lowest values found in the lake. The phytoplankton community structure was poorly developed, and it is assumed that the dense macrophyte growth restricted the phytoplankton production in some manner not completely understood. It is also believed that the more turbid conditions in this area may have inhibited phytoplankton growth.

Although no estimates of production by macrophytes were made, it is likely that they are the major source of autotrophic production. Field observations of Area III indicate that over 60% of this water area is inhabited by a very dense growth of macrophytes. The evidence indicates that these waters are strongly mesotrophic, with most shallow areas being heavily enriched and eutrophic. A summary of the distinguishing characteristics of each area is presented in Table 5.

B. Macrobenthic Communities

Benthic macroinvertebrates may play an essential role in recycling nutrients from the sediments and are the main source of food in their nymphal or larval stages for most fish. They are excellent indicator organisms because many species are extremely sensitive to changes in water quality. They are relatively sedentary and have a complex life

Table 5. Selected characteristics of the three trophic areas of Lake Coeur d'Alene. July-November, 1971.*(Parker, 1972.)

Parameter	Area I	Area II	Area III
Nitrates (mg/l)	0.13	0.19	0.21
Phosphates (mg/l)	0.03	0.09	0.22
Alkalinity (mg/l)	24.2	27.6	31.0
pH	7.2	7.2	7.25
Average depth (m)	>20	>15	>7
Transparency (m)	3	3	2.5
Diatoms/ml	150	260	120
$mgC/m^3/4$ hrs	400	525	275
Macrophytes	Very rare	Rare	Very abundant
Periphytic blue-green algae	Rare	Common	Abundant

* Delineation of trophic areas are shown in Figure 25.

cycle of a year or more. Thus, their presence or absence may reflect physical or chemical changes in the water over a period of time or in different portions of an aquatic system. Where their habitat requirements are known, they may also aid in classifying lakes or streams.

Benthic sampling stations were selected at four depths (2, 5, 10, and 20 + m) in four areas of the lake along a north-south axis as previously shown in Figure 10(a). Sampling collections were made in July and September, 1971 and in March, 1972. Sixty-two types of benthic invertebrates were identified and counted. They consisted of 26 species of Chironomidae, 9 Hydracarina, 9 Trichoptera, 5 Ceratopagonidae, and 14 other groups (listed in Table A-1, Appendix A). Chironomids made up 51-74.5% and oligochaetes 25.5-49% of the total number of organisms collected.

Samples from the 2 m depth contained the greatest diversity and number of organisms, amounting to approximately 60% of the total collected. The 2 m station in Chatcolet contained the highest number of oligochaetes collected (Table 6). However, only four species and 11 organisms were collected at the 2 m station in the Harrison area, near the mouth of the Coeur d'Alene River. Samples from station 4A, at the head of the Spokane River, yielded a large number of organisms in July but a low diversity since Tanytarsus and Micropsectra made up 85% of the collection. Few organisms were collected at this station in September and March. Stations at a 10 m depth consisted mostly of Procladius and Chironomus. Macroinvertebrate numbers showed a wide variation at the three deep stations exceeding 20 m.

Sediment Chemistry

Dredge sediments for heavy metal analysis by neutron activation and atomic absorption were collected in September, 1971 and March, 1972, respectively. The atomic absorption method resulted in lower values--possibly because of incomplete digestion of the sediment or the incorporation of the metals in lattice structures of clay. Sediment for organic content analysis was collected in July, 1971 and March, 1972. The highest percentage of organic carbon in the sediments was found in Cougar Bay (17%) where the lake bottom is littered with bark, and the lowest percent (5.7%) in samples from the Chatcolet area (Table 7)--although dense macrophyte

Table 6. Density estimates of chironomids and oligochaetes collected from the Coeur d'Alene Lake system on three dates. (Winner, 1972.)

Station	Water Depth (m)	Chironomidae/m^2				Oligochaeta/m^2			
		July	Sept.	March	Average	July	Sept.	March	Average
Chatcolet									
1A	2	2,776	1,657	8,845	4,426	22,682	10,050	1,033	11,255
1B	5	905	495	1,291	897	603	86	2,066	918
1C	10	646	22	430	366	2,335	839	1,313	1,496
Harrison									
2A	2	108	22	0	43	22	0	0	7
2B	5	667	1,636	366	890	108	1,291	65	488
2C	10	2,001	947	1,442	1,463	194	1,506	258	652
2D	>20	108	1,011	323	481	0	108	0	36
Carlin Bay									
3A	2	5,703	6,869	1,141	4,571	1,076	5,100	1,958	2,711
3B	5	839	344	667	617	581	194	43	273
3C	10	237	387	387	337	22	0	0	7
3D	>20	22	0	43	22	0	0	0	0
Cougar Bay									
4A	2	5,703	689	258	2,216	0	0	0	0
4B	5	108	495	452	352	237	430	430	366
4C	10	108	215	968	352	22	22	108	51
4D	>20	194	2,647	2,958	1,933	753	624	1,313	897

Table 7. Estimated percentage organic carbon in the sediments of the Coeur d'Alene Lake system for July, 1971, and March, 1972. (Winner, 1972.)

Area	Date	Water Depth (m)			
		2	5	10	>20
Chatcolet	July, 1971	6.4	6.7	7.1	....
	March, 1972	5.8	6.6	7.9	....
Harrison	July, 1971	8.1	6.7	8.4	8.1
	March, 1972	8.6	7.5	7.4	8.0
Carlin Bay	July, 1971	7.3	7.3	9.5	9.7
	March, 1972	9.7	6.5	6.7	8.8
Cougar Bay	July, 1971	7.1	13.3	17.7	11.8
	March, 1972	3.0	10.6	8.9	9.6

growth is present in the latter area. High amounts of organic carbon were found at the mouth of the St. Joe River and at Conkling Park. The organic debris from decaying vegetation may be transported by the St. Joe River to the Conkling Bay area where it is deposited by decreased currents. The resulting nutrients released by decay may help explain the high primary production found in this area (Area 11, Figure 25).

The organic content of the sediment was inversely related to the number of chironomids and oligochaetes, probably because sediment organic content increased with depth. This phenomenon is caused by the greater sedimentation of plankton in the open water where there is less eddy diffusion and a slower rate of decay due to colder temperatures (Odum, 1971). The organic content was slightly higher in March than in July.

Zinc constituted 0.45-0.73% of the top 3 cm of the sediment collected in September, 1971 in the lake north of Harrison, but decreased to .06% in the east end of Carlin Bay and was not detected in the sediments of Chatcolet or Round Lakes (Table 8). Approximately 10% of the top sediment in the Harrison area was Fe while concentrations of this element ranged from 3.0 to 7.5% at all other stations. Iron concentrations increased with depth. Antimony in the sediments varied from 1-120 mg/kg and was higher in Lake Coeur d'Alene than in Chatcolet. Ellis (1932) observed rock flour from the mines passing down the Coeur d'Alene River and spreading over most of the lake. The high metal concentrations observed in the top 3 cm of sediments indicate that the rock flour noted by Ellis has not been entirely buried by natural sedimentation or has been buried by more rock flour.

In sediments collected in March, 1972, the Cu concentrations were 3-6 mg/kg in Chatcolet and reached 87 mg/kg in Coeur d'Alene Lake (Table 9). Magnesium varied from 180-362 mg/kg in Chatcolet and 160-660 mg/kg in Coeur d'Alene Lake. Concentrations of Zn and Pb decreased with the distance south of the Coeur d'Alene River delta (Figure 26). Although upper sediments from the St. Joe River were low in these metals, concentrations of Zn increased to 2,000-4,000 mg/kg between Conkling Park and the Coeur d'Alene River. The general flow of the lake is south to north, but wind and currents may have carried particulate matter containing heavy metals from the Coeur d'Alene River as far south as the area immediately off Conkling Park.

Table 8. Metal concentrations in lake sediments (mg/kg) by neutron activation collected September, 1971 (Winner, 1972.)

Station	Water Depth (m)	Concentration (mg/kg)		
		Zn	Fe	Sb
Chatcolet				
1A	2	ND[a]	31,700	1
1B	5	ND	44,900	23
1C	10	ND	53,000	1
Harrison				
2A	2	...[b]	20,800	32
2B	5	6,760	111,300	101
2C	10	5,140	95,100	77
2D	>20	6,200	100,000	93
Carlin Bay				
3A	2	627	35,900	3
3B	5	4,640	53,430	43
3C	10	4,100	55,100	43
3D	>20	6,700	75,100	120
Cougar Bay				
4A	2	1,430	48,800	5
4B	5	7,320	54,800	107
4C	10	7,220	75,700	63
4D	>20	...	...	...

[a] ND = not detected.

[b] ... = no data.

Table 9. Metal concentrations in lake sediments (mg/kg) by atomic absorption collected March, 1972. (Winner, 1972.)

Station	Water Depth (m)	Concentration (mg/kg)		
		Zn	Cu	Mg
Chatcolet				
1A	2	10	5	362
1B	5	10	3	375
1C	10	105	6	180
Harrison				
2A	2	635	20	350
2B	5	640	22	362
2C	10	1,120	48	385
2D	>20	1,225	61	435
Carlin Bay				
3A	2	588	6	160
3B	5	1,405	33	325
3C	10	3,400	87	450
3D	>20	3,400	68	660
Cougar Bay				
4A	2	1,400	10	225
4B	5	3,475	67	612
4C	10	5,125	64	425
4D	>20	5,050	49	485

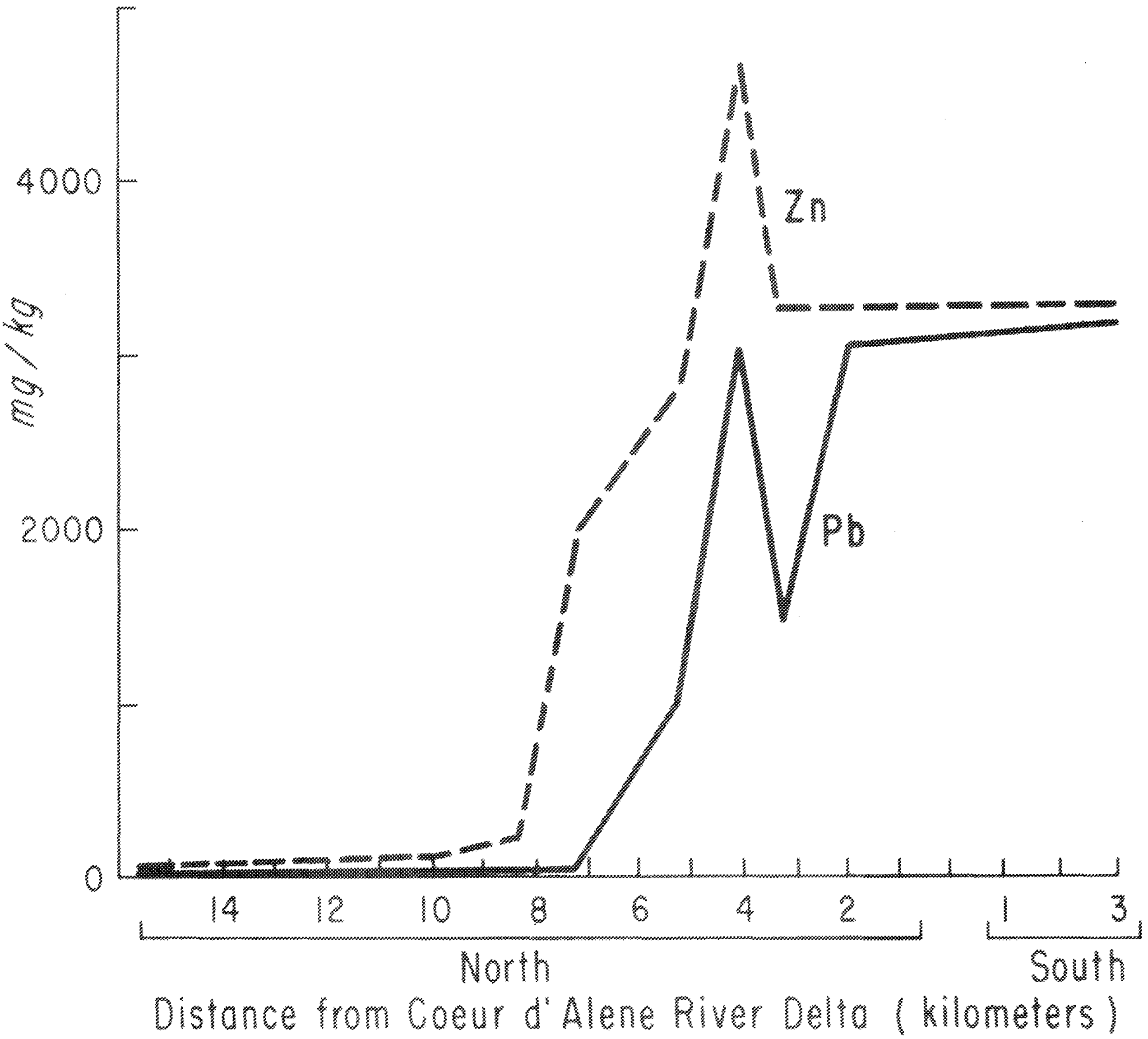


Figure 26. Analysis of Metal Concentration in the Upper 3 cm of Sediment from the Coeur d'Alene River Delta Area. (Winner, 1972.)

Substrate Conditions

Within a given lake, there usually exists a high correlation between the nature of the substrate and the number of species and population density (Reid, 1961). Some important factors affecting limiting benthic communities are oxygen, temperature, pH, dissolved constituents and nature of the substrate surface, as well as the chemistry of the upper few centimeters of the sediments.

Oxygen is not a critical factor in the northern portion of the lake because of its oligotrophic nature. The lowest concentration observed for this part of the lake was 4 mg/l in July, 1971. Many benthic organisms can survive in waters at even lower DO concentrations. Bark may depress oxygen levels and create a physical barrier for the development and maintenance of a healthy benthic community (Hansen, et al, 1971). Although the bark-littered substrate at station 4B and 4C contained fewer benthic organisms than the other stations at similar depth, the dissolved oxygen was never below 6 mg/l probably because of depth, low temperatures and continuous flow near the lake outlet.

Uniform low temperatures influence the composition of the benthic fauna in the profundal (deep) zone (Ruttner, 1963). Temperatures at the profundal stations in Cougar and Carlin Bays probably do not greatly exceed the 6.5 C measured in March. In Lake Coeur d'Alene, few macroinvertebrates are adapted to living in this cold dark habitat. Only Chironomus sp. and a turbellarian were found in these deep areas where they apparently avoid competition for both food and space. The highest bottom temperature recorded was 11 C in Chatcolet in July. This would be expected since this area also contains the most shallow regions of the lake--maximum depths range from 1.0 to 10 m.

The pH ranged from 7.5 at the surface to 6.2 near the bottom of all benthic stations over more than 20 m depth in Coeur d'Alene Lake and 10 m depth in Chatcolet. The pH of 6.2 recorded near the lake bottom at all stations is not limiting for most organisms.

Sceva (personal communication) measured .5 mg/l Zn in the water near the bottom of the lake in the Harrison area whereas 5,100-6,100 mg/kg were detected in the sediments at this locale. The water is considered "soft" in Coeur d'Alene Lake in most areas. Dissolved solids are low for the most part; conductivity ranges less than 50 μ mhos in most areas after the spring run-off period. These conditions are fatal to most fish (Pickering, 1964; Rudolfs, 1950; Jones, 1938; Sappington, 1969). However, fish are commonly caught in the area of the lake around Harrison. Wissmar (1972) reported a decrease in the inhibitory effects of Zn and Cu to carbon fixation by phytoplankton with an increase in concentrations of Ca, Mg, Na, K, and Mn. Concentrations of 180-660 mg/kg Mg were found in the lake sediment at the Harrison station (Table 10) and Maxfield (personal communication) reported Mg concentrations more than twice the concentrations of Zn in the sediments of the delta.

In spite of the high Zn concentration and relatively soft water, 11 genera of Chironomidae, 4 Hydracarina, 4 Trichoptera, and 1 Turbellaria were observed at the 10 m depth in the Coeur d'Alene delta area. Warnick and Bell (1969), Jones (1940), and Flentje (1945) have recorded high levels of resistance of aquatic insect larvae to dissolved metal salts. The benthic community in the Coeur d'Alene River delta may be inhibited primarily by high sedimentation rates rather than toxic levels of metal ions.

Areas containing aquatic vegetation also contained the greatest numbers and diversity of benthic invertebrates. The aquatic plants apparently supply food, shelter, and a diverse habitat for the organisms. The large number of invertebrates, high percentage of oligochaetes (66%), shallow water, high temperatures and low oxygen levels are indicative of the eutrophic conditions of the southern portion of the Coeur d'Alene Lake system. The chironomid, Tanytarsus, common to the northern portion of the lake, was identified by Theinemann (1918) as characterizing the bottom fauna of an oligotrophic lake. High oxygen concentrations and low temperatures in the water adjacent to the substrate are habitat requirements for this organism.

In this manner, the data on the benthic communities tend to corroborate the physicochemical evidence that Coeur d'Alene Lake functions as three separate bodies of water in relation to biological productivity.

C. Chemical Composition and Diatom Populations of Coeur d'Alene Lake Sediments

Chemical Composition

As a portion of this investigation, sediment cores were taken at five points on an east to southwest transect across the lake width from the delta mouth of the Coeur d'Alene River to Camp Easterseal (Cottonwood Bay). (Phase II of this study is scheduled to begin with OWRR funding in April, 1973, and will examine the metallic constituents of 10 cores to be taken lengthwise on a south to north axis from the St. Joe River to the Coeur d'Alene Lake outlet.) Locations and lake depths of the initial cores are indicated in Figure 10(c). Concentrations and changes of various constituents are presented by core number. The data are summarized in Figures 29-42 and Tables B-1 to B-5, Appendix B.

Core 1, Delta, (Depth - 9.1 m)

Analysis of a 79.5 cm core from 9.1 m depth in the Coeur d'Alene River delta showed significant increases of several metallic elements above the 79.5 cm level [Figures 27(a), 27(b), and 27(c); Table B-1, Appendix B].

Neutron activation analysis revealed significant increases in concentrations of Mn, Co, Sb, and Fe above the 79.5 cm level. There were higher concentrations of V, Al, Cr, Cs, Sc, and Rb below 70 cm than that found in the overlying sediments. Nickel and Se were not present in detectable amounts. The Fe/Mn ratio was higher at the 79.5 cm level than in the overlying sediments.

Arsenic increased from 70 cm to 20 cm, but was not detectable above nor below these depths.

Atomic absorption analysis revealed significant increases in concentrations of Cu, Cd, Fe, Mg, Mn, Mo, Ni, and Zn above the 79.5 cm depth. Low concentrations of Pb and Cu were noted at the 10 cm depth. Cadmium, Mn, and Zn were all higher at the 10 cm level. Lead showed a slight decrease below the 70.5 cm depth. The Fe/Mn ratio of atomic absorption decreased above the 79.5 cm depth.

Illitic clays predominated with some hematite and clay-sized quartz.

Neutron activation analysis in this and subsequent cores showed at least a one-fold greater metallic element content than atomic absorption measurements. It is our opinion that the extraction process utilized for the metallic components removed that amount available for solubilization while leaving

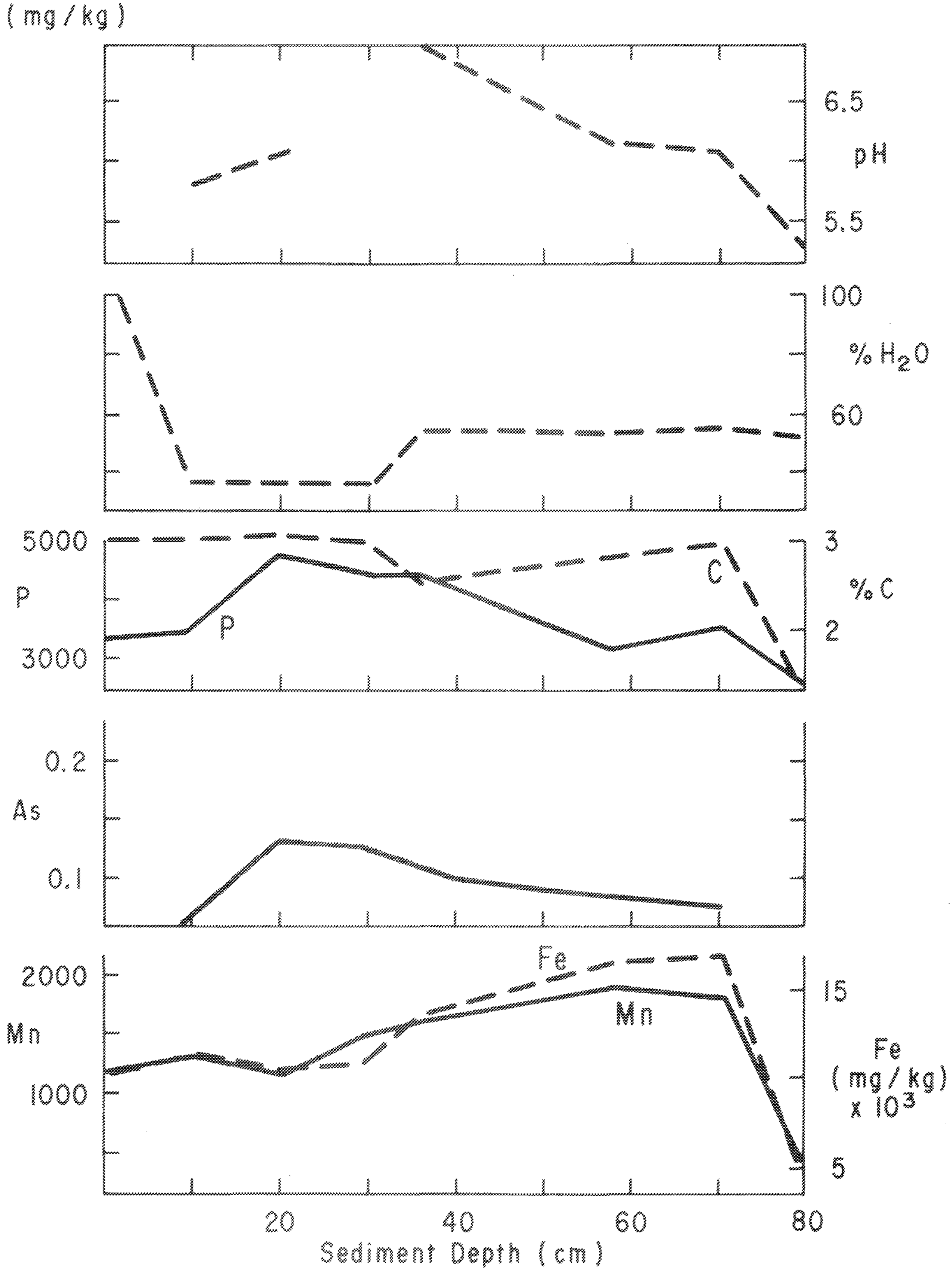


Figure 27(a). Standard Chemical and Atomic Absorption Analysis of Core 1. (Delta, 9.1 m water-depth). (Dunigan, 1972.)

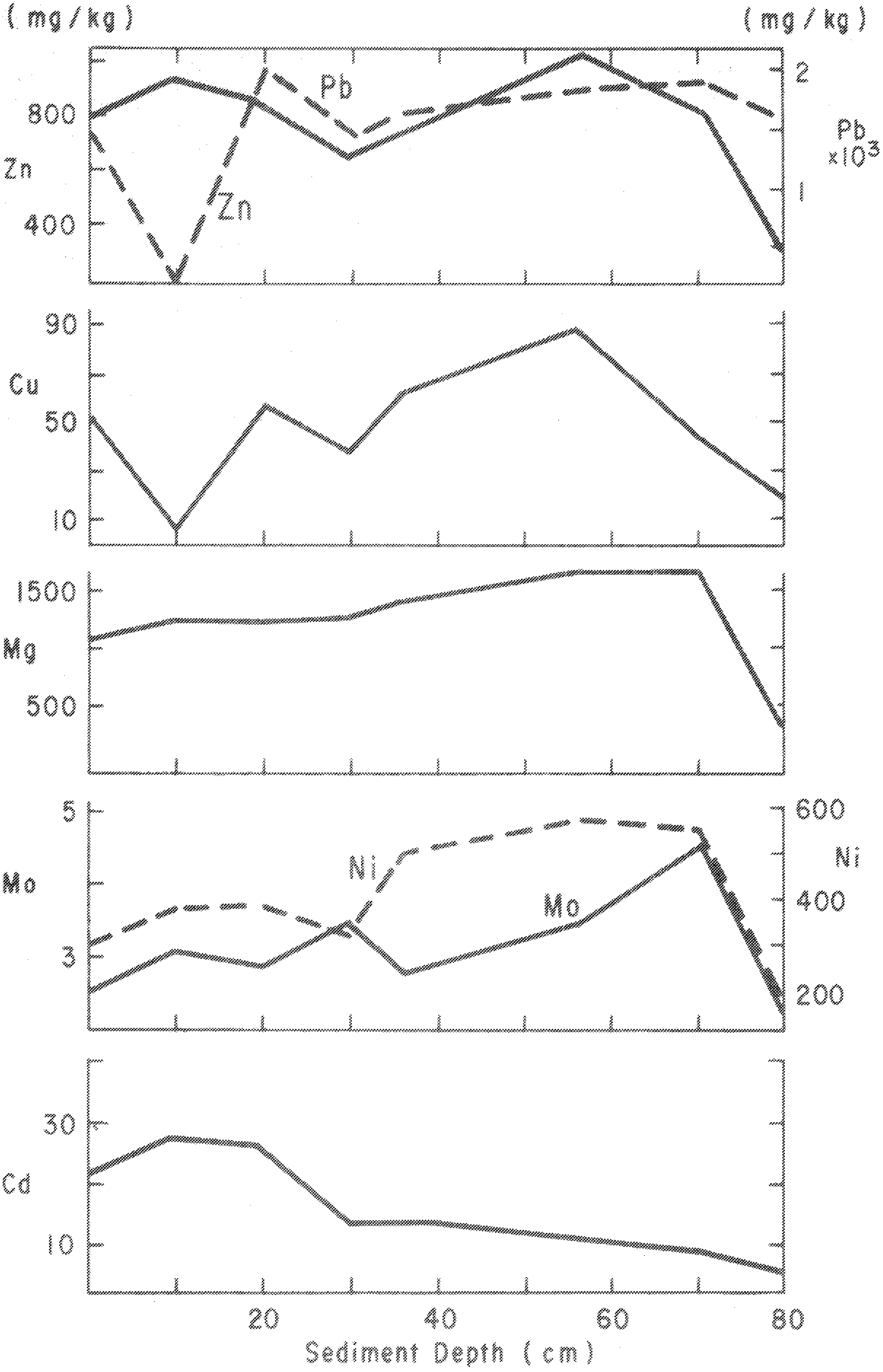


Figure 27(b). Atomic Absorption Analysis of Core 1.
(Delta, 9.1 m water-depth). (Dunigan, 1972.)

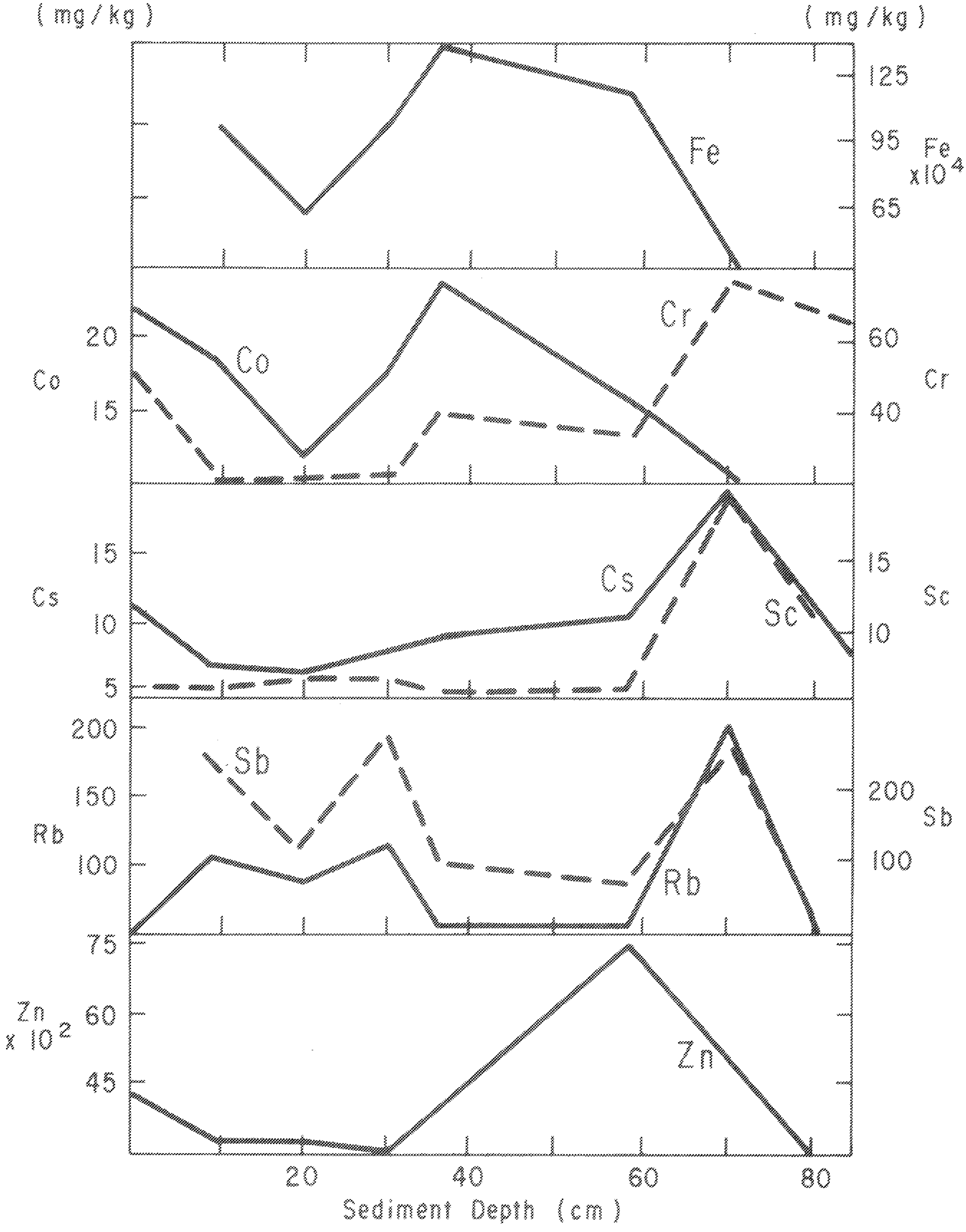


Figure 27(c). Neutron Activation Analysis of Core 1 (Delta, 9.1 m water-depth). (Dunigan, 1972.)

a considerable amount bound (possibly) to clay lattice structures. Neutron activation analysis, on the other hand, indicated that amount present regardless of what form or structure that it occupied.

Core 2, Center off Delta, (Depth - 18.3 m)

The 72.5 cm cored sediment sample from the center off the delta showed a similar increase in concentrations of some elements above the lower sediment depths to that measured in core 1.

The pH and percentage carbon were significantly lower at 72.5 cm than in the overlying sediments [Figures 28(a), 28(b), 28(c), and Table B-2, Appendix B]. The percentage of water content and total phosphorous showed an overall increase with decreasing sediment depth.

Arsenic was higher at the lower sediment depths except at the 40 cm level. It is interesting to note that most maxima and minima levels of the metallic elements analyzed occurred at the same depth within a core. However, some variation occurred and is probably due to different flows and loads in the river caused by changes in mining operations and loss of watershed vegetation which in turn has allowed soil constituents to wash into and mix with mine tailings.

Among the elements analyzed by neutron activation, Mn, Se, Sb, Fe, Zn, Co, and Ag showed a marked increase in concentration above the 72.5 cm sediment depth. Vanadium, Al, and Rb showed increases at 72.5 cm. Chromium, Cs and Sc fluctuated throughout the core profile. Scandium and Cs had maxima at 62.5 cm. Selenium was below the limit of detection in all but two samples.

Duplicate samples prepared for neutron activation analysis by freeze-drying showed the same pattern of increase as the samples prepared by heat drying. The freeze-dried samples gave results an average of 2.8% above heat dried samples.

Elements analyzed by atomic abosrption that increased in concentration above the 72.5 cm depth were Cu, Fe, Mg, Mn, Mo, Pb, and Zn. Cadmium concentrations fluctuated with no apparent pattern. The Fe/Mn ratio decreased above the 72.5 cm depth.

Illitic clays dominated the clay mineralogy with some clay-sized quartz.

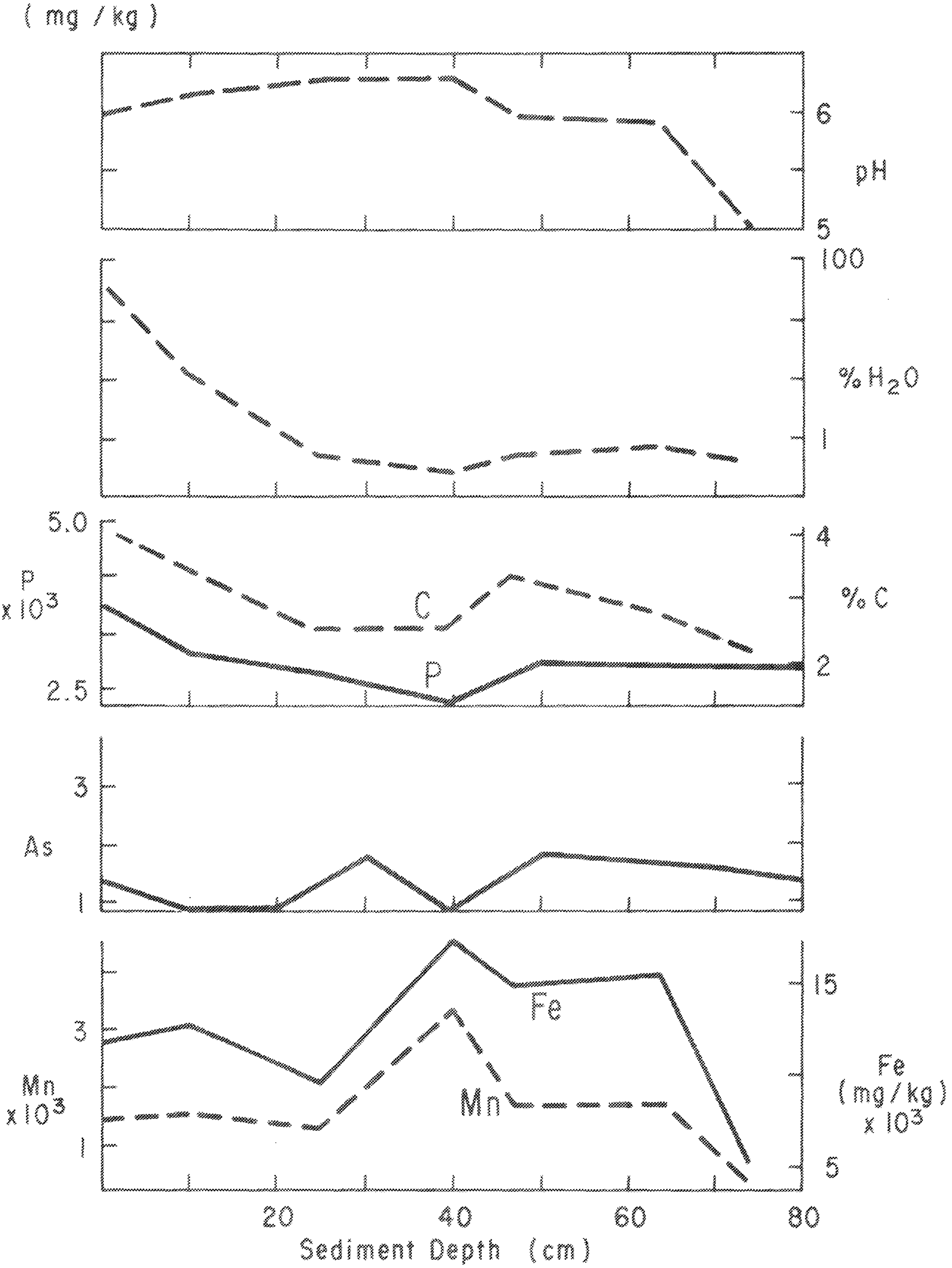


Figure 28(a). Standard and Atomic Absorption Analysis of Chemical Core 2. (Center off Delta, 18.3 m water-depth). (Dunigan, 1972.)

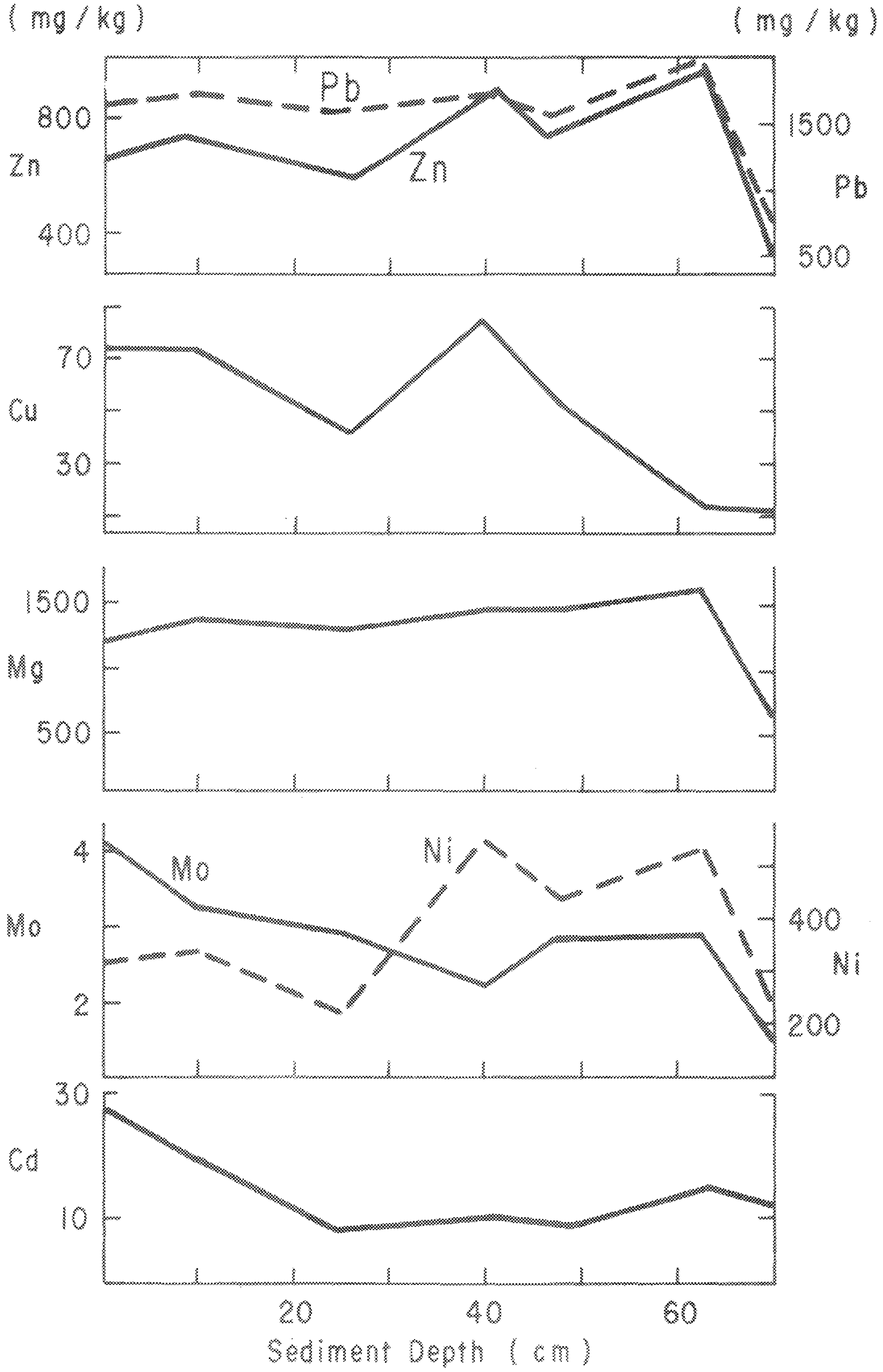


Figure 28(b). Atomic Absorption Analysis of Core 2 (Center off Delta, 18.3 m water-depth). (Dunigan, 1972.)

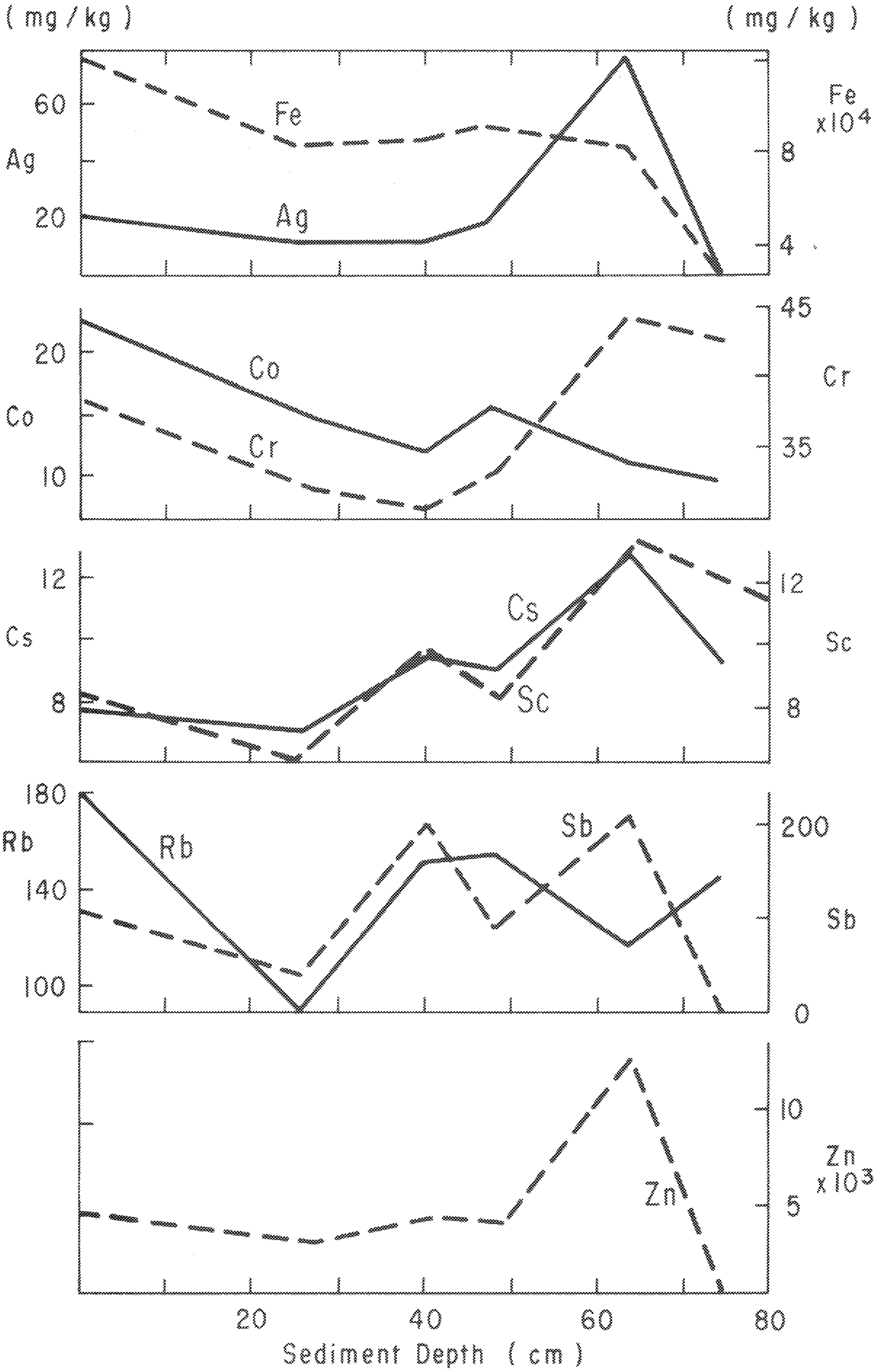


Figure 28(c). Neutron Activation Analysis of Core 2 (Center off Delta, 18.3 m water-depth). (Dunigan, 1972.)

Core 3, 189 m off Delta, (Depth - 18.3 m)

The 58.2 cm cored sediment sample taken 189 m off the Coeur d'Alene River delta showed no pattern of concentration shift [Figures 29(a), 29(b), 29(c), and Table B-3, Appendix B]. probably because it did not penetrate beyond the 60 cm depth. Clay minerals were predominantly illitic, with some quartz-sized particles.

Core 4, 1.6 km off Camp Easterseal, (Depth - 19.8 m)

The 79.5 cm cored sediment sample from 1.6 km off Camp Easterseal showed a marked increase in concentrations of some elements above 40 cm sediment depth [Figures 30(a), 30(b), 30 (c), Table B-4].

Arsenic, total phosphorous, and pH showed no pattern. Total carbon increased steadily with decreasing sediment depth, while percent water content decreased.

Neutron activation analysis showed higher levels of Ag, Ba, Fe, Sb, Zn, and Zr from the 10 th 40 cm level. Selenium was detectable only at the 70 cm depth. Chromium, Cs, Ha, Sc, Ta, and Y showed higher concentrations at the 40 cm depth than above or below.

Atomic absorption analysis showed higher levels of Cd, Cu, Mn, Mo, Ni, and Pb above the 40 cm depth. Iron and Mg concentrations increased above 40 cm depth. Zinc concentration generally increased toward the surface with a high value at the 50 cm sediment depth. The Fe/Mn ratio decreased considerably above the 50 cm sediment depth.

Illitic clays were the dominant clay minerals at all sediment depths analyzed. Hematite was present in measureable quantities above 40 cm.

Core 5, 274 m off Camp Easterseal, (Depth - 17.9 m)

The 69 m cored sediment sample from 274 m off Camp Easterseal showed significant decreases of some elements [Figures 31(a), 31(b), 31(c), and Table B-5, Appendix B].

The pH increased above 30 cm, and gradually increased with depth below the 30 cm sediment level. Total phosphorous and total carbon decreased at 50 cm depth and then increased above the 30 cm level. Neutron activation analysis of Cr, Sb, Se showed no definite shift. Cobalt increased above

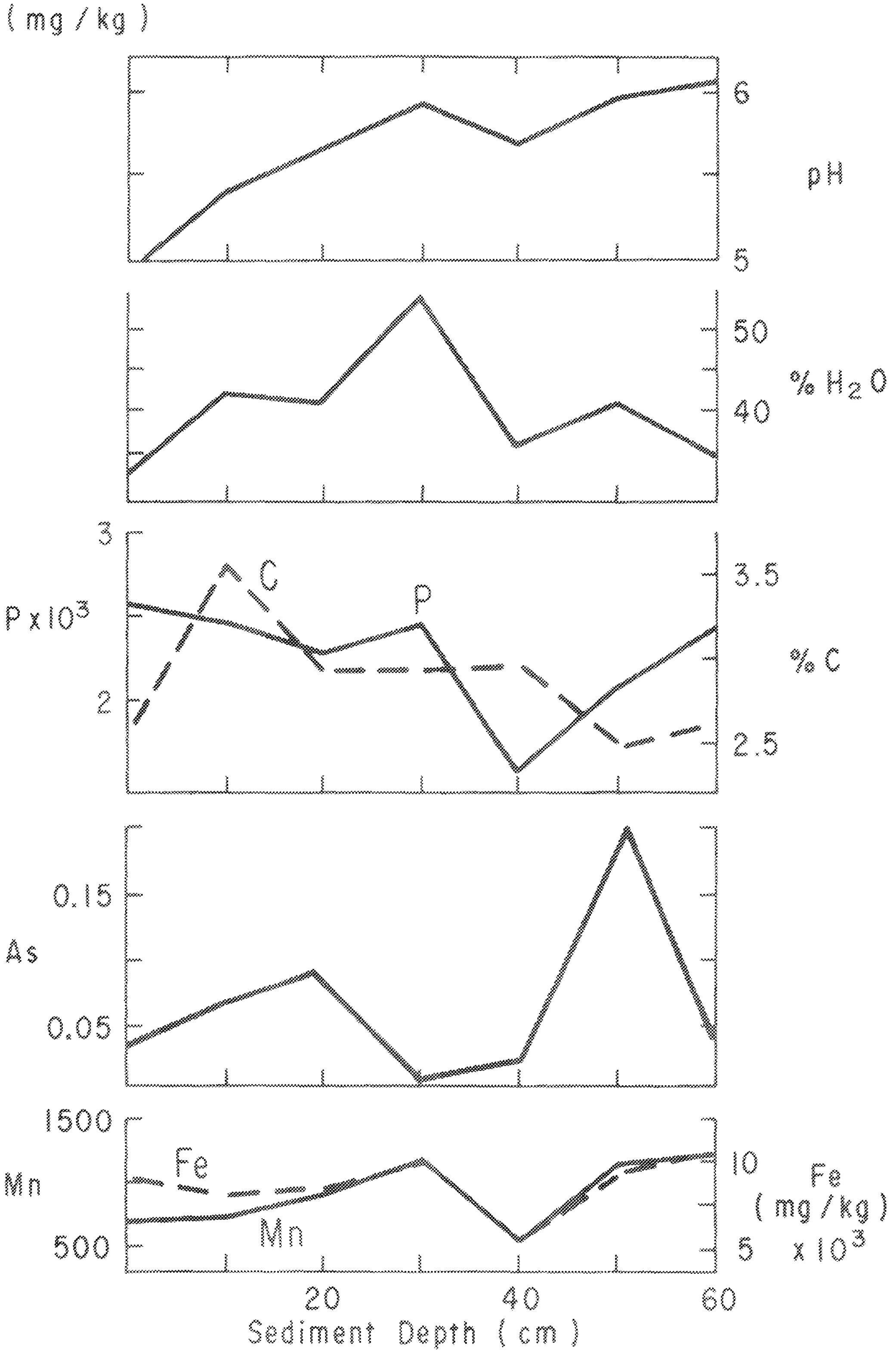


Figure 29(a). Standard Chemical and Atomic Absorption Analysis of Core 3. (189 m off Delta, 18.3 m water-depth). (Dunigan, 1972.)

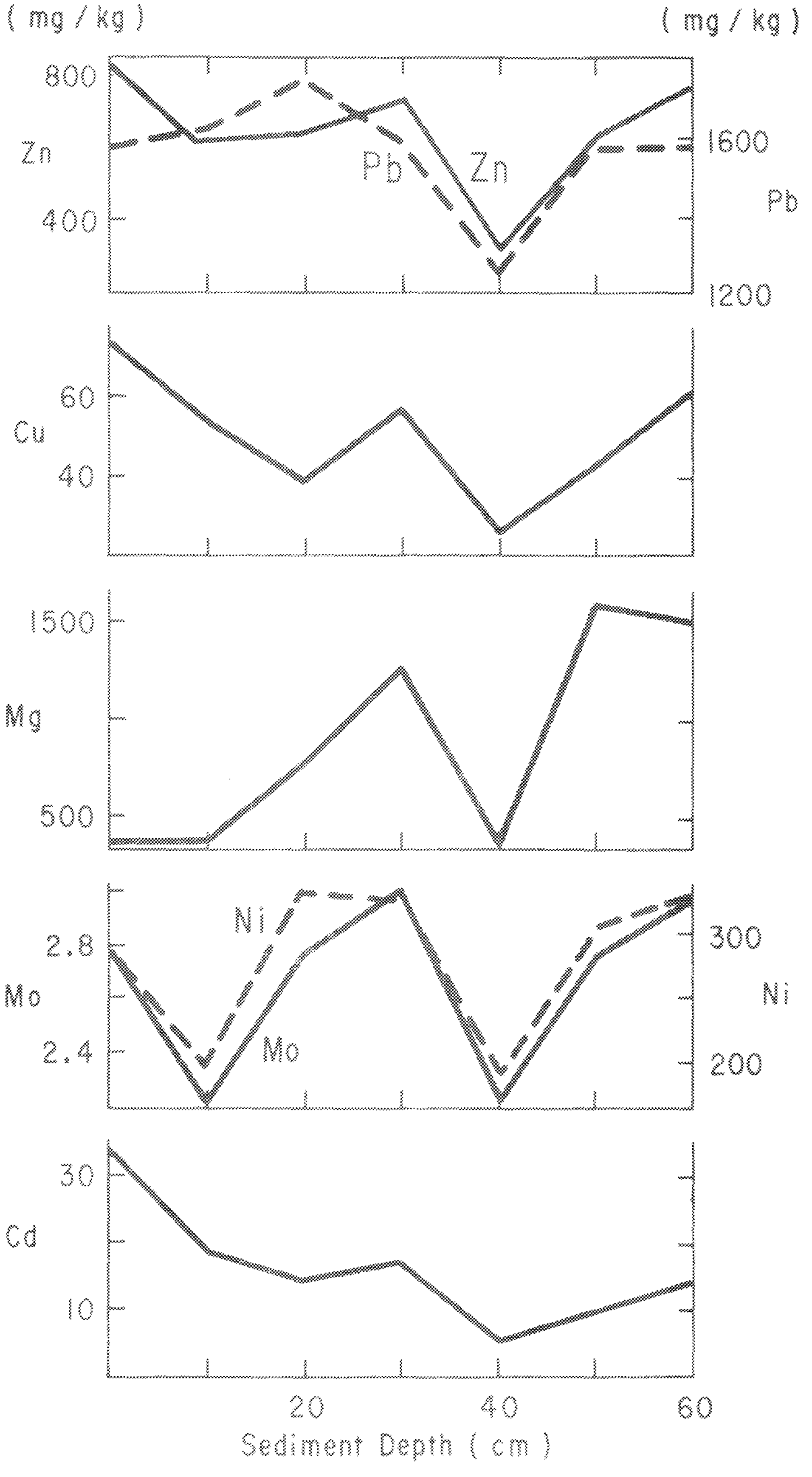


Figure 29(b). Atomic Absorption Analysis of Core 3 (189 m off Delta, 18.3 m water-depth). (Dunigan, 1972.)

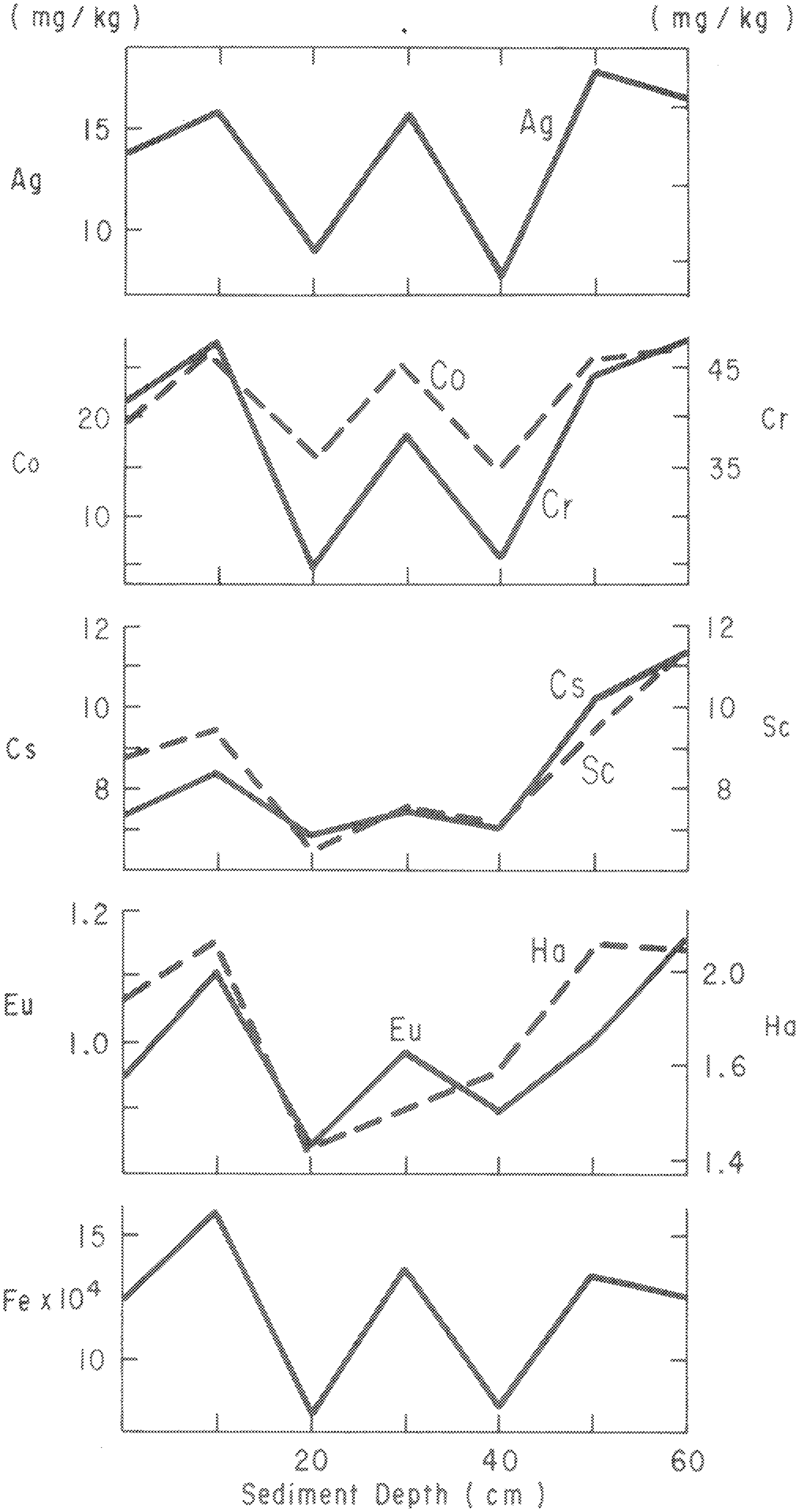


Figure 29(c). Neutron Activation Analysis of Core 3 (189 m off Delta, 18.3 m water-depth). (Dunigan, 1972.)

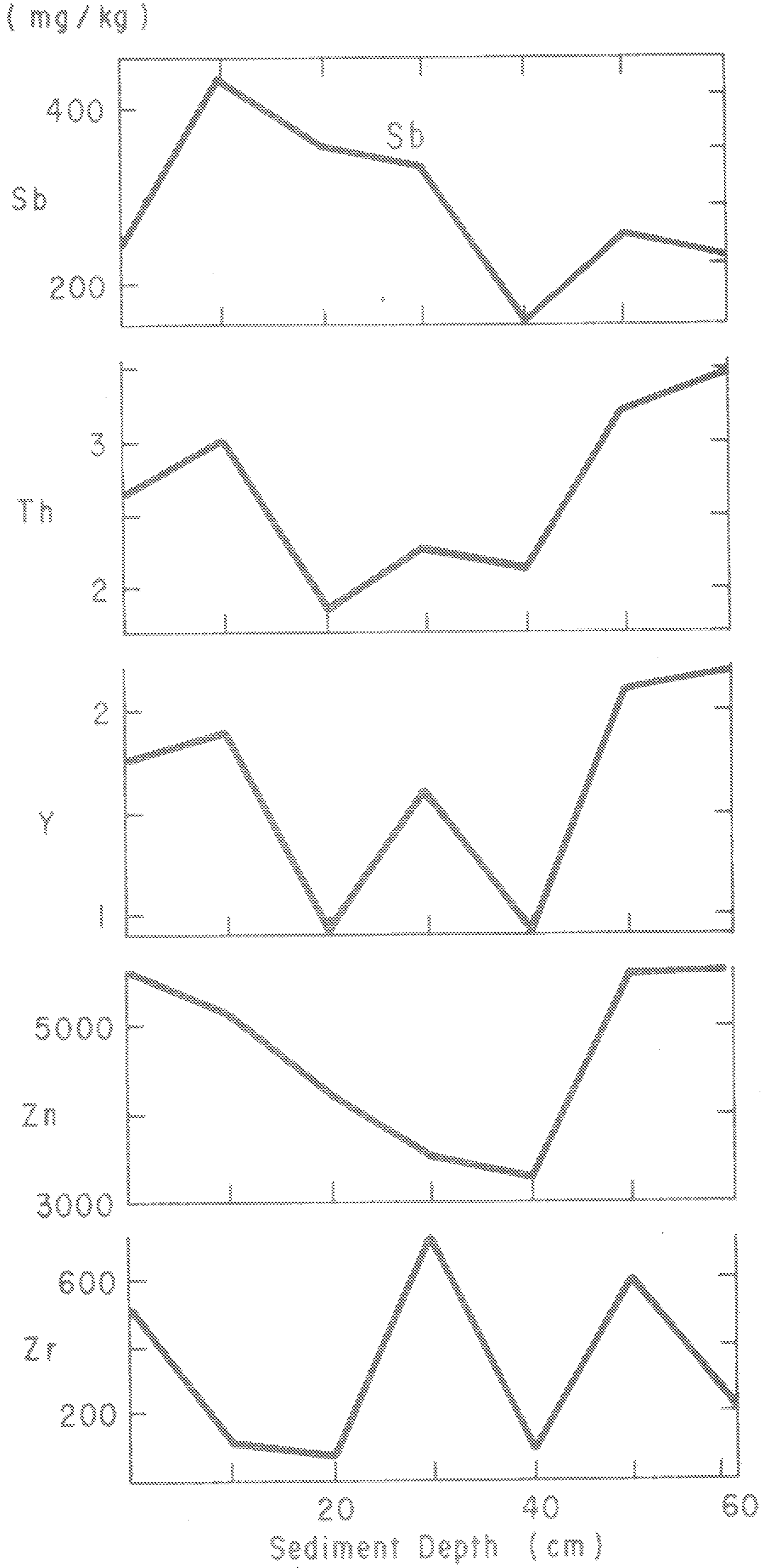


Figure 29(c-cont) Neutron Activation Data of Core 3 (189 m off Delta, 18.3 m water-depth). (Dunigan, 1972.)

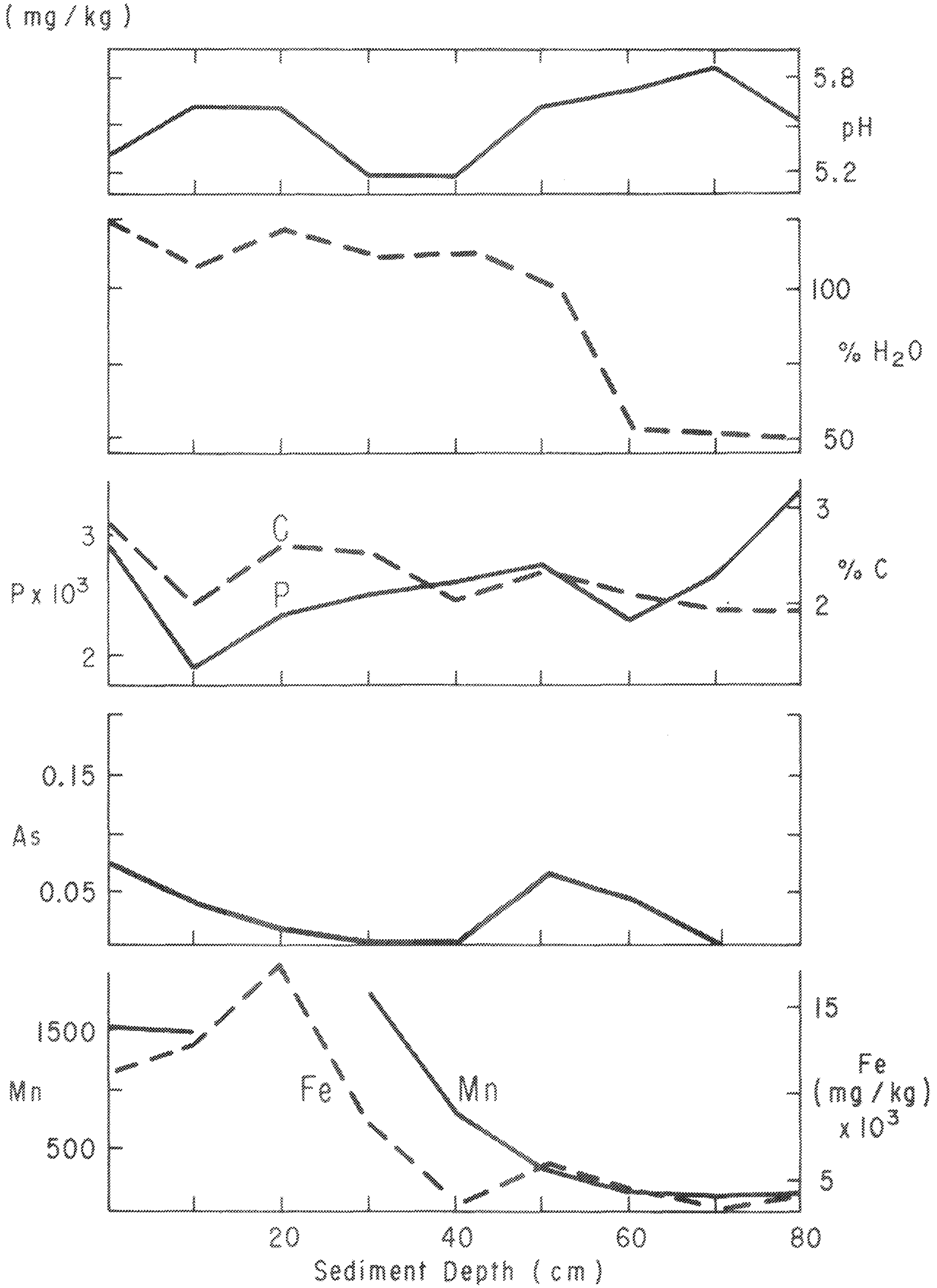


Figure 30(a). Standard Chemical and Atomic Absorption Analysis of Core 4 (1.6 km off Camp Easterseal, 19.8 m water-depth). (Dunigan, 1972.)

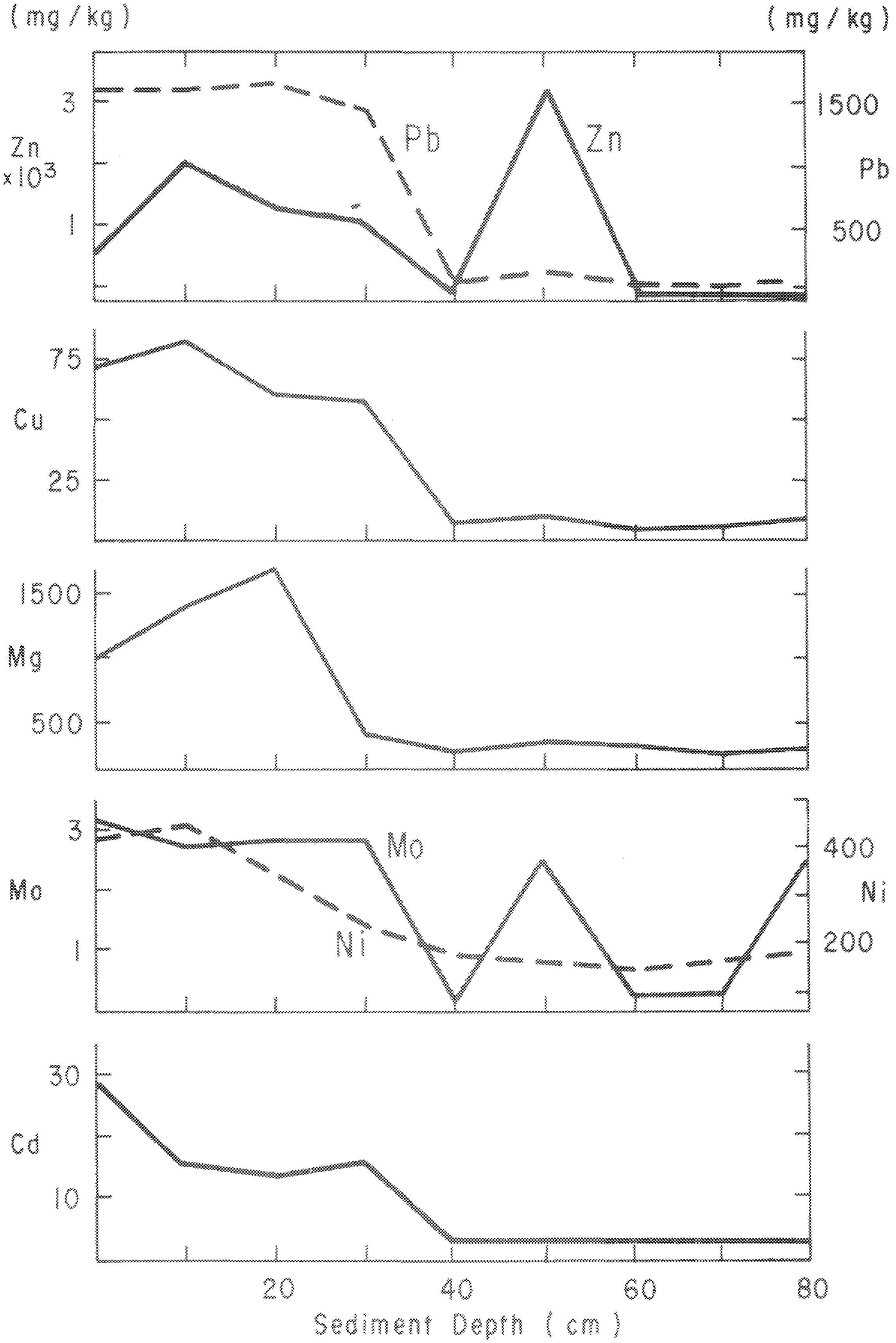


Figure 30(b). Atomic Absorption Data of Core 4 (1.6 km off Camp Easterseal, 19.8 m water-depth). (Dunigan, 1972.)

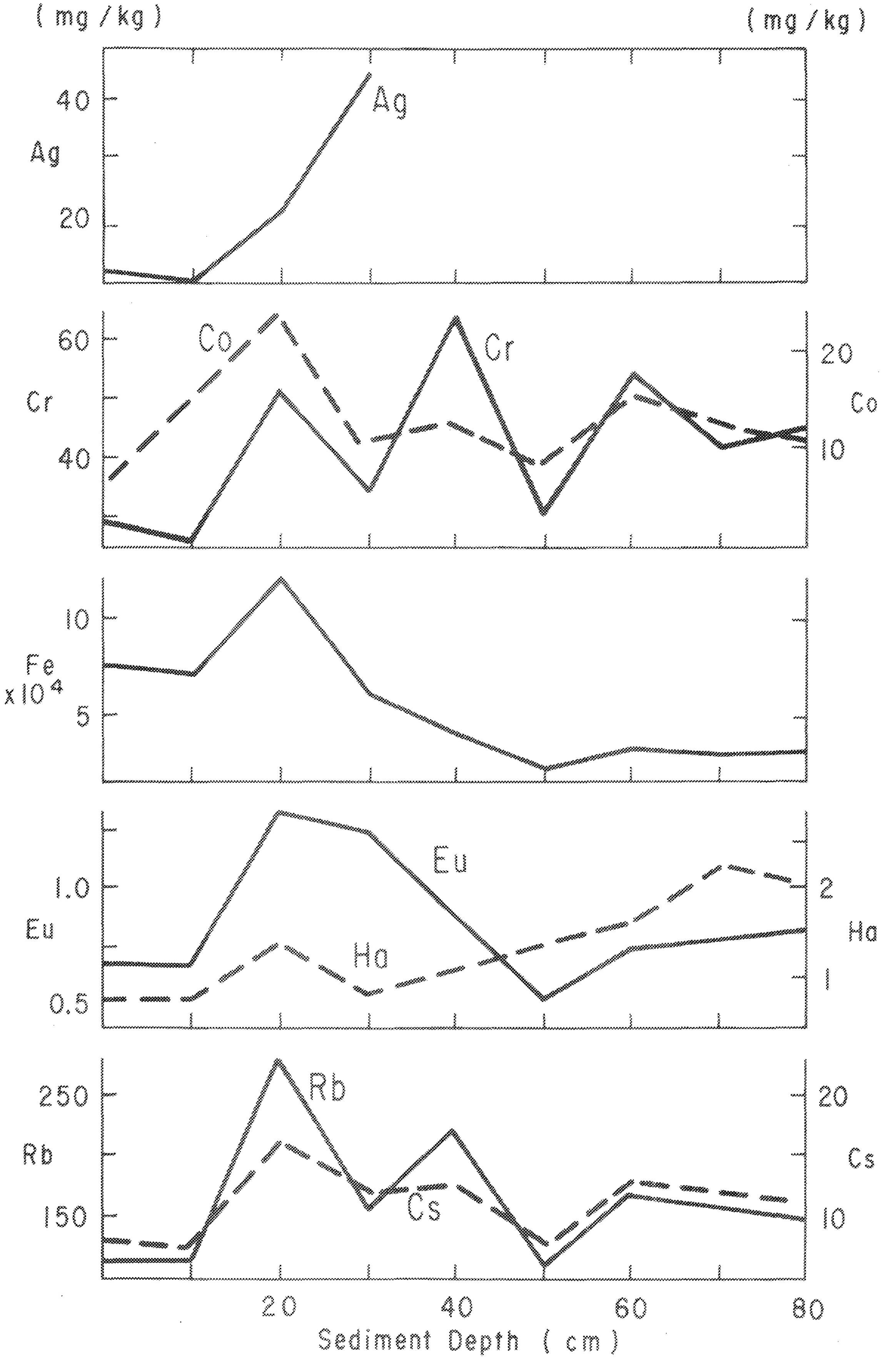


Figure 30(c). Neutron Activation Analysis of Core 4 (1.6 km off Camp Easterseal, 19.8 m water-depth). (Dunigan, 1972.)

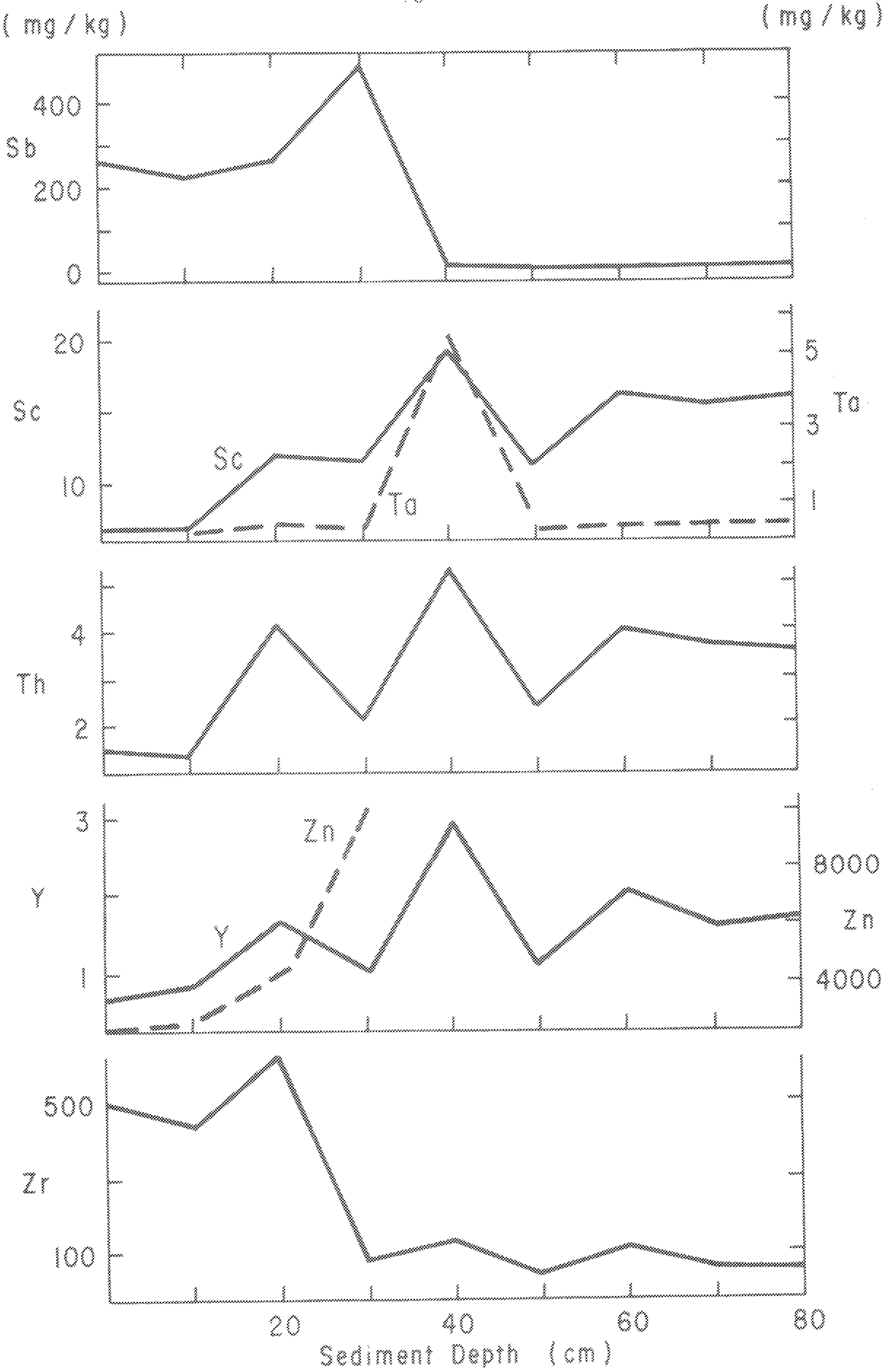


Figure 30(c-cont). Neutron Activation Analysis of Core 4 (1.6 km off Camp Easterseal, 19.8 m water-depth). (Dunigan, 1972.)

30 cm, Fe increased above 40 cm, and Cs increased above 50 cm--peaking at the surface. Silver showed only two concentrations above the limit of detection. Rubidium was detectable in three samples, surface, 10, and 20 cm depths. Zinc phenomenally increased above the 30 cm depth.

Atomic absorption indicated concentration increases in Cd, Cu, Fe, Mg, Mn, Ni, and Pb above the 30 cm depths. Zinc concentration increased above 30 cm. Molybdenum showed no pattern. The Fe/Mn ratios based on atomic absorption data decreased above 30 cm.

Illite was the dominant clay mineral at all depths.

Rate of Sedimentation

Changes in amounts of metallic elements present in the sediments as well as changes in the number and types of diatom valves (silicon cell walls) present occurred at the same depths in the core samples.

Mining, the most likely cause of the increase of metal concentrations in the sediments, began around 1884 in the Coeur d'Alene region. Using 1884 as the base year and 1971 as the closing year, an approximate rate of sedimentation can be calculated for the 87 year interval.

Significant shifts in metal concentrations was found in all the cored sediment samples except core 3, 189 m off delta. Core 3 penetrated only to the 60 cm depth. The shift in core 1 (delta area) occurred between the 79.5 and 70 cm sediment depth. In core 2 (off the delta area), the shift was between 72.5 and 62.5 cm. In core 4, 1.6 km off Camp Easterseal, the shift occurred between 40 and 30 cm. Core 5, from 274 m off Camp Easterseal, shifted between 30 and 20 cm.

Diatom analysis of core 2, center off delta, and core 5, 274 m off Camp Easterseal (discussed in the following section), showed population shifts at the same depths as the metal shifts.

The diatom shift observed was possibly caused by metal toxicity and the increase in water turbidity that accompanied the mining activity in the Coeur d''Alene Mining District. Many of the Asterionella cells in the strata above the shifts had deformed and twisted frustules (Condit, 1972).

The metal concentration and diatom shifts indicate a pronounced change

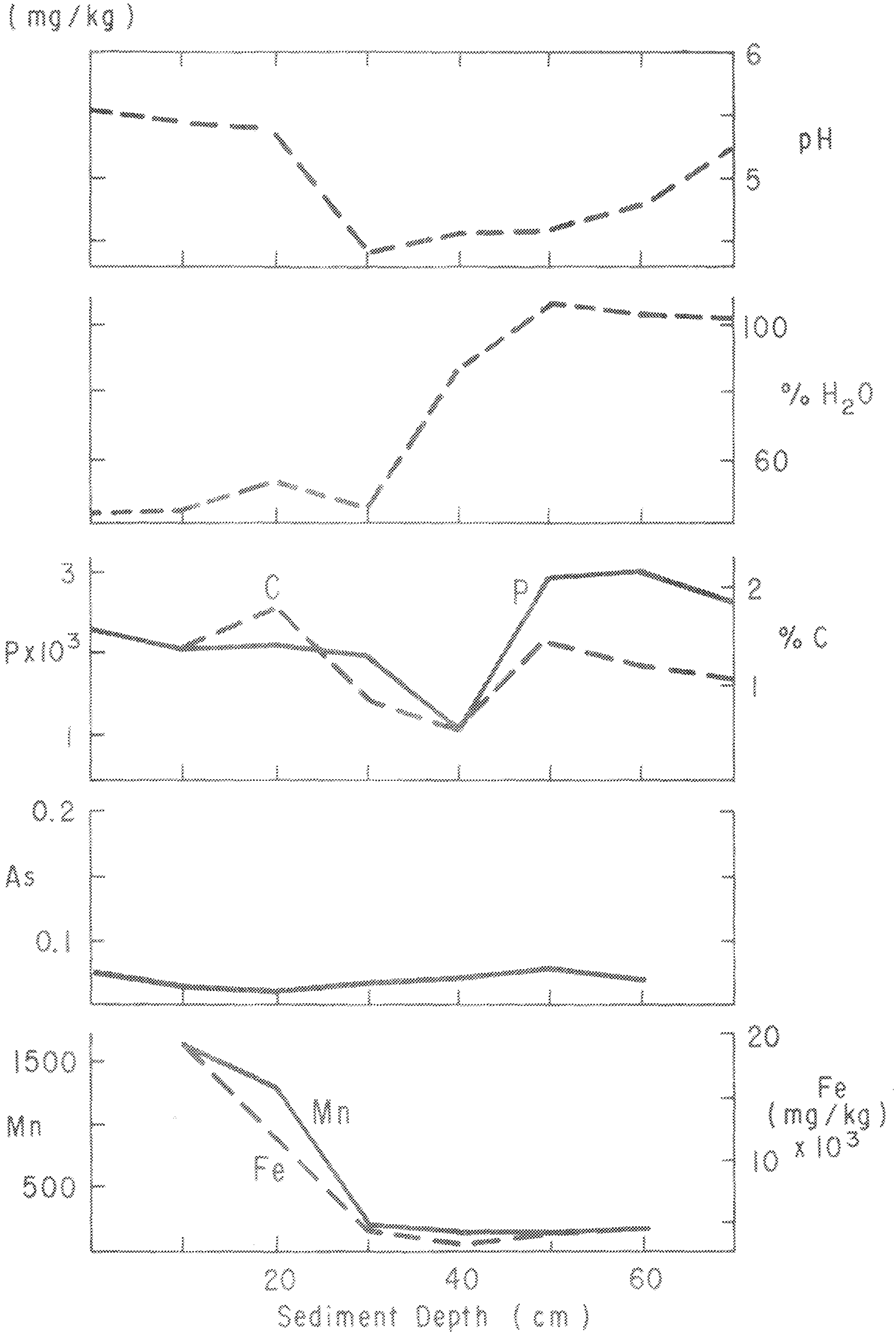


Figure 31(a). Standard Chemical and Atomic Absorption Analysis of Core 5 (274 m off Camp Easterseal, 17.9 m water-depth). (Dunigan, 1972.)

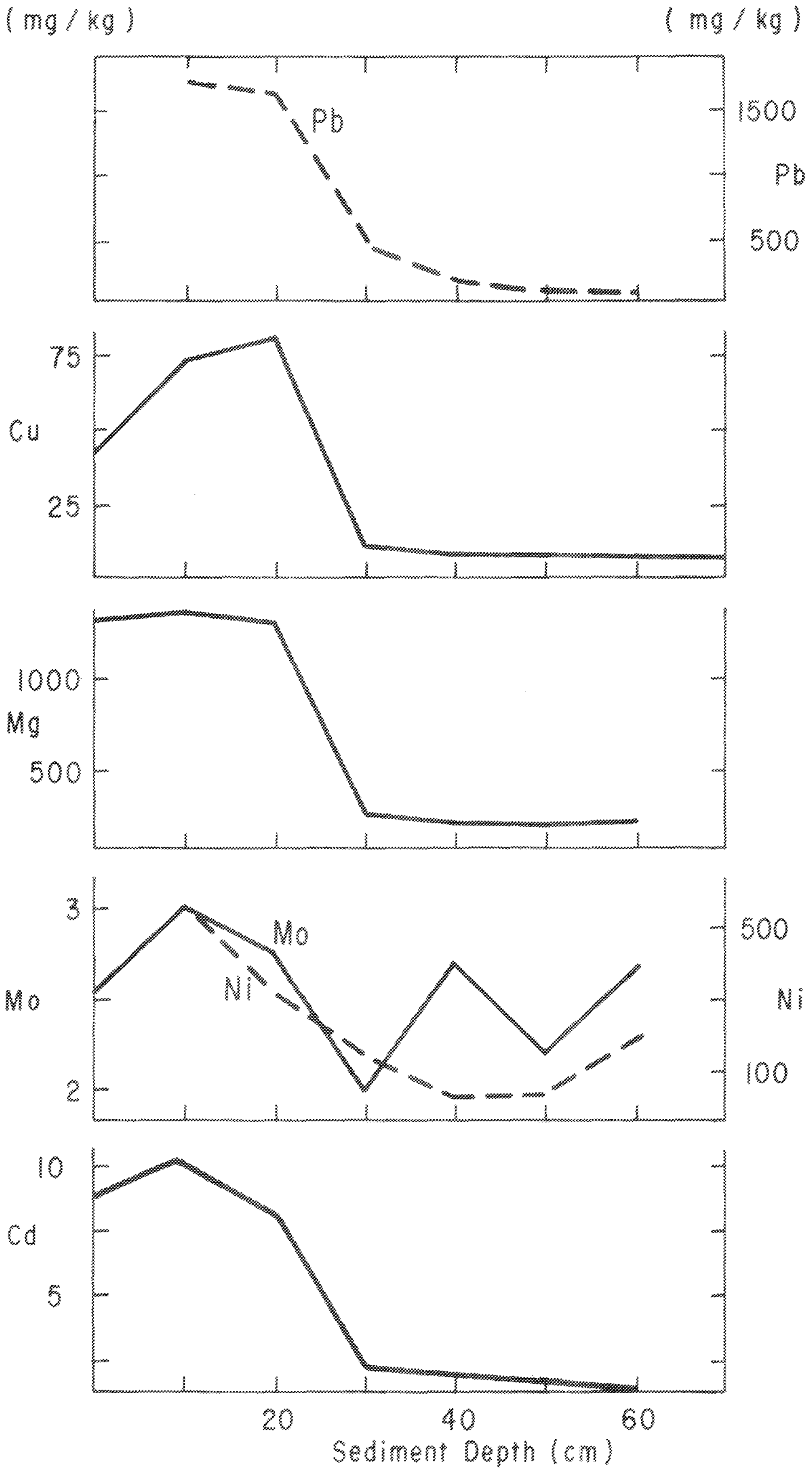


Figure 31(b). Atomic Absorption Analysis of Core 5 (274 m off Camp Easterseal, 17.9 m water-depth). (Dunigan, 1972)

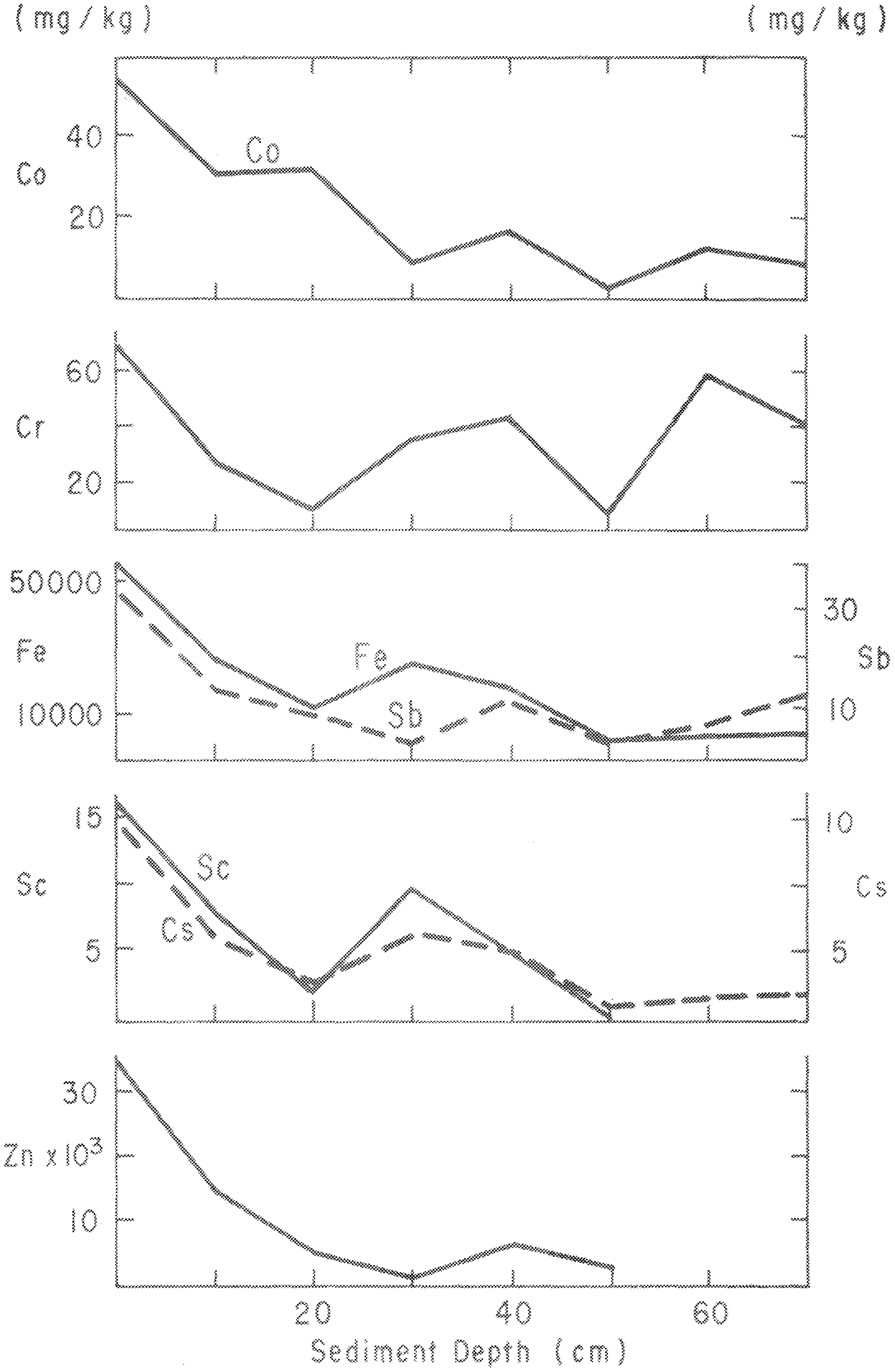


Figure 31(c). Neutron Activation Analysis of Core 5 (274 m off Camp Easterseal, 17.9 m water-depth). (Dunigan, 1972.)

in the composition of the lake, probably reflecting a change in the composition of the waters feeding the lake. Since this shift occurred in all cores, the difference in depth of occurrence indicated different rates of sedimentation.

As stated, the metallic shift in core 1 was between 79.5 and 70 cm sediment depth so the depth of 74.75 cm was used as an approximation of the actual shift. The approximate rate of sedimentation was .86 cm per year at this point.

The shift in core 2 was between 72.5 and 62.5 cm. Thus, 67.5 cm was used as an approximate depth of the shift. The 66 cm level appeared to postdate the shift. The approximate average rate of sedimentation was .77 cm per year at this point.

Core 4 shifted between 40 and 30 cm. The average was 35 cm, giving an average rate of sedimentation of .40 cm per year at this point.

Core 5 shifted between 30 and 20 cm. The average was 25 cm, giving an approximate average rate of sedimentation of .28 cm per year at this point.

The decrease in sedimentation rate with distance from the mouth of the Coeur d'Alene River reflects a particle size differential. Larger particles tend to settle nearer the mouth of the river. Smaller particles tend to settle nearer the middle of the lake or wherever the current is at a minimum.

Sedimentation rates before 1884 could not be approximated because no reference point existed. Prior to 1883, little development occurred in the Coeur d'Alene area. The cores were not deep enough to show any volcanic ash deposits used to date older sediments. Core 3 was not deep enough to show the metal shift of 1884.

Sands predominated in the delta cores 1, 2 and 3. Clays were more common in the farthest cores from the mouth of the river cores 4 and 5. Sand made up a higher percentage of the sediment in core 3 than in the others.

The color of the sediments were also variable with core location. Orange-gray was common in the upper strata of the delta samples cores 1 and 2. Dark brown was more common below the shift. Cores 3, 4, and 5 were dark brown throughout.

Diatom Populations

There are two basic types of diatoms in aquatic systems: round (order Centrales) and elongate (order Pennales). Order Pennales can be further broken down into four tribes: Araphidineae (A), Biraphidineae (B), Monophidineae (M) and Raphidioidineae (R). Members of the order Centrales (C) and tribe A are considered to be primarily free floating or planktonic, while the majority of the pennate tribes (B, M and R) are chiefly of shallower depths or littoral in origin (Stockner, 1971).

In general, the order Centrales in considered to be indicative of oligotrophic waters since it reaches its greatest diversity and numbers in low nutrient environments. Nygaard (1949) was one of the first to use the ratio of Centrales to Pennales as an indicator of lake enrichment. Stockner and Benson (1971) proposed a ratio of Araphidineae to Centrales as a more sensitive indicator of lake trophy. Based on studies of the ratio of A/C in sediments of numerous lakes, he suggested the following broad trophic classification for temperate lakes:

Type	A/C
Oligotrophic	0 - 1.0
Mesotrophic	1.0 - 2.0
Eutrophic	>2.0

However, Stockner's lakes were either little influenced by cultural enrichment, or those that were received nutrients derived primarily from domestic sewage and/or agricultural runoff. The composition of the wastes received by Lake Coeur d'Alene are of a different nature. They are, relatively speaking, lower in essential plant macronutrients such as nitrogen and phosphorus, while being very high in the heavy metals--many of which are essential for primary production at micro-levels, but become inhibitive or toxic to many species or groups of algae at levels above the amount optimal for growth. The effects of high metal concentrations on a total trophic system, and specifically on algal communities, are little understood.

Two cores, #2 in the delta and #5 in the lake, as mentioned in the preceeding section, were examined for diatoms. Although species compositions were comparable in both cores, shifts in rank order of abundance occurred in the two cores at different depths (Figures 32 and 33). Cyclic diatoms

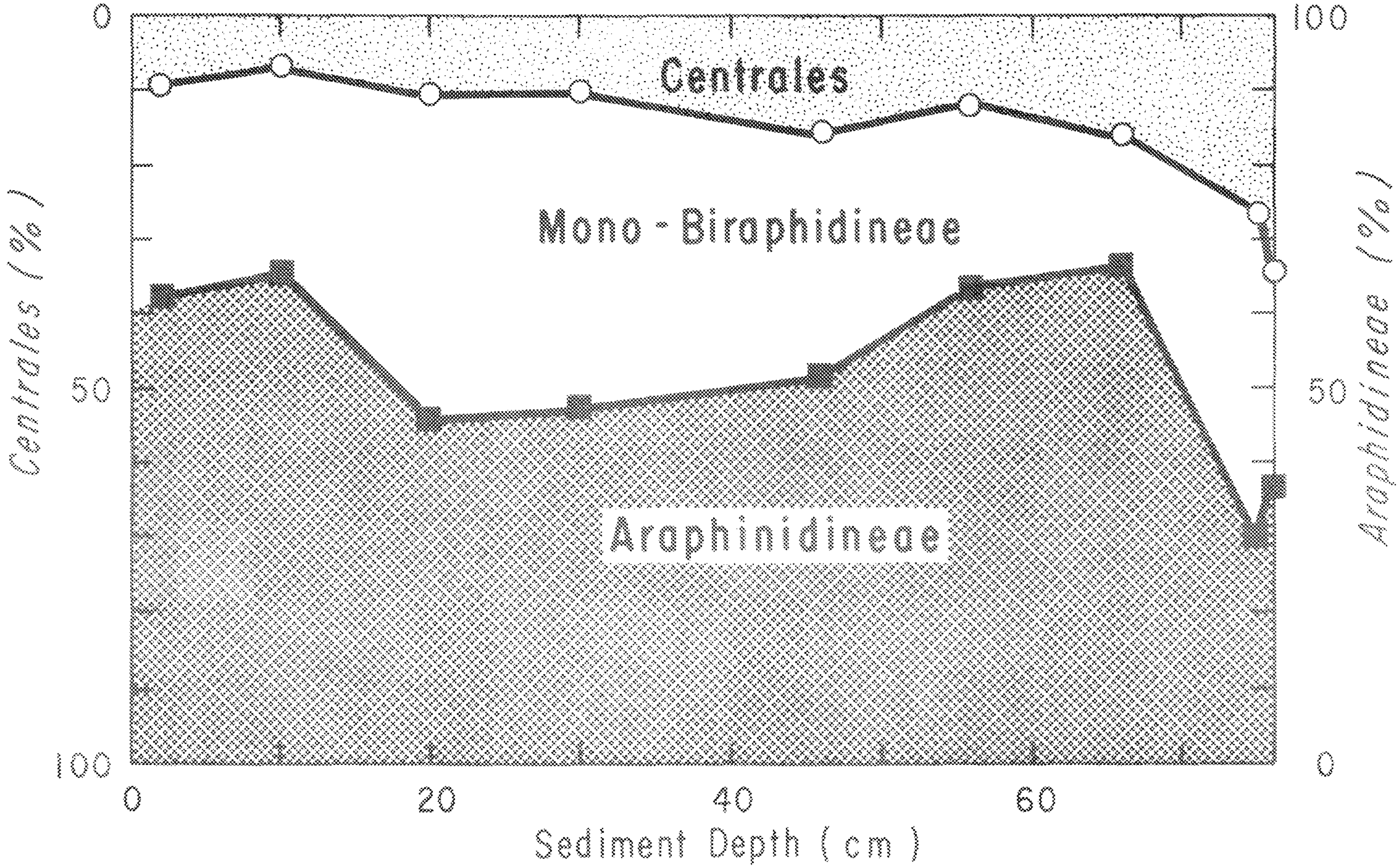


Figure 32. Percent Diatom Abundance of the Araphidineae and Centrales with Depth in Sediment. Core Taken 23 September 1971 in 18 m of Water on the Coeur d'Alene River Delta. (Condit, 1972.)

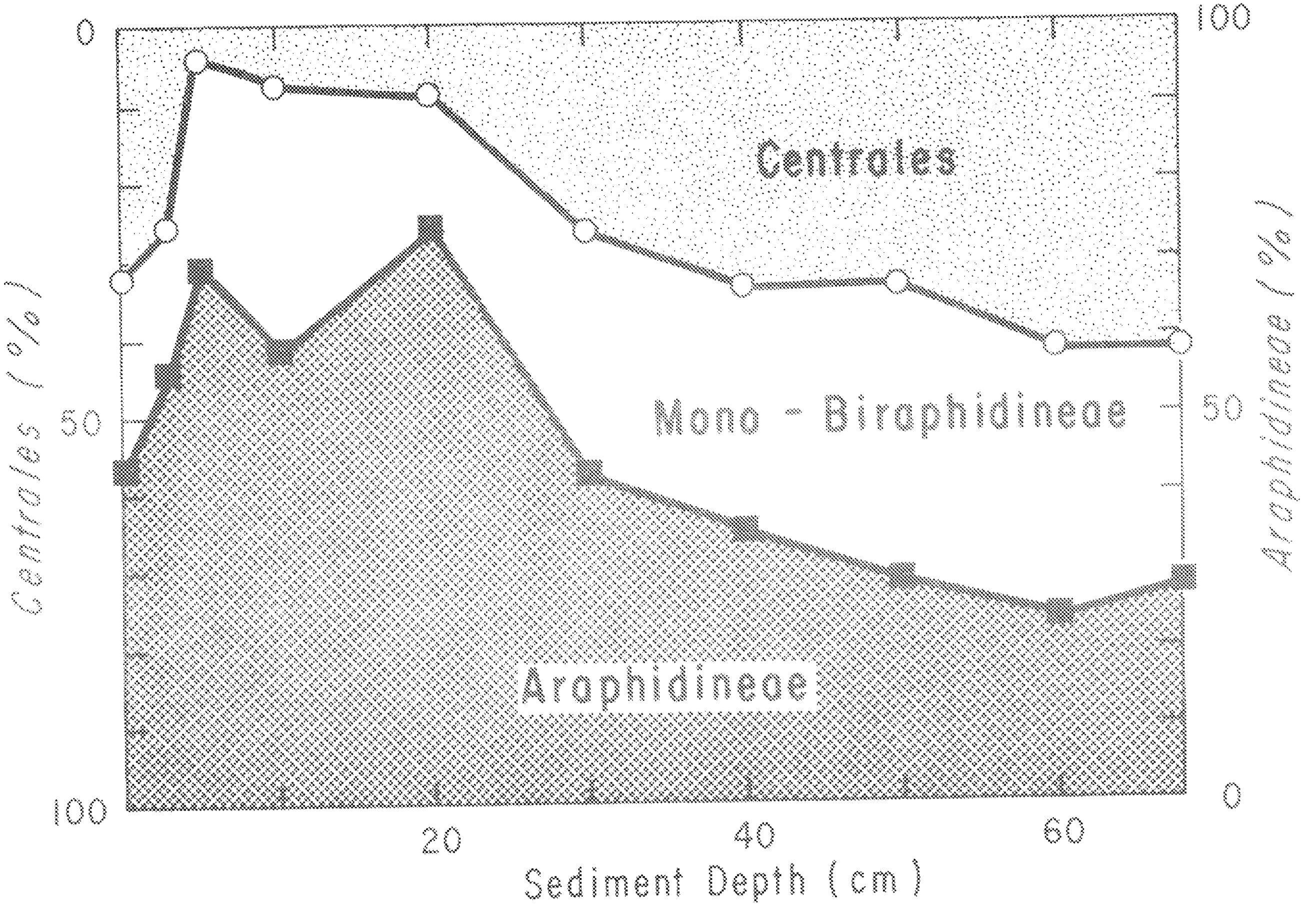


Figure 33. Percent Diatom Abundance of the Araphidineae and Centrales with Depth in Sediment. Core Taken 23 September 1971 in 18 m of Water, 274 m off Camp Easterseal. (Condit, 1972.)

(Centrales) declined sharply at and above the 75 cm depth in the delta core and 30 cm depth in the lake core. The A/C ratios in the delta core increased from 0.93 at 76 cm to 9.5 at 10 cm, indicating a change in water quality more favorable to the araphidinate diatom populations. In the lake core the A/C ratios increased gradually from 0.72 at 68 cm to 1.60 at 30 cm and more rapidly thereafter to 18.7 at 5 cm. These shifts in diatom assemblages correspond with the shifts in metal concentrations observed between the 72.5 and the 62.5 cm depths for the delta core and between the 30 cm and the 20 cm depths for the lake core (Table 10).

A rapid improvement in the A/C ratios of the lake core appears at the 3 cm level as well as in the surface sediments with A/C ratios of 3.65 and 1.7, respectively. This trend is also shown to a lesser extent in the delta with A/C ratios of 9.5 at 10 cm and 6.6 at 2 cm. This trend may reflect changes in waste disposal practices instituted by the mining industry in 1968 such as the construction of settling ponds to impound mill wastes.

Table 10. Significant changes in the diatom assemblages. (Condit, 1972.)

Type of Change	Depth at which change occurs (cm)	
	Delta core	Lake core
(1) Sharp Centrales decline	75-66	30-20
(2) A/C ratio >2.0	75-66	30-20
(3) *M. italica* replaces *M. distans* as dominant cyclic diatom	66	20
(4) *A. formosa* replaces *M. italica* as 1st in rank order of abundance	66	20
(5) *T. fenestrata* replaces *A. formosa* as 1st in rank order of abundance	56	10
(6) Sharp decline in A/C ratios (Lake core <2.0)	2	3

II. Coeur d'Alene River

A. Benthic Invertebrate Communities

Water Quality Conditions

Benthic invertebrates and water samples have been collected and substrate conditions have been observed during the September low flow period at eight stations (Figure 14) in the Coeur d'Alene River for four years (1968-1971). The first collection was made in 1968 to determine conditions prior to the impoundment of mine tailings. Subsequent collections were made to determine the effect of the predicted reduction in silt load (95%) on the structure of the benthic communities (Savage, 1970). The water quality parameters sampled by Mink *et al* (1971) for the years 1968-1969 are shown in Table 11. The major change that occurred in water quality during the four years of study has been the reduction in turbidity. Specific conductivity and metal concentrations have remained high, but dissolved oxygen and pH are comparable to those at a control station (#34) on the North Fork. The fertilizer plant located near station 13 (about 10 km above the confluence with the North Fork) is apparently a source of a considerable amount of nutrients. Mink (1969) measured nitrate and phosphate levels of 1.16 and 0.74 mg/l respectively at this location in the fall of 1969.

Substrate Conditions

All collections were made in riffle areas where a cobble substrate well suited to bottom dwelling animals was present. The water depth was 15-30 cm (Figure 19). Turbid conditions obscured the substrate in the South Fork and main stem in 1968. The substrate cobbles at station 13 were buried under 15 cm of fine sediments (25% organic, 75% inorganic) while the cobbles at station 9 were coated and impacted by fines.

By the fall of 1969, the fines had been washed away by the current leaving only a thin coating on the cobbles at both stations. In subsequent years another major change in substrate conditions was observed as a dense algal growth consisting of *Oscillatoria*, *Chlamydomonas*, *Chlorella* and *Nitzchia* covered the cobbles. This growth can be attributed to increased light penetration, a stable substrate and moderate to high levels of macronutrients.

Table 11. Chemical and physical parameters at selected stations in the Coeur d'Alene River during low flow, 1968-1971.

Date	Station	Flow m^3/s	pH	D.O. mg/l	Temp. C	Cond. µmhos	Turbidity JTU	Alkalinity mg/l	Zn mg/l	Cd mg/l	Cu mg/l	Pb mg/l
1968 *	North Fork 34	8.04	8.0	9.2	18	58	<25	21	0	-	0	0
	Main Stem 9	12.39	7.1	8.9	16	180	<25	14	4.15	-	0	0
	South Fork 13	3.17	5.5	8.8	17	420	490	3	15.05	-	0	0.8
1969 *	North Fork 34	6.20	7.2	9.0	13	29	<25	28	<0.1	<0.01	<0.1	0.1
	Main Stem 9	9.56	6.2	8.8	14	113	<25	26	5.3	0.05	<0.1	0.1
	South Fork 13	2.89	6.2	8.8	15	220	<25	20	21.0	0.05	<0.1	<0.1
1970 **	North Fork 34	-	7.0	10.2	7	50	-	-	<0.1	<0.02	<0.05	-
	Main Stem 9	-	6.6	10.1	7.5	185	-	-	5.1	0.05	<0.05	-
	South Fork 13	-	6.1	10.1	7.5	525	-	-	17.3	0.2	<0.05	-
	17	-	7.1	9.4	5.5	250	-	-	0.6	-	-	-
	21	-	7.0	11.3	3.0	195	-	-	3.0	-	-	-
	23	-	7.0	10.7	3.0	180	-	-	3.1	-	-	-
	25	-	7.2	11.2	2.5	130	-	-	0.3	-	-	-
	28	-	7.4	10.7	3.0	80	-	-	<0.1	-	-	-
1971 **	North Fork 34	-	6.7	9.9	11.5	46	-	-	<0.1	<0.05	<0.05	-
	Main Stem 9	-	6.4	10.0	12.5	144	-	-	4.2	0.05	0.06	-
	South Fork 13	-	5.7	10.3	12.5	358	-	-	19.9	0.2	<0.05	-

*From: Mink, Williams and Wallace, 1969

**From: L. L. Mink, unpublished data

Community Structure

Diversity in an ecosystem increases where environmental conditions are favorable for a period of time long enough to allow development of a stable and mature community. Whilm and Dorris (1966) found that species diversity of stream benthos, as expressed by the Shannon diversity index ($\bar{d}$), was greater than 3.0 in a clean productive stream and dropped to 1.0 or less in a heavily polluted stream. This method applied to the Coeur d'Alene River resulted in the values listed in Table 12.

The North Fork control station as well as station 28 on the South Fork, which lie above any waste effluents, have diversity values consistently above 3.0. There were many species present and a high density of individuals per square-foot sample. No organisms were found in pre-impoundment collections from the South Fork at station 13 and only one subfamily of midge fly larvae (Chironomidae: Orthocladinae) was observed at station 9, five miles below the confluence of the North and South Forks. In 1969 midge fly larvae had colonized the station 13 riffle and two new species were observed at station 9--a riffle beetle (Elmidae) and *Atherix variegata*, the larva of the snipe fly. The midge larvae are mostly vegetative in their feeding habits while *A. variegata* is a carnivore, most likely feeding on the midges. Little change in faunal composition or diversity values was observed at either station during the next two years. An increase in density in 1970 was followed by a decrease in 1971, probably reflecting the degradation of the habitat caused by the algal mat.

Stations 17, 21 and 23 are located between Smelterville and Wallace on the South Fork. The water quality at these stations was similar to that at station 13 except for lower Zn concentrations (Table 11). The fauna in this section of the river consisted primarily of Chironomidae and the mayfly *Baetis tricaudatus* with the occasional presence of single individuals of other species. Attached algal growth was present on the substrate cobbles at each of these stations. Station 25, immediately above Wallace and the mouth of Canyon Creek, showed a considerable improvement in substrate appearance and faunal composition. The benthos consisted predominantly of dipterous species, but stoneflies, mayflies and caddis flies were also present. The diversity value was 2.225.

Table 12. Diversity ($\bar{d}$), density (N) and number of species (s) of macroinvertebrates at selected stations in the Coeur d'Alene River, 1968-1971.

Date	Station	$\bar{d}$*	N*	s**
Sept. 8, 1968	North Fork 34	3.329	368	27
	Main Stem 9	0	125	1
	South Fork 13	-	-	-
Sept. 6, 1969	North Fork 34	3.481	163	29
	Main Stem 9	0.214	176	3
	South Fork 13	0	36	1
Aug. 28, 1970	North Fork 34	3.356	385	33
	Main Stem 9	0.192	312	4
	South Fork 13	0.030	138	2
	17	0.734	71	4
	21	1.328	25	5
	23	0.199	33	2
	25	2.225	155	13
	28	3.488	170	20
Oct. 1, 1971	North Fork 34	1.328	349	22
	Main Stem 9	0.986	34	2
	South Fork 13	0.073	131	4

*Average number of organisms per 0.1 m^2 sample (Surber sample).

**Value for a sample size of 0.5 m^2 at stations 9, 13, and 34 and 0.2 m^2 at stations 17, 21, 23, 25, and 28.

B. Heavy Metal Toxicity

Fish and Invertebrates

The lethal effect of heavy metal ions to salmonid fishes has been well documented (Skidmore, 1964). These fish appear to produce a heavy secretion of mucous to rid their systems of metals absorbed from the water. Death follows as a result of gill hyperplasia. Chronic exposure to low levels of metals also results in internal stress reactions. Ellis (1932) noted these reactions and subsequent death of native trout placed in Coeur d'Alene River water containing mine wastes. Tolerance depends on such factors as stage of development and water hardness. Sappington (1969), using unpolluted North Fork water with an alkalinity of 24 mg/l as $CaCO_3$, reported 96-hour TLm values for Cutthroat trout fingerlings of .09 mg/l Zn. Zinc concentrations in the altered portions of the Coeur d'Alene River greatly exceed this level (Tables 11 and 13).

Less is known of the effect of metals on invertebrates; however, some insects seem to be quite tolerant to high concentrations of metals. Warnick and Bell (1969), in bioassay tests on mayfly, stonefly, and caddis fly nymphs, found these organisms to be unaffected by up to 64 mg/l of most metals. Jones (1940) found a diverse benthic community in a stream polluted by mine wastes and containing 60 mg/l Zn. In the Coeur d'Alene River, midge fly larvae and pupae were found where Zn concentrations were as high as 22 mg/l and several other insects were found at concentrations to 4 mg/l (Savage, 1970).

Phytoplankton

Photosynthesis by phytoplankton produces the majority of organic matter necessary for the development of higher trophic levels, yet few attempts have been made to assess the impact of mine pollution on phytoplankton production. The occurrence of occasional high productivity pulses in the Coeur d'Alene River precludes the possibility of all algae being chronically suppressed by metals. Figure 34 shows the relative differences in phytoplankton productivity in the Coeur d'Alene and St. Joe Rivers (Wissmar, 1972).

Previous research on the toxic effects of heavy metals to algae has dealt primarily with the effects of Cu and $CuSO_4$, the latter of which is a

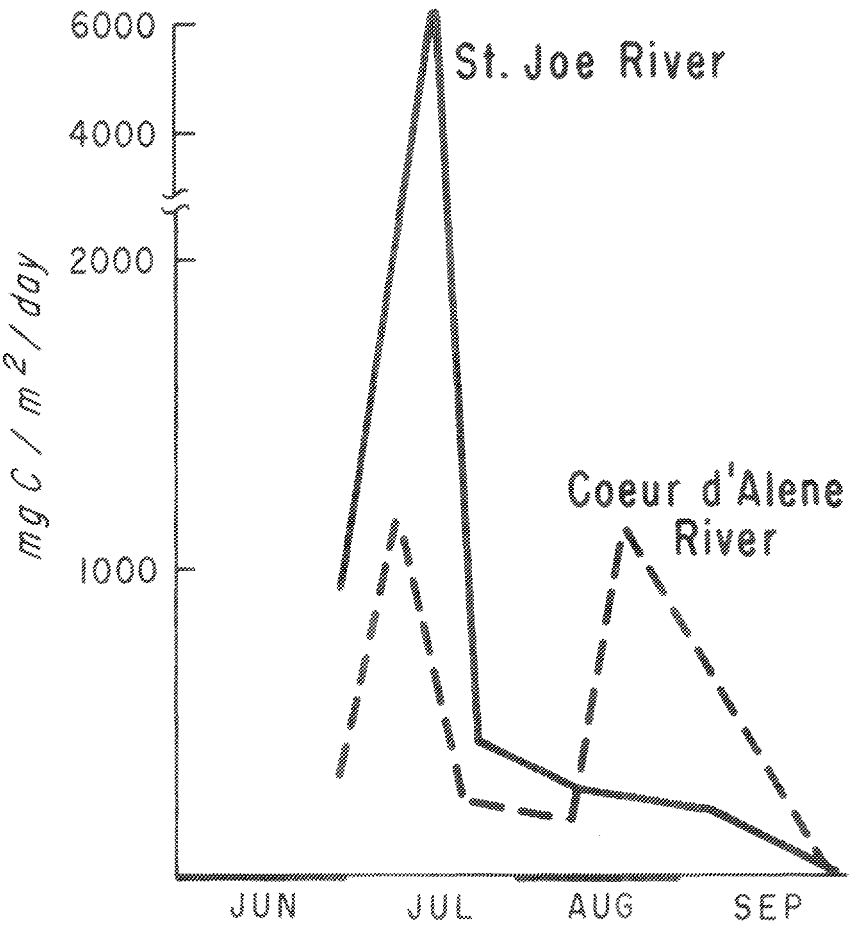


Figure 34. Variation in Primary Productivity (mg C/m^2/day) for the Coeur d'Alene River and St. Joe River. (Wissmar, 1972).

commonly used algicide. Wissmar (1972) studied the effects of Cu, Cd, and Zn, alone and in combination, and the effect of Coeur d'Alene River water on carbon uptake by nannoplankton from Coeur d'Alene Lake. Treatment by separate metals produced the following toxic order: Cu>Cd>Zn. Inhibitory effects increased with the addition of more than one metal with the maximum inhibitory effect at highest concentrations of all three metals (1.5 mg/l Zn, .75 mg/l Cu, and .3 mg/l Cd). Copper had an overriding effect on all treatments but appeared to be synergistic with Zn.

Increased volumes of Coeur d'Alene River water (up to 50%) added to lake water at the same time Zn and Cu were added decreased the inhibitory effect of the metals. Increased volumes of river water corresponded to increased concentrations of Ca, Mg, Na, K and Mn ions. These cations appear to compete with Zn and Cu for available exchange sites on certain enzymes, thus the antagonistic effect. For this reason, algae can be controlled with lower concentrations of $CuSO_4$ in soft water than in hard water and fish can tolerate higher concentrations of metal ions in hard water.

The effects of Cu, Cd, and Zn and Coeur d'Alene River and Lake water on the growth of the green alga Selanastrum capricornutum were evaluated as part of this research program. The data in Table 13 indicates the toxic concentrations of Cu, Cd, and Zn for S. capricornutum in AAP; BT medium. Growth rates of cultures treated with these metals are presented in Figures 35, 36, 37, 38, 39, 40 and Table 14. The most noticeable effect is a shift in the lag growth phase with increasing metal concentrations. A 24-hour extension is noted with 50 and 60 μg/l Cu. Seventy μg/l results in a two-day extension and 80 μg/l in a six-day extension. Zinc and Cd treatments result in similar extensions. Higher concentrations of Cu and Cd produced near normal growth rates upon resumption of growth. Zinc concentrations approaching complete inhibition resulted in depressed growth.

The growth rates of S. capricornutum treated with combinations of Zn and Cu and Zn and Cd resulted in growth rates similar to equal concentrations of zinc alone. Combinations of Cu and Cd resulted in greater growth than equal concentrations of Cu, suggesting that Cd inhibits the toxicity of Cu.

Zinc was chosen as the dominant metal in combination tests because of high concentrations of this element existing in the South Fork and main stem

Table 13. Toxic Levels (μg/l) of Copper, Zinc and Cadmium for *S. capricornutum*. (Bartlett, *et al.*, 1973.)

Element	Incipient Inhibition	Complete Inhibition	Algicidal
Copper	50	90	300
Zinc	30	120	700
Cadmium	50	80	650

Table 14. Maximum specific growth rates. Zinc, Zinc and Copper, Zinc and Cadmium. (Bartlett, *et al.*, 1973.)

Zn		Zn + Cu		Zn + Cd	
Conc. μg/l	$\mu_{max.}$ day^{-1}	Conc. μg/l	$\mu_{max.}$ day^{-1}	Conc. μg/l	$\mu_{max.}$ day^{-1}
60	0.197	50/10	0.375	50/10	0.305
70	0.277	50/20	0.375	50/20	0.571
80	0.322	50/30	0.403	50/30	0.403

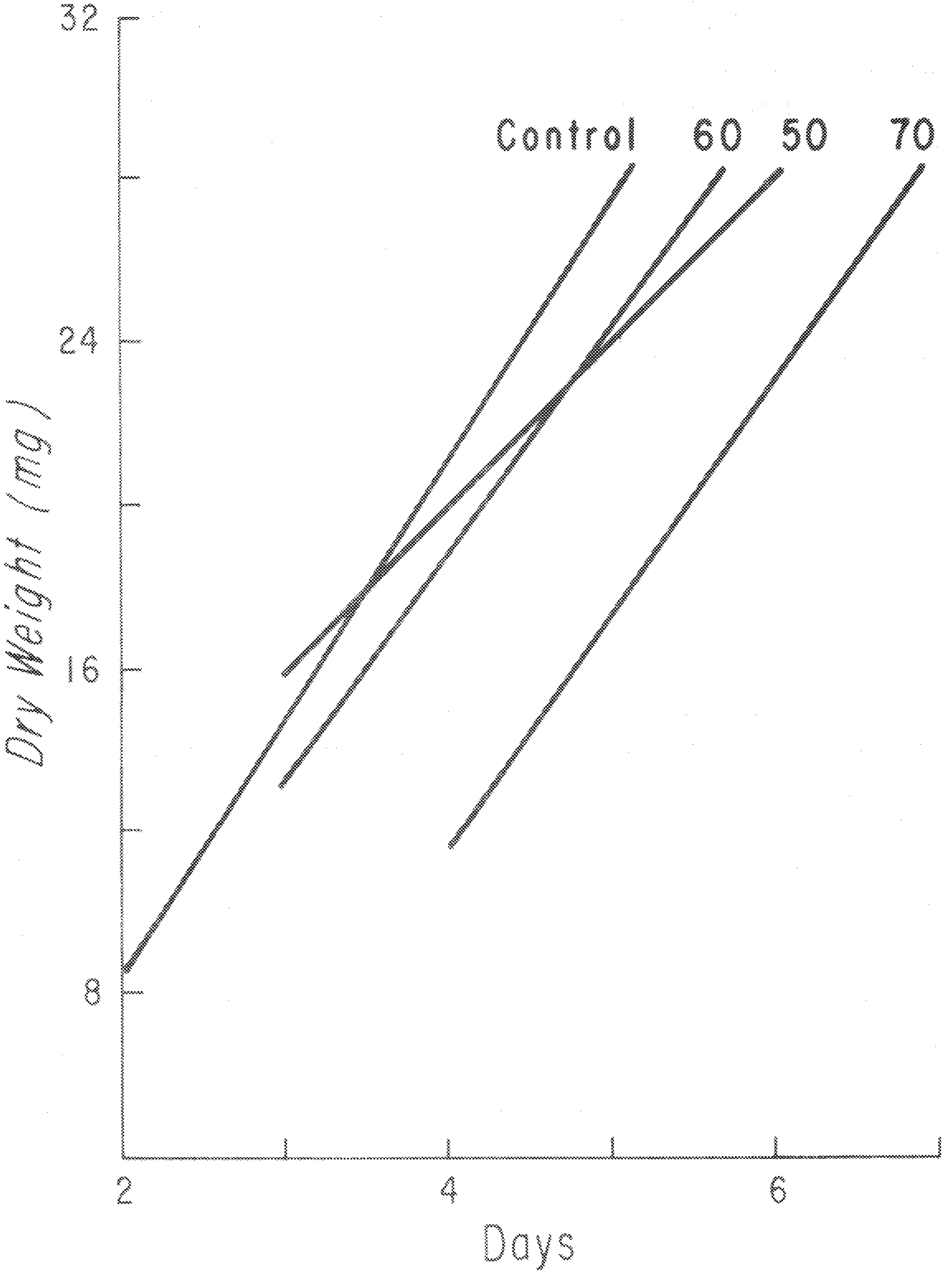


Figure 35. Growth Rates of Selanastrum capricornutum Treated With Copper (μg/l). (Bartlett *et al.*, 1973.)

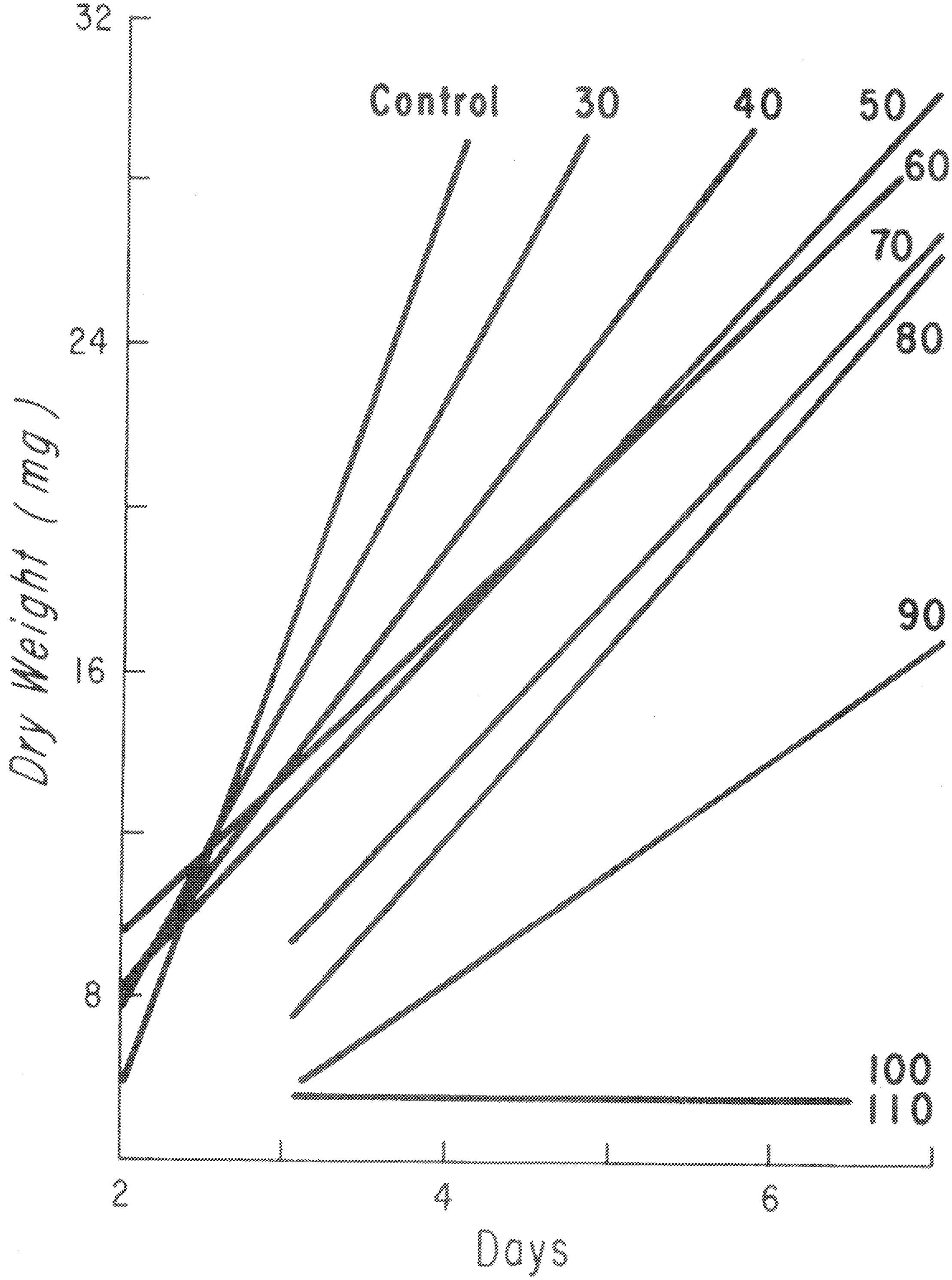


Figure 36. Growth Rates of Selanastrum capricornutum Treated With Zinc (μg/l). (Bartlett et al., 1973.)

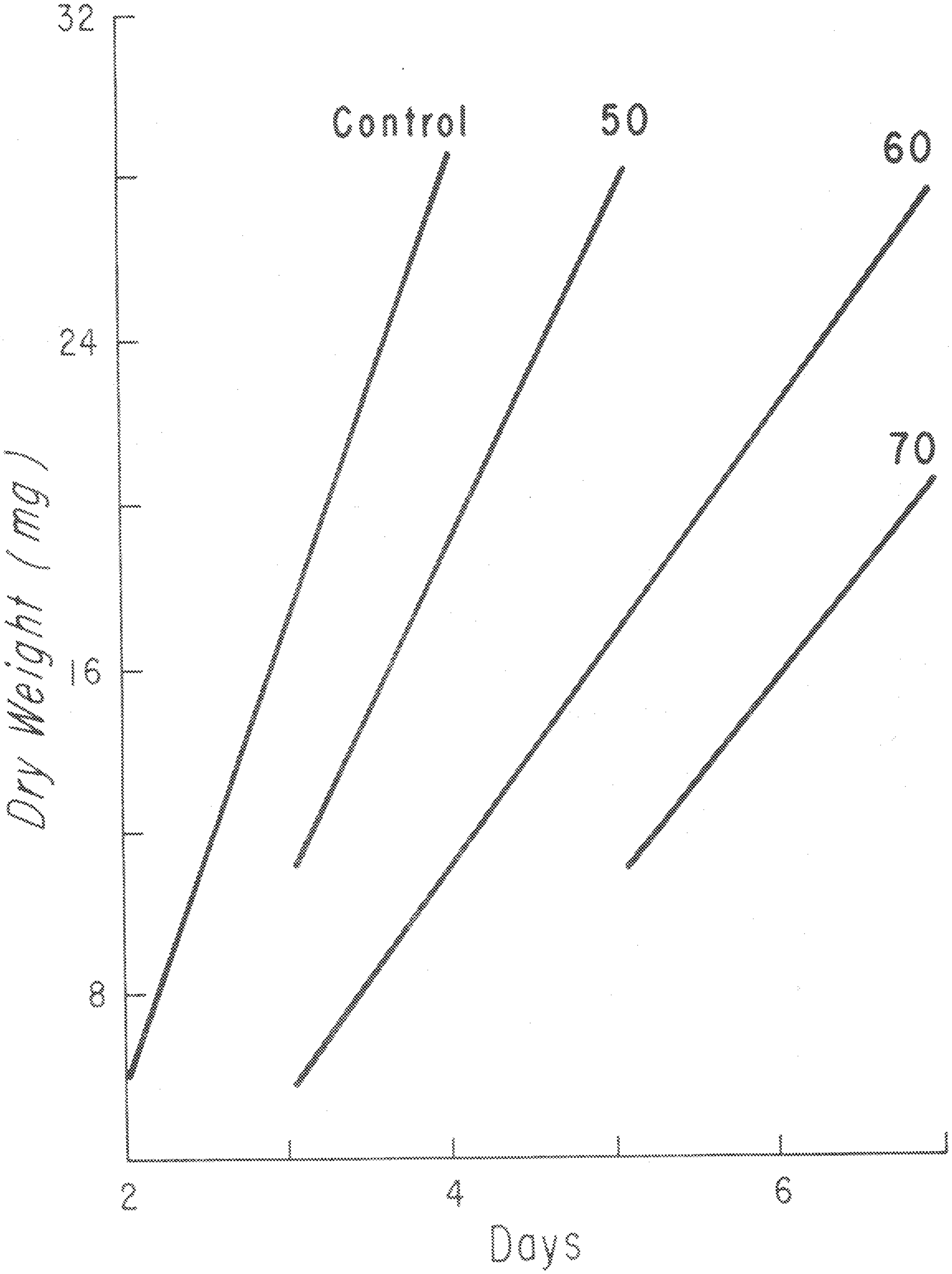


Figure 37. Growth Rates of Selanastrum capricornutum Treated With Cadmium (μg/l). (Bartlett *et al.*, 1973.)

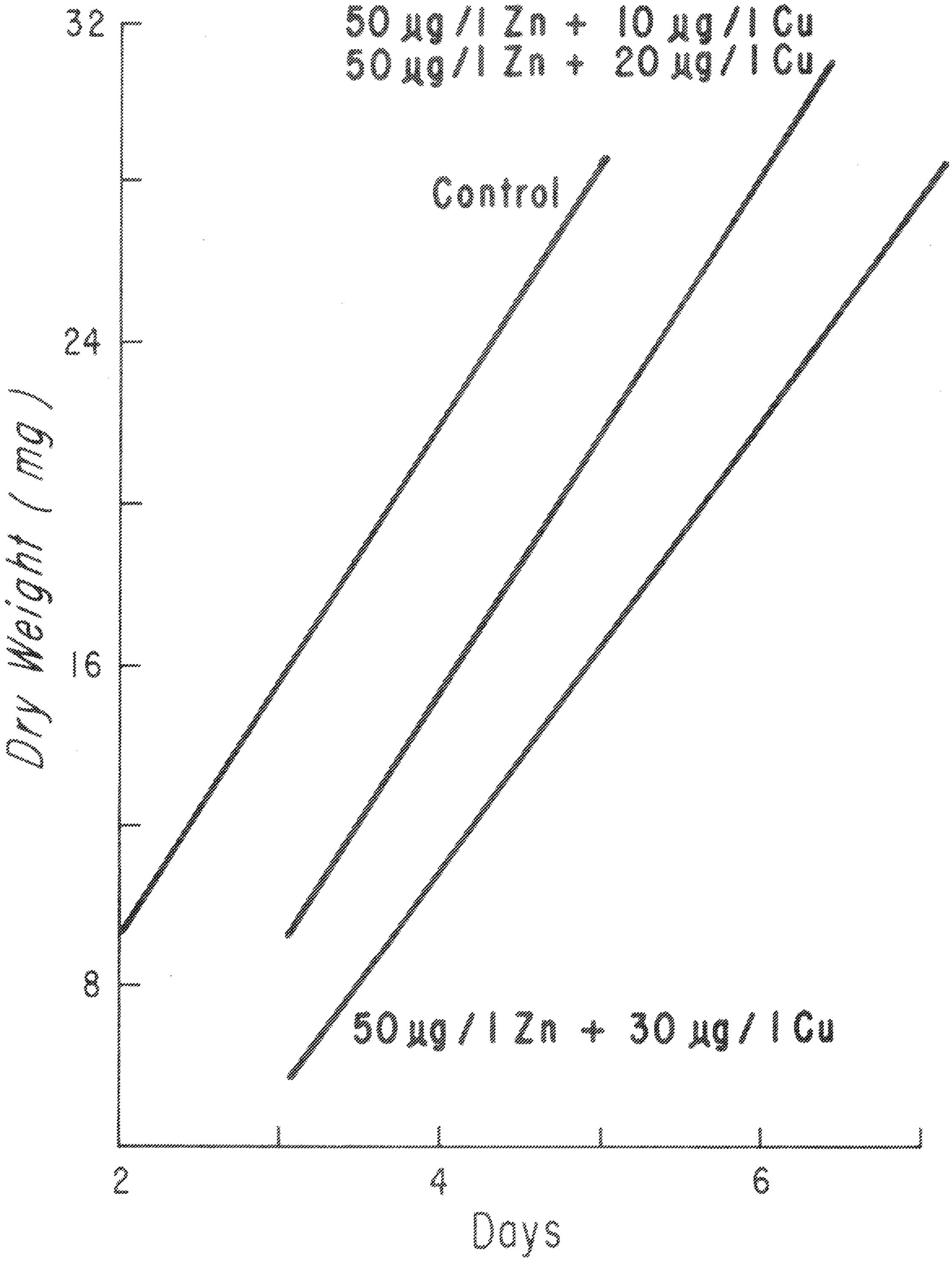


Figure 38. Growth Rates of Selanastrum capricornutum Treated With Zinc and Copper. (µg/l). (Bartlett et al.,1973)

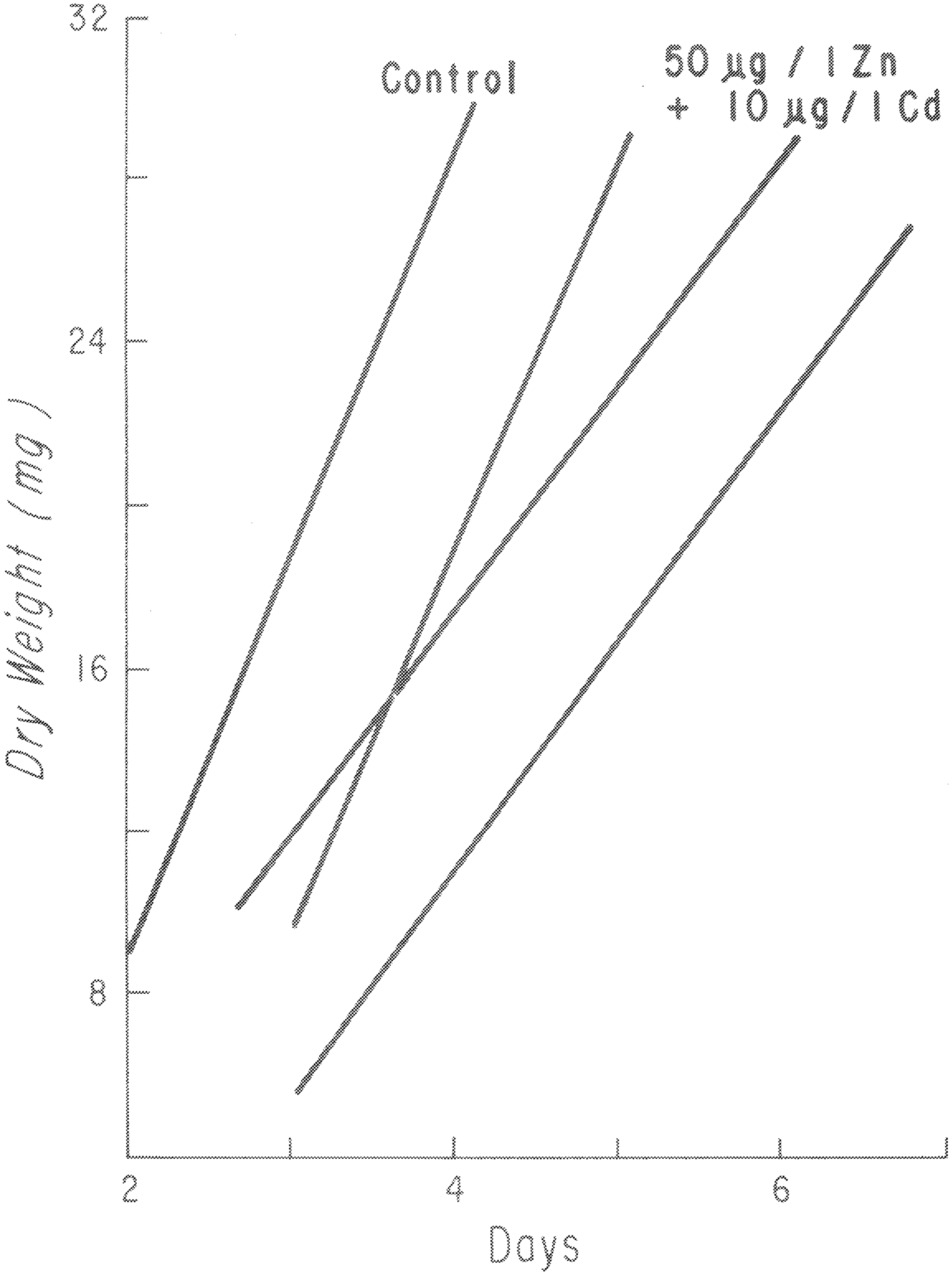


Figure 39. Growth Rates of Selanastrum capricornutum Treated With Zinc and Cadmium. (µg/l). (Bartlett *et al.*, 1973.)

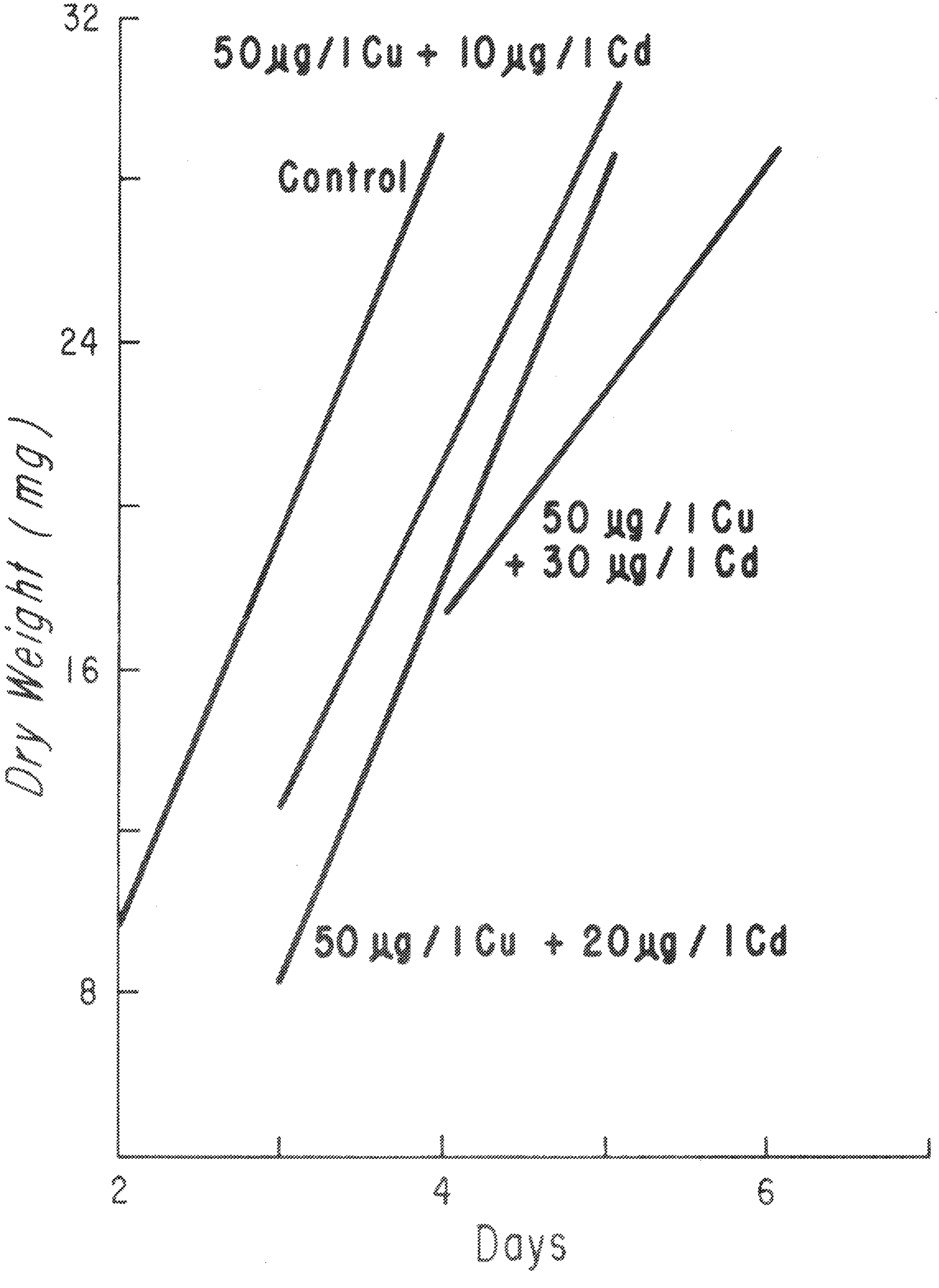


Figure 40. Growth Rates of Selanastrum capricornutum Treated With Copper and Cadmium. (µg/l). (Bartlett *et al.*, 1973.)

of the Coeur d'Alene River at low flows (Table 15). Of the six bioassay water collection sites in the River and Lake (delta), only those taken from Shoshone Park and North Fork supported growth of *Selanastrum*. These are the sites not exposed to heavy metal pollution.

A standardized bioassay test using a sensitive species such as *S. capricornutum* appears to have great value as a means of detecting changes in water quality over a period of time.

Table 15. Heavy metal concentrations in the Coeur d'Alene River system. October 3, 1971. (Bartlett *et al*. 1973.)

Station	Concentration (mg/1)		
	Cu	Zn	Cd
Shoshone Park, Mullan, Idaho	0.0004	0.041	0.0014
North Fork Coeur d'Alene River 0.5 mi. above confluence	0.0004	0.016	0.0027
South Fork Coeur d'Alene River 0.5 mi. above confluence	0.0021	19.1	0.17
Cataldo, Idaho	0.0015	5.5	0.044
Coeur d'Alene River delta	0.0004	1.13	0.010
Spokane Point, Lake Coeur d'Alene	0.0015	0.55	0.005

III. Upper Spokane River

A. Water Quality

Physicochemical Conditions

Nineteen physicochemical parameters were monitored weekly from October to December, 1971 and then monthly for an additional nine month period at five stations on the Spokane River. On occasion two to three more stations were tested for comparative purposes. The station locations are shown in Figure 11 (page 21) and are listed by river mile (RM) in Table C-1, Appendix C.

Temperature ranges showed a continual drop from 15 C in October 1971 to near 2 C in early February 1972. By mid-March a continual rise was measured until highs of near 26 C were noted at the lower stations (RM 100-80). Figure 41 shows composite temperature measurements near the Post Falls station (RM 100). Figure 41 also indicates that discharge from the Post Falls Dam had little secondary effect upon the water temperatures. The controlling effect appeared to be direct solar radiation upon Coeur d'Alene River-Lake, and to some smaller extent upon the Spokane River.

Biochemical oxygen demand appeared to be mainly governed by the runoff during the late winter and early spring months. A secondary BOD high occurred in mid- and late-summer, probably as a result of increased biological activity during that period. In comparing COD measurements, highs were noted during the runoff period with lows in the late summer period. This factor also gives credence to the suggestion that the BOD secondary peak is due to late summer biological productivity. Comparison of both BOD and COD data (Figures 42 and 43) indicated some degradation of the Spokane River water as it passes from Lake Coeur d'Alene downstream toward the city of Spokane. There appeared to be a small but subtle increase in both BOD and COD.

There is a great deal of human activity along the river in this region which include additions of materials from domestic sewage effluent, four lumber mills, and an industrial park. Conductivity (Figure 44) also reflects

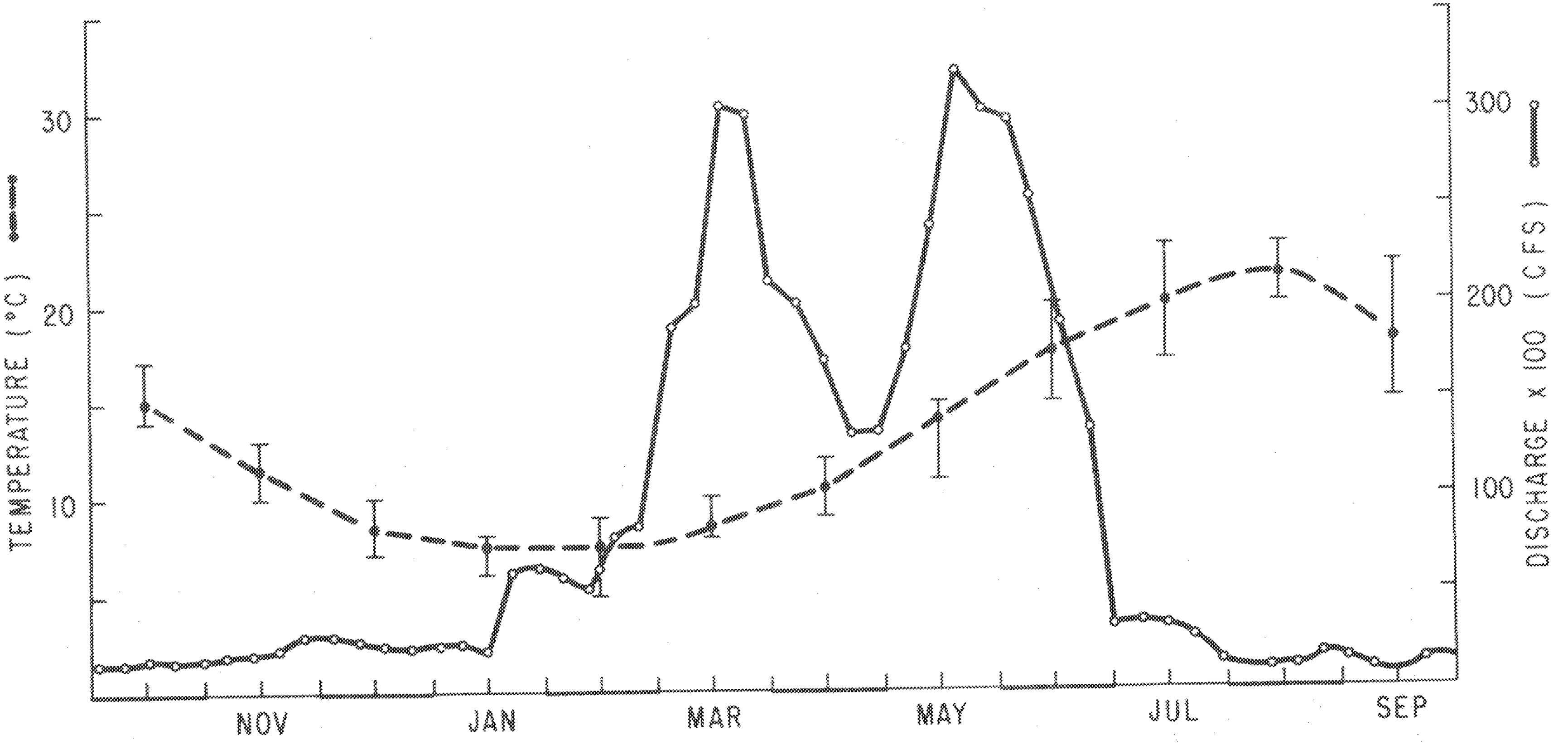


Figure 41. Composite Temperature and Stream Flow below Post Falls Station 1971-72.

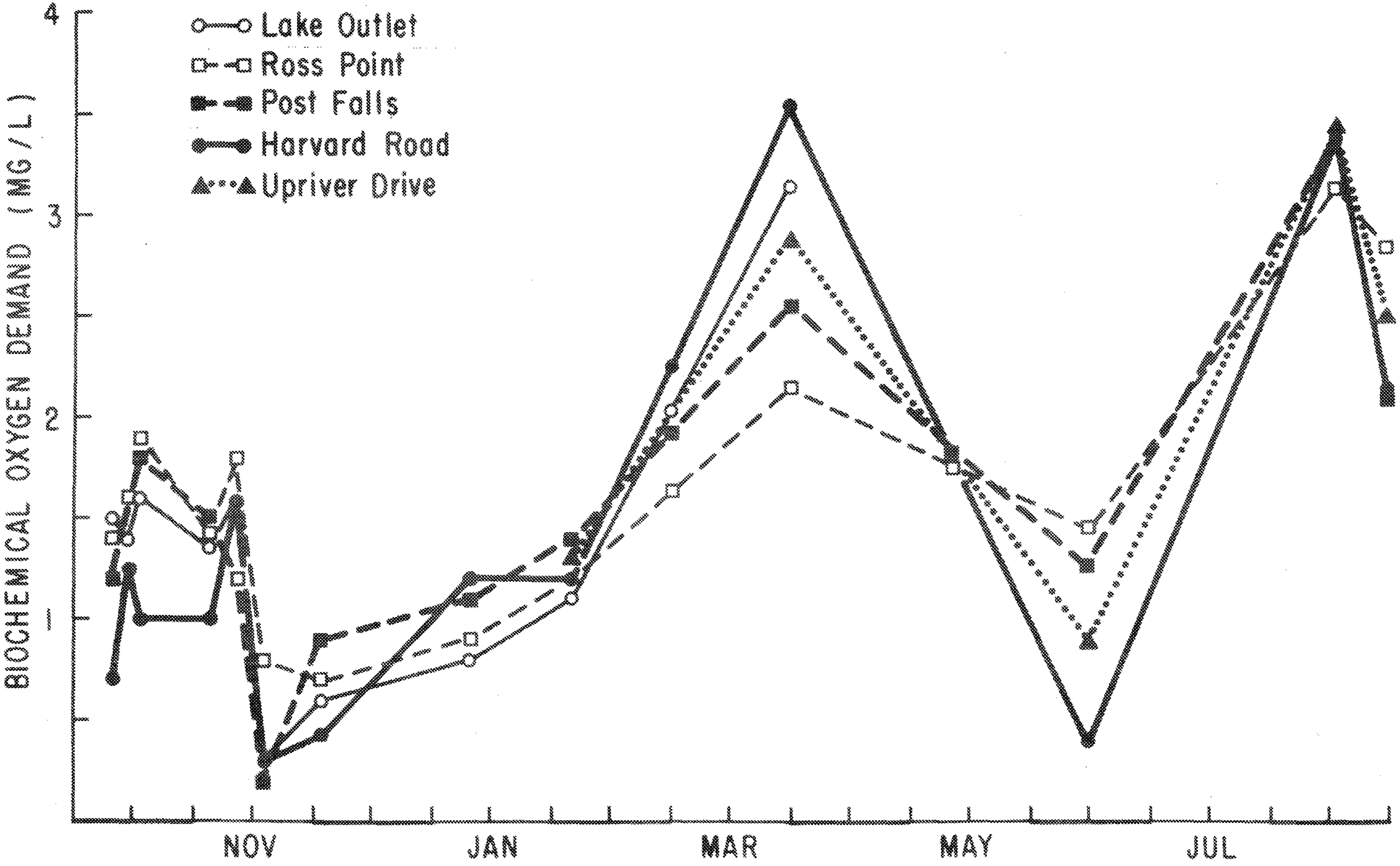


Figure 42. Biochemical Oxygen Demand, Spokane River Stations 1971-72.

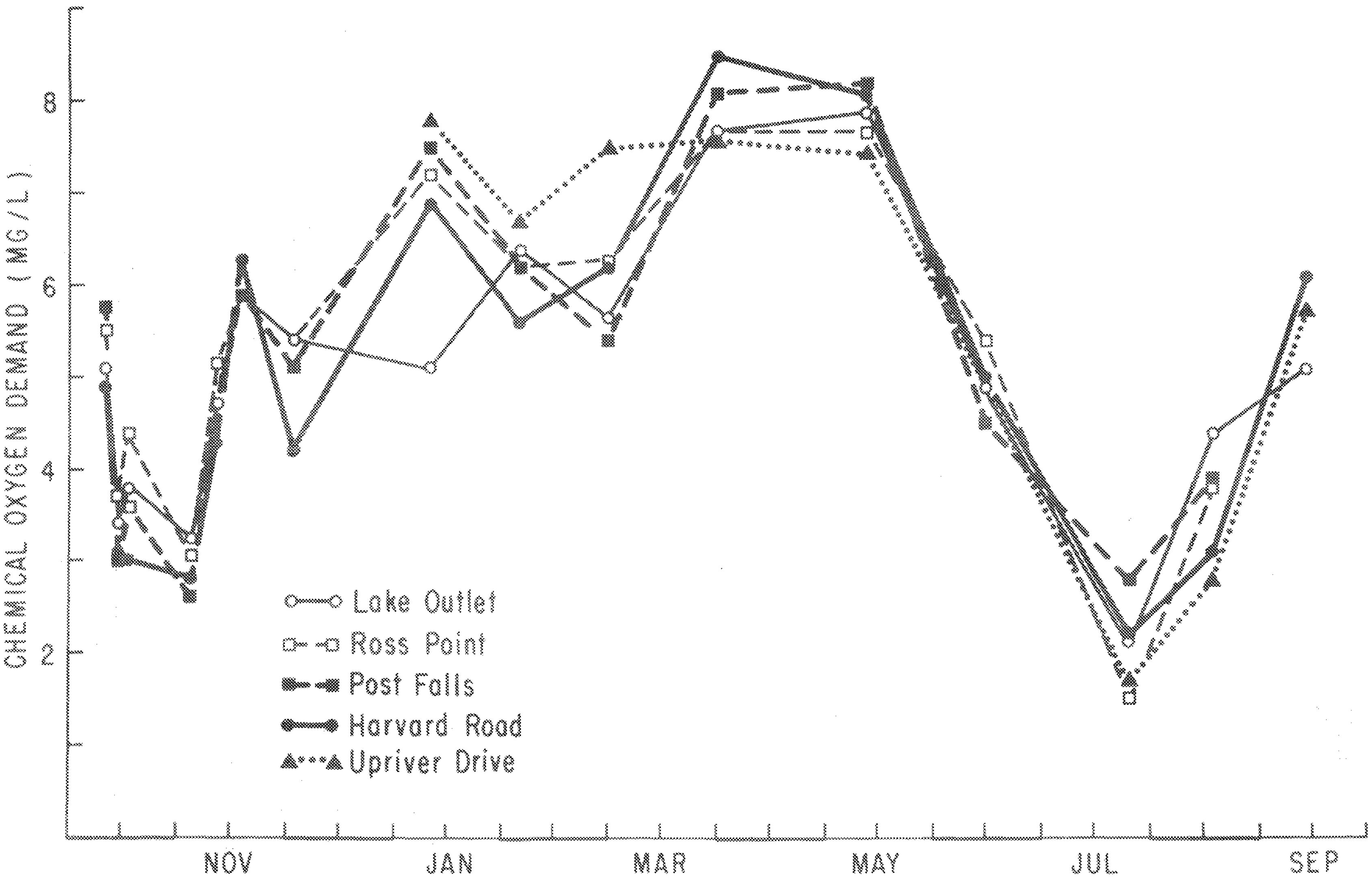


Figure 43. Chemical Oxygen Demand, Spokane River Stations 1971-72.

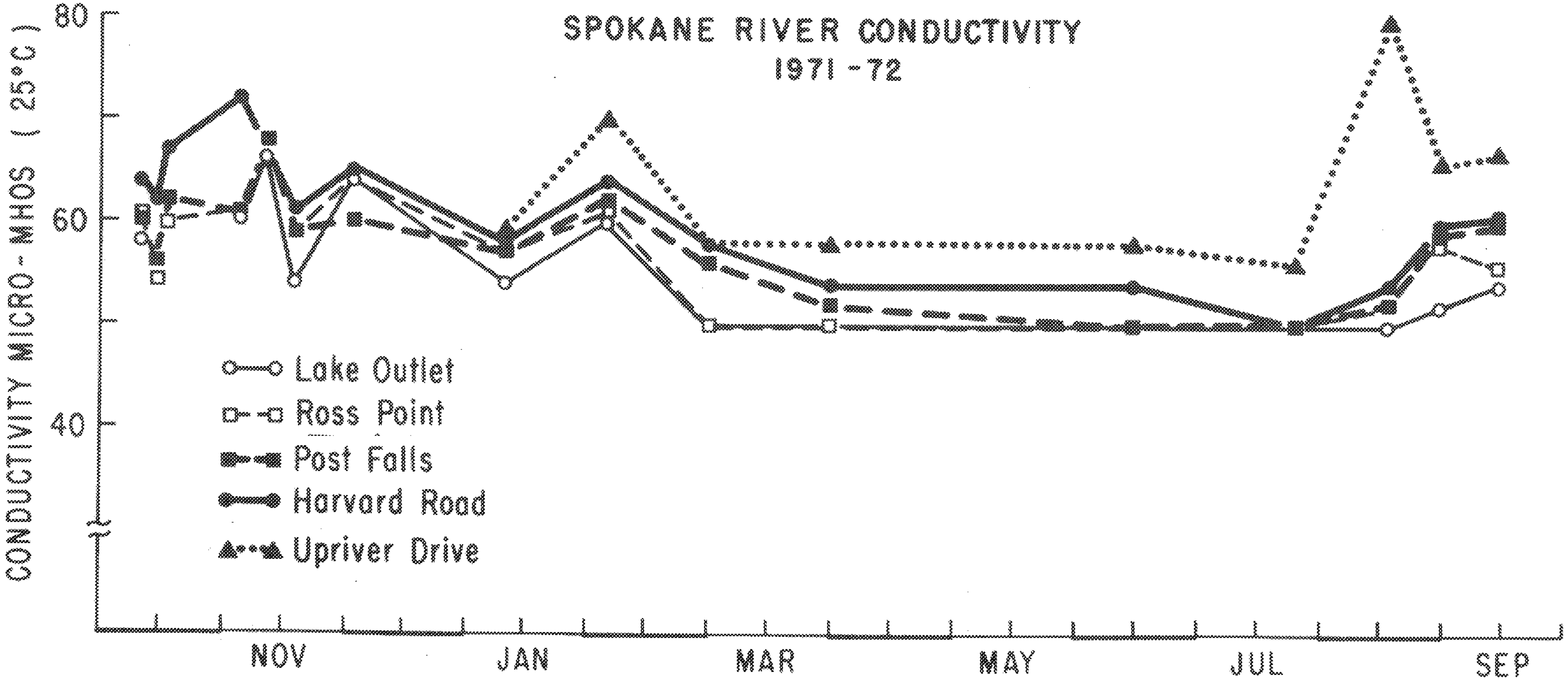


Figure 44. Conductivity Measurements, Spokane River Stations 1971-72.

a slight but constant increase in dissolved solids and on occasion a 30-50% increase is noted at the lowest river sampling station at Upriver Dr. (Felts Field - RM 80). It is suspected that periodically slugs of water pass downstream with higher than average dissolved solids and may be the result of industrial or domestic releases or possibly natural bottom scouring of the stream.

The dissolved oxygen measurements obtained (Figure 45) reflect the generally good condition of this portion of the Spokane River (RM 107-90), ranging between 81 and 108% saturation. The latter figure represents high daytime summer O_2 productivity generated by abundant periphyton and plankton growth between RM 90-80.

Higher sulfate measurements appeared to coincide with the spring runoff and periods of precipitation in the immediate area of the Upper Spokane River. The sampling stations at the lake outlet (RM 107) and Ross Point (RM 102) generally exhibited a slightly higher sulfate content. On occasion, samples at lower stations such as at Harvard Road (RM 90) have resulted in similar or even higher measurements. Data are presented in Figure 46 and Table C-1, Appendix C. Appreciable amounts of sulfide are relatively rare. The highest measurement was .007 mg/l, taken just downstream (RM 97) from Post Falls (Table C-1, Appendix C).

The river waters are relatively soft but apparently a good buffering system is in operation; bicarbonate alkalinity ranges for the most part between 20 and 45 mg/l HCO_3 (Figure 47). A trace to 3.0 mg/l CO_2 is present in the late fall. Low carbonates (1.0 mg/l) are occasionally found. Bioreactive nutrients, such as phosphorus and nitrogen, are present in relatively limited quantities in the river waters. Phosphorus, however, is usually present in sufficient quantities so as not to be immediately limiting to the growth of most aquatic organisms. The possible exception to this case may be in late summer-fall when diatom and late green algal growth reduce orthophosphorus to nearly undetectable quantities (Figure 48). Nitrogen (NH_3, NO_3, NO_2), when considered a macronutrient, is usually not so plentiful. In fact, in late summer this nutrient may become limiting at all of the upriver sampling stations (Figure 49). However, to maintain the river in its present state of early mesotrophy, control of these two nutrients will be essential.

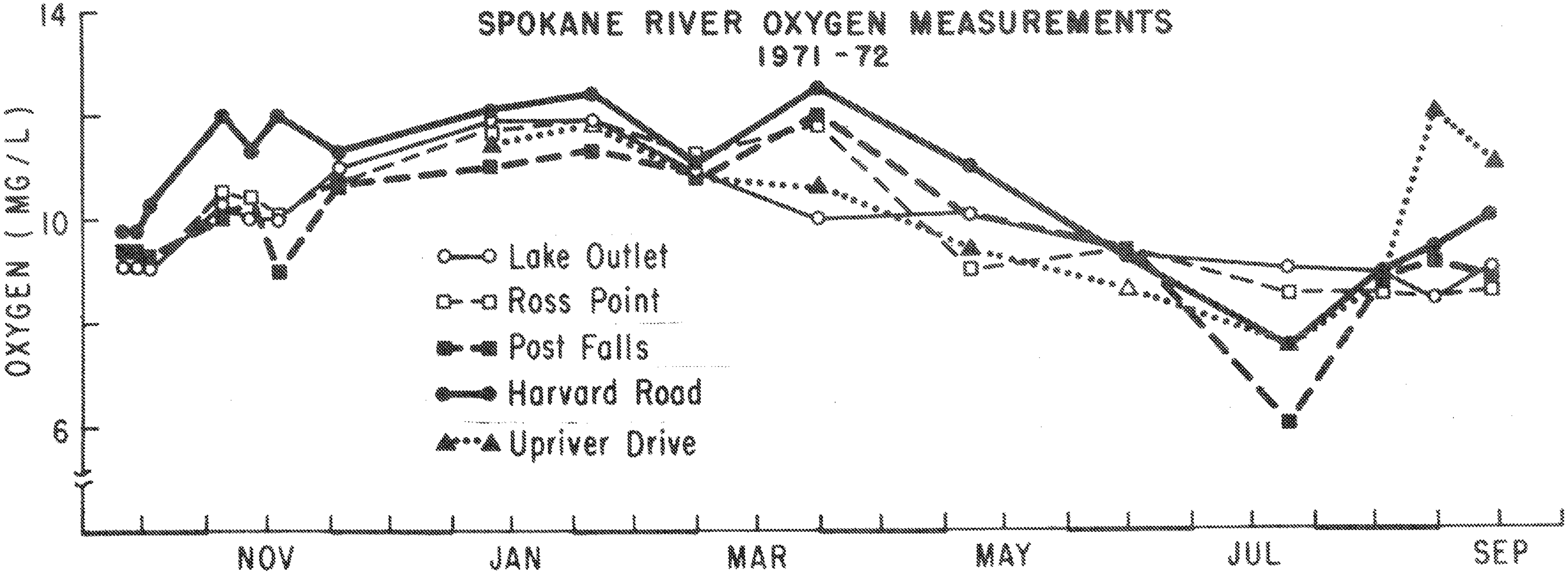


Figure 45. Dissolved Oxygen Measurements, Spokane River 1971-72.

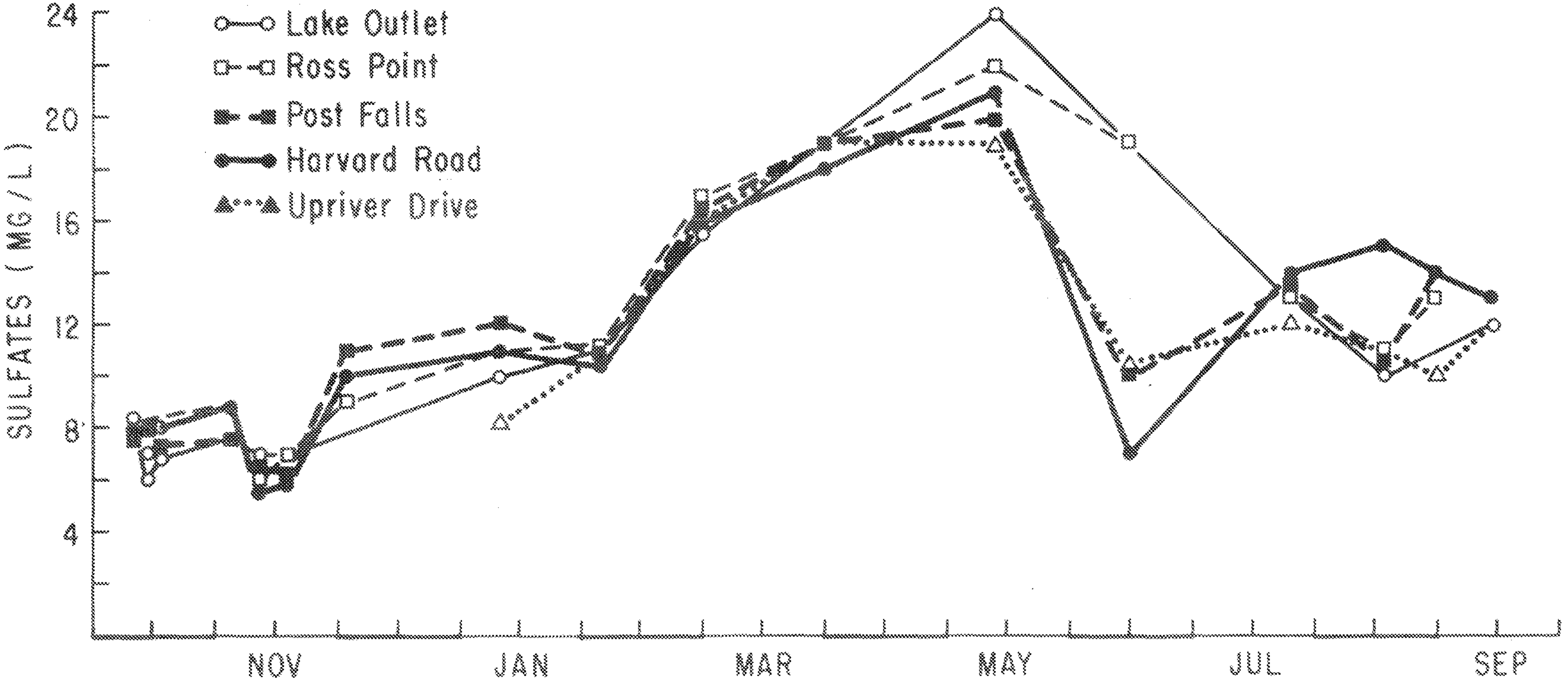


Figure 46. Sulfate Measurements, Spokane River Stations 1971-72.

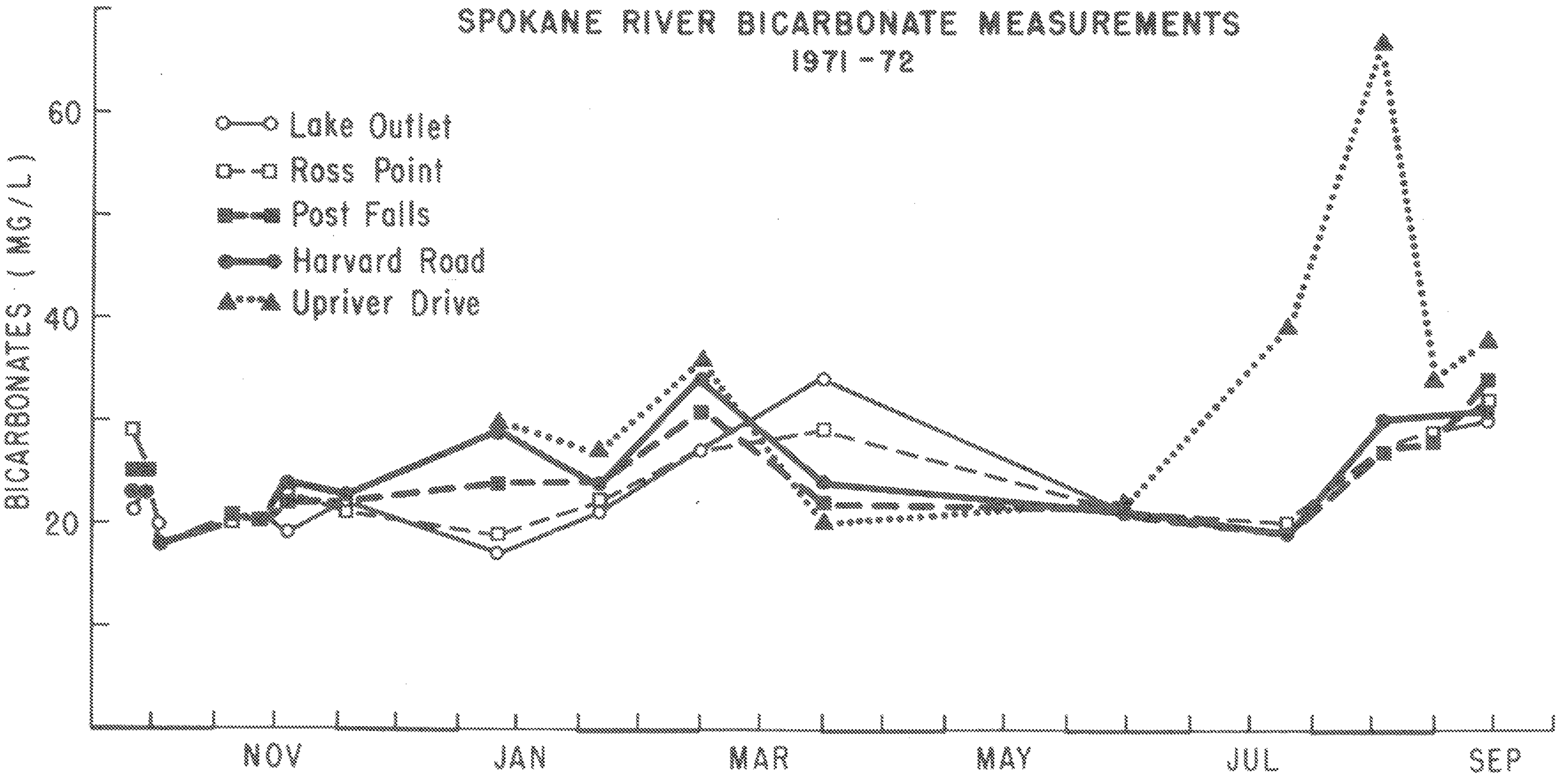


Figure 47. Bicarbonate Measurements, Spokane River 1971-72.

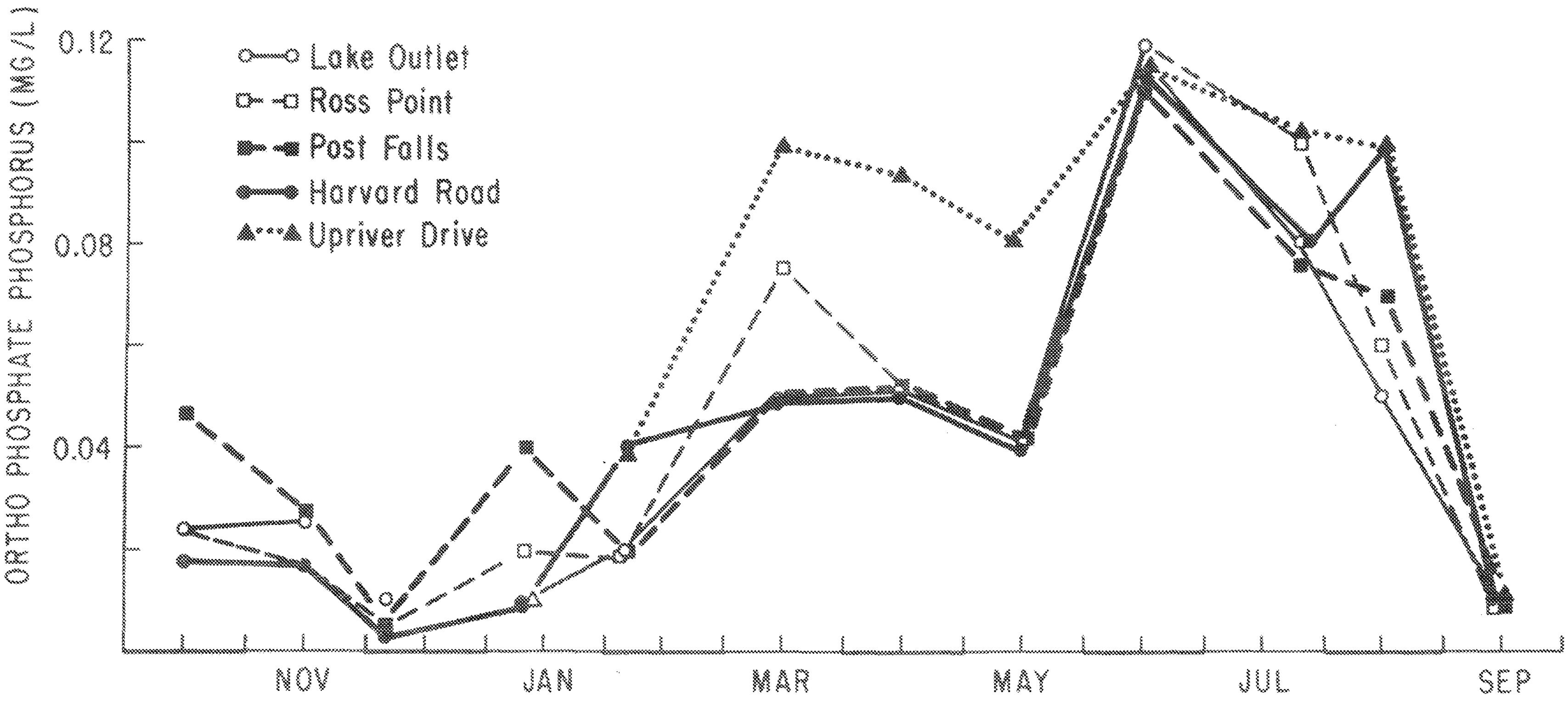


Figure 48. Orthophosphate-phosphorus Measurements, Spokane River 1971-72.

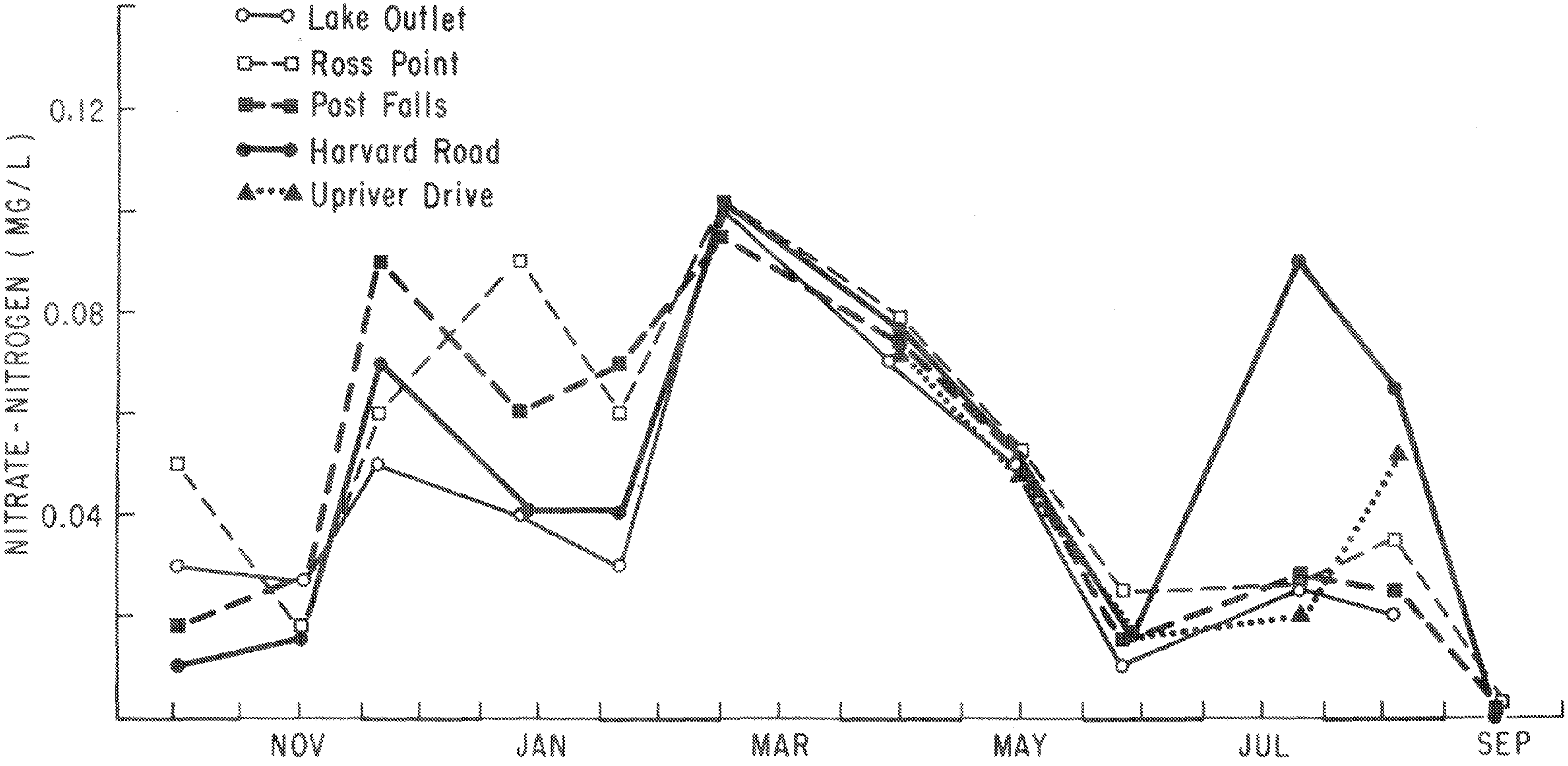


Figure 49. Nitrate-nitrogen Measurements, Spokane River 1971-72.

Bacteria of Water Quality Significance

The Spokane River is classified as class A from the mouth to the Idaho-Washington border, according to Water Quality Standards for Interstate and Coastal Waters of the State of Washington (Washington State Pollution Control Commission, 1970).

Coeur d'Alene Lake waters enter the Spokane River near the Cedars sampling station (RM 107). At this point the waters have a median value for total coliforms of 316/100 ml. At Ross Point (RM 102) the mean increases almost five fold to 1,427 total coliforms/100 ml. The river as it enters Washington does not at this time meet the class set forth in the Standards; in fact, it is degraded to class B. There appears to be a significant source of coliforms within a five mile reach of the river. From Ross Point (RM 102) to the Idaho-Washington state line (RM 94), the median numbers of total coliforms decline slightly to 738/100 ml and rises to 1,355 total coliforms/100 ml at Upriver Drive (RM 80). The upper Spokane River, except from the Cedars station (RM 107) to Coeur d'Alene Lake, is of low quality based on total coliforms. However, when numbers of fecal coliforms are considered the quality is relatively good. Again, the number of bacteria increase at Ross Point (RM 102). The fecal coliforms average 23/100 ml as compared to 3/100 ml at the Cedars station (RM 107).

The ratio of fecal coliforms to fecal streptococci increases from upstream to the downstream stations. The increase is indicative of domestic sources of intestinal bacteria (FC/FS ratios less than .6 indicate other than domestic sources, e.g. livestock or wildlife). Bacterial counts are summarized in Table 16. Individual raw counts of the upper Spokane River are shown in Table C-2, Appendix C.

Metallic Element Composition

The metallic element composition of the upper Spokane River are considerably higher than that found in lakes in the immediate area. Funk, et al. (1969) and Koehling (1971) measured several of the metallic constituents of Rock Lake and Williams Lake waters by similar methods and found the elemental composition in most cases to be several magnitudes below those shown in Table 17. Cushing and Rancitelli (1972) measured the metallic constituents of the Columbia River; their results also show considerably lesser amounts of

Table 16. Ranges and mean concentrations of bacteria sampled in the upper Spokane River, 1971-72. (Thompson, 1972.)

Station (RM)	No. of Samples	Total Coliform		Fecal Coliform		Fecal Strep.		$[R] = \frac{FS}{FC}$	
		Range	Mean	Range	Mean	Range	Mean	Range	Mean
Cedars (107)		12-620	171.7	1-10	2.8	0-22	5.2	0-5	1.09
Spokane Yacht Club (106)		130-200	165	1-6	3.5	7-10	8.5	0.14-0.6	0.37
Ross Point (102)		114-2740	778.1	0-96	23.8	2-61	23.6	0-7.5	2.21
Post Falls (100)		25-1670	550.5	1-53	14.7	0-45	10.5	0.08-6.5	2.5
Corbin Park (97)		550-1100	806.7	2-16	11.3	4-5	4.3	0.5-4.0	2.5
State Line (94)		316-1160	896.5	1-4	1.8	1-17	6.5	0.2-1.0	0.44
Harvard Road (90)		100-2100	559.4	0-42	8.6	0-55	5.4	0-5.3	1.21
Upriver Drive (80)		110-2600	792.3	0-28	8.1	2-10	4.2	0-7.0	2.62
Gonzaga (76)		1680-6300	3990	0-800	400	2-180	91.0	0-4.45	2.22

Table 17. Metal Composition of the Spokane River as Determined by Activation and Atomic Absorption Analysis (mg/l). (Funk and Bennett, 1972.)

Element	Coeur d'Alene Lake Outlet	Upriver Drive	Ft. Wright
Co	.002	.0034	.006
Cr	.032	.039	.0146
Cs		.0005	
*Cu	.02	.01	.01
Eu			
Fe	1.634	.2182	.7121
*Mn	.01	.01	
Sb	.037	.0383	.03139
Sc	.0052	.0059	
Se		.0014	.0084
Th		.0031	.0020
Zn	.8127	1.397	.9389
*Pb		.0015	.0025

*Atomic absorption analysis

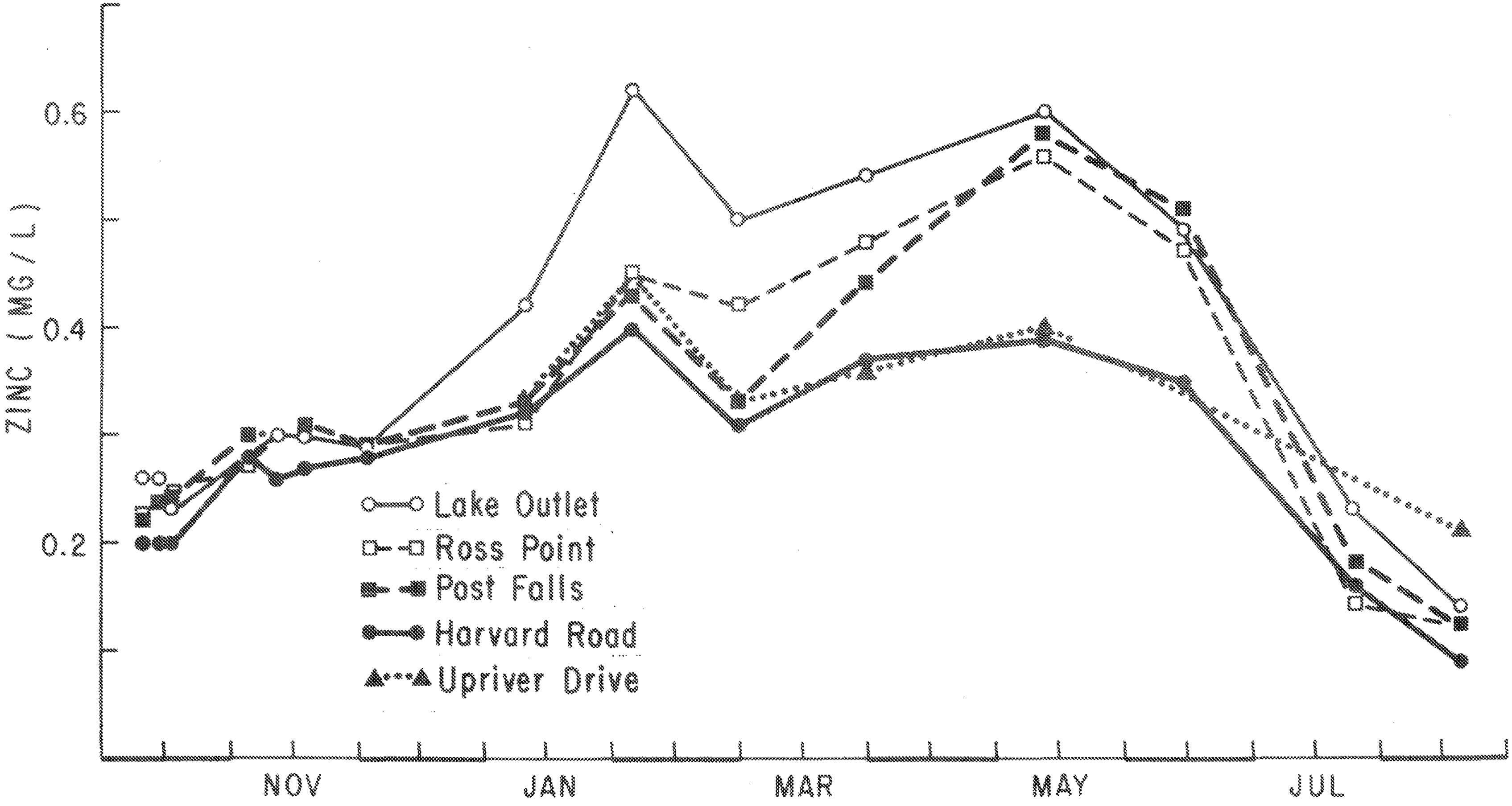


Figure 50. Zinc Measurements, Spokane River 1971-72.

these elements. Preliminary analysis of the metals in certain algae of Newman Lake (Bennett, 1971) indicate that they (metals) are also lower than those present in the algae of the nearby (~10 km) Spokane River.

Atomic absorption analysis indicated that Zn is present in unusually high amounts ranging from .2 to .62 mg/l (Figure 50) probably as colloidal or dissolved Zn (capable of passing through a .45 μ filter).

Neutron activation analysis of subsamples at this time revealed a level of .81 to 1.39 mg/l Zn. The latter figures most likely represent all forms of Zn. Other trace metals, with the exception of Fe, are not as abundant as Zn. Analytical results of the waters at Upriver Drive (Felts Field RM 80) are shown in Table 17 and in Appendix Table C-1.

B. Algae Composition

Algae composition of the upper Spokane River in 1971-72 resembled that of Coeur d'Alene Lake and several of the lakes in the Spokane area. September populations at the five stations ranged from 67 to 92% *Aphanizomenon flos aquae* in numbers of 50 to 1,440 standard units. *Fragilaria crotonensis* and other miscellaneous diatoms varied from 12% of the outlet to less than 7% of the most downstream station (Felts Field). By mid-October the diatom *Tabellaria fenestrata* dominated the populations, making up from 50 to 70% of the counts/ml. In December another shift occurred, *Ulothrix*, a green form, became prevalent making up 29 to 50% of the cell counts. Diatoms again became numerous in midwinter and *Melosira italica* dominated 50 to 90% of the algal population at all stations. This domination continued through April 1972. Cell counts/ml rose as high as 3,688 cells/ml. Cell counts were down in May at the free flowing river stations, at the lake outlet, and at Ross Point (700-1,100 cells/ml) but were high at the pool stations, Post Falls (2,568 cells/ml) and Upriver Drive (2,972 cells/ml). *Melosira sp.* was again the most numerous form accounting for 90-95% of the cell counts. Numbers dropped considerably in June and July to 70 to 1,400 cells/ml. *Melosira italica* made up 70 to 90% of the cell counts. August algal populations were mixed with *Tabellaria fenestrata* dominating the pool areas and *Fragilaria sp.* dominating the free flowing areas. Cell counts were less than 200 cells/ml in most instances. Fall populations were made up of blue greens such as Oscillatoria sp., a yellow green, Tribonema sp., with a recurrence of Melosira italica. No particular species was dominant for a very long period of time. Algae identification and counts are shown in Table C-3, Appendix C.

Analysis of Certain Metals in Phytoplankton Cells

Atomic absorption was used to determine several of the metallic constituents present in the river phytoplankton at five of the sampling stations. These determinations are presented in Table 18. The measurements cannot be directly compared with those of Funk et al. (1969); Cushing and Rancitelli (1972), because of different analytical methods. Neutron activation analysis may have given higher figures, as previously discussed in the sections on water and core analysis, as well as for reasons given by Cushing (incomplete dissolution of cells). Nonetheless, there is apparently a considerable concentration of metals by the phytoplankton. While it is difficult to determine if the metals are actually within the cells, entrapped within the gelatinous matrix, or cellular excretions of the cells (Funk et al. 1969), it is readily apparent that considerable concentration takes place. This concentration is most likely mediated by the algal cells. Analysis of bottom organisms, aquatic plant, and fish tissue (discussed in following sections) strongly indicate that many of the metals occur within the tissues of those organisms.

Metallic Concentration (expressed as mg/kg - dry weight) in Certain Benthic Organisms and Aquatic Plants

It is recognized that although this sampling series may represent only a few organisms of the aquatic community, there appears to be a constant trend in the results.

Certain organisms, such as the larva of the caddis fly: Hydropsyche [known for its ability to increase enormously in rivers containing masses of plankton derived from lakes (Illies, 1956) (Hynes, 1960)], reflect the concentration of the metallic elements that appear to be initially present in the algae. Very high mean concentrations (mg/kg - dry weight) of Cu (50), Zn 3,000+), Fe (6,500), Cd (45), Mn (930), Hg (.4), Pb (350) are present in the larvae of this organism. The may fly, Baetis sp., also found in large numbers

Table: 18 Metal Concentration (mg/kg dry weight) by Algae in the Upper Spokane River, 1971. Analysis by Atomic Absorption.

Element	9/16	10/1	10/10	10/21	11/4	12/2
			Lake Outlet (RM-107)			
Cd	140	85	160	190	170	76
Fe	9,600	10,700	9,000	12,100	10,900	13,100
Mn	3,200	2,700	2,800	2,200	5,000	5,800
Pb	640	500	625	140	940	860
Zn	4,100	3,600	3,500	2,700	5,100	4,800
			Ross Point (RM-102)			
Cd	115	30	---	140	140	85
Fe	9,400	8,300	14,800	8,100	9,600	12,100
Mn	2,600	1,000	1,300	2,100	3,200	5,600
Pb	710	480	380	500	640	830
Zn	4,500	2,900	2,800	3,000	4,100	4,200
			Post Falls (RM-100)			
Cd	76	38	160	---	76	---
Fe	13,300	29,400	18,400	14,000	11,400	11,900
Mn	1,410	1,420	3,600	2,900	2,500	4,000
Pb	300	210	900	670	600	410
Zn	710	2,730	6,000	4,000	3,600	3,500
			Upriver Drive (RM-80)			
Cd	80	---	270	130	160	85
Fe	13,600	11,500	20,800	6,900	3,300	11,900
Mn	2,000	2,250	4,600	2,200	3,000	4,000
Pb	780	540	1,900	800	750	600
Zn	3,700	3,800	7,300	3,600	3,400	3,400

and also an algae consumer (Hynes, 1960) demonstrates similar mean concentrations: Cu (140), Zn (3,100), Mn (300), Fe (7,400), Cd (70), Hg (.7), and Pb (230).

A similar high concentration of metals was exhibited by the snail, *Physa sp.*, which apparently not only ingests algae, but also scavenges dead plant and animal matter (Pennak, 1953). Mean metal concentration in the tissues of *Physa sp.* were: Cu (250), Zn (2,300), Fe (900), Mn (1,000), Cd (97), Pb (51), and Hg (.3).

Somewhat surprising were the relatively lower amounts of metals found in the sediment dwelling chironomid, *Glyptotendipes sp.*, which apparently feeds on organic detritus. Mean concentration for this organism were: Cu (26), Zn (1,050), Cd (16), Fe (2,500), Mn (240), Pb (6), and Hg (<.1). An aquatic earthworm (unidentified) also appeared to contain lesser quantities of the metals of interest; mean concentrations were Cu (17), Zn (450), Cd (4.3), Fe (590), Mn (40), Hg (<.3), and Pb (16).

Aquatic plants such as Pondweed (*Potomegeton crispus*), a moss (*Amblystegium*), and attached algae such as *Cladophora sp.* were also tested for Cu, Fe, Mn, Zn, Cd, Pb, and Hg and are reported in mg/kg dry weight.

Potomegeton crispus leaves and stems had mean concentrations of Cu (32), Zn (1,310), Cd (20), Fe (4,000), Mn (660), Hg (<.04), and Pb (320).

Cladophora sp. was present as periphyton attached to rocks and submerged objects in the river. Analysis of filaments gave the following mean concentrations: Cu (32), Zn (1,900), Cd (36), Fe (2,900), Mn (450), Hg (1.1), and Pb (170). Moss such as *Amblystegium* was also present on submerged objects. Analysis revealed the following mean concentrations of metals present in the plant bodies: Cu (<14), Zn (1,320), Cd (8), Fe (4,500), Mn (460), Hg (.3) and Pb (50). These measurements are summarized in Figures 51(a) and 51(b).

C. Fish Tissue Analyses

Analyses of fish tissues were made by neutron activation techniques for Co, Cr. Cs, Eu, Fe, Hf, Ni, Rb, Sb, Sc, Se, Th, and in some instances for Ba, Ta, and Te. Mercury was also included in the analysis but had to be disavowed

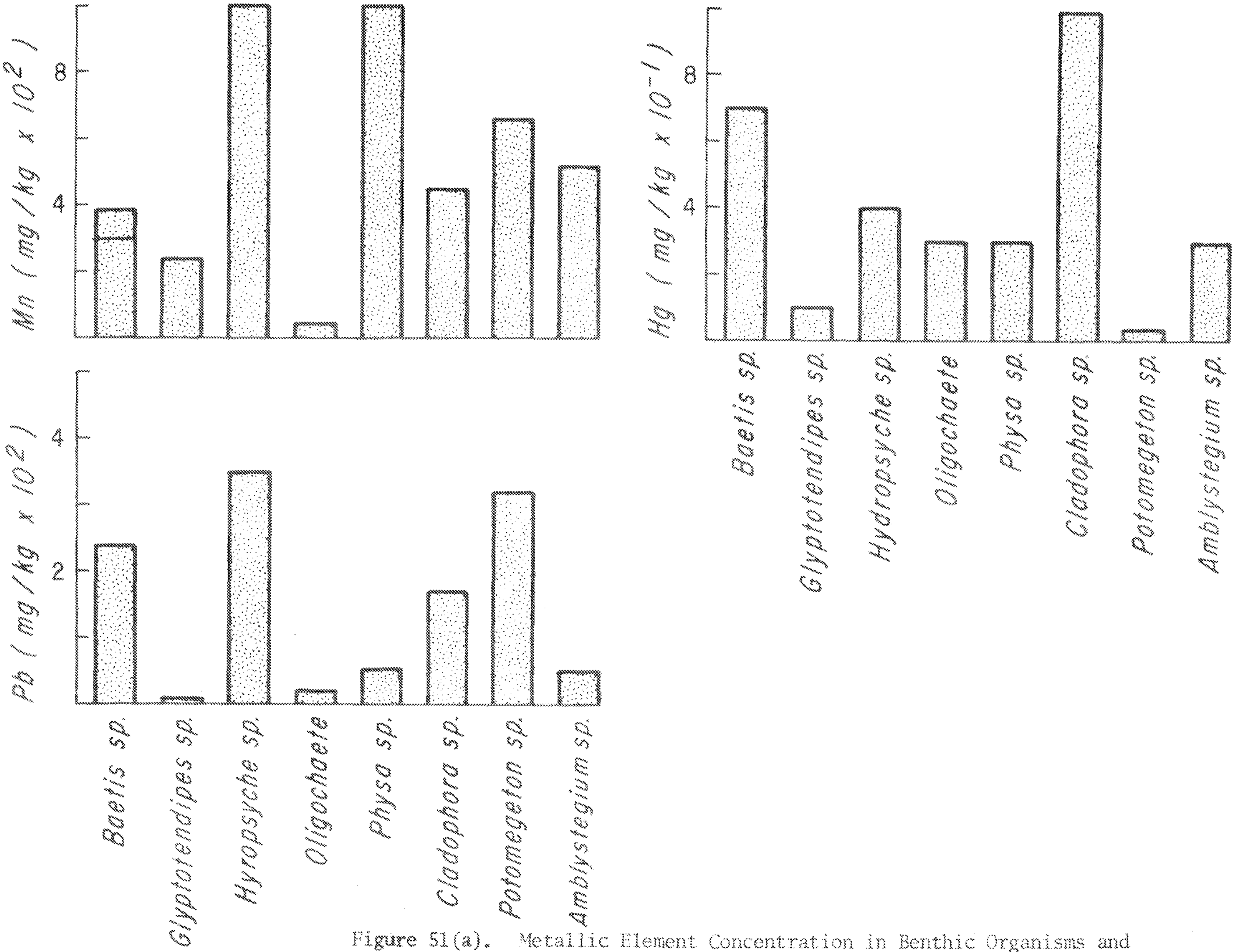


Figure 51(a). Metallic Element Concentration in Benthic Organisms and Aquatic Plants. (Funk, et al., 1973.)

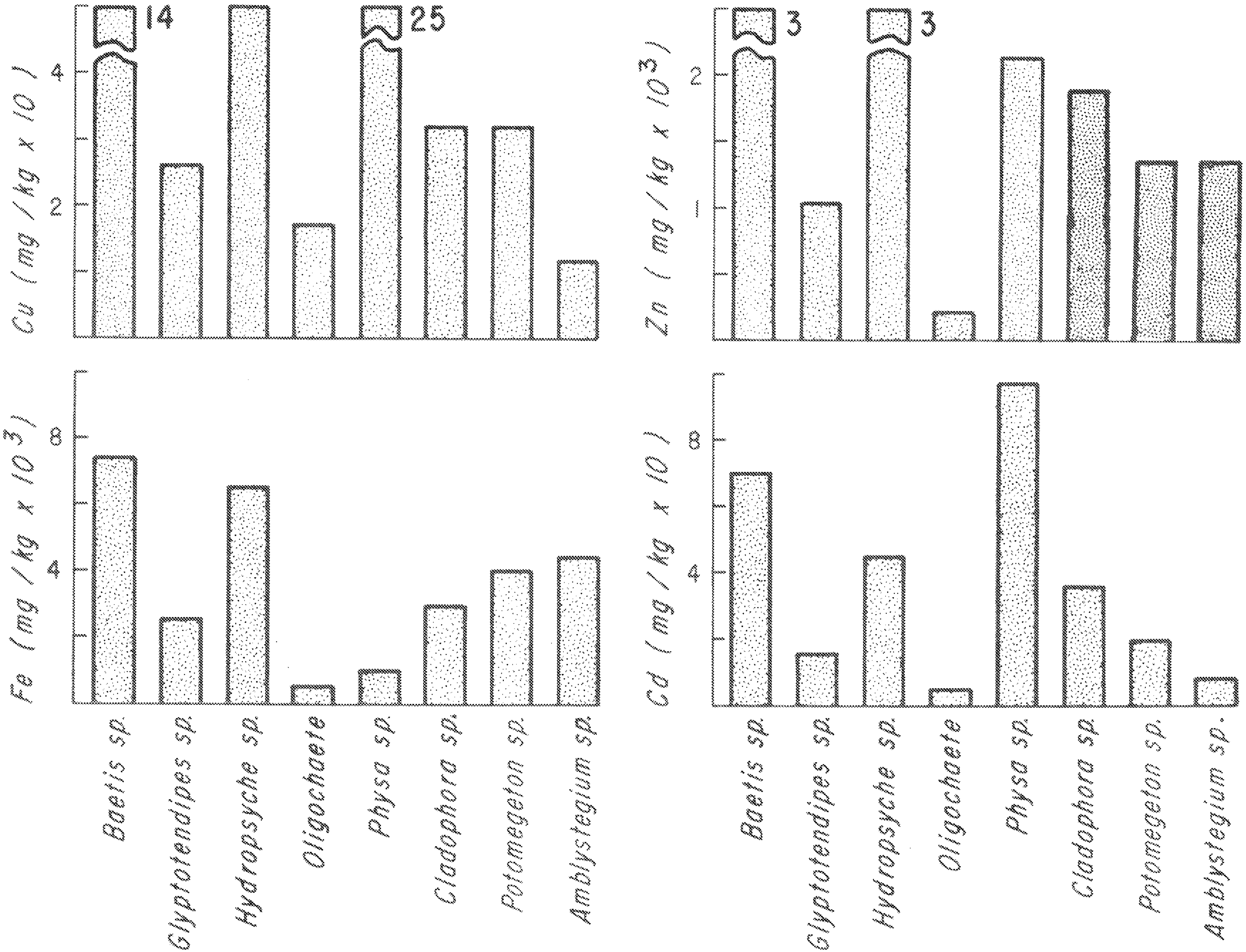


Figure 51(b). Metallic Element Concentration in Benthic Organisms and Aquatic Plants. (Funk, et al., 1973.)

because of selenium interference. All the elements tested for are reported on a dry weight basis. For the initial evaluation, three species of fishes were collected in the mid-Spokane River area (Below Upriver Drive - Felts Field, RM 80). Another species was collected at this site and also from above the Post Falls dam station for comparative purposes.

Other speciments have been obtained from Long Lake and Hangman Creek and subjected to atomic absorption analysis. These analyses will be included in a later report.

Inspection of the data indicates, as we would suspect, larger quantities of the heavy metals in the filter bodies (kidney and liver tissue) of all species of fishes. Zinc, for example, ranged from over 80 mg/kg in the Perch to over 119 and 200 mg/kg respectively in the Black Bullhead and Squawfish liver tissue. Figure 52 illustrates the activation spectra for a fish specimen.

Iron is a common constituent of blood and liver tissue, so it is not surprising to find it in amounts ranging from several hundred to over 4,000 mg/kg in the liver tissues of the fishes examined. Selenium was slightly higher in the Bullhead tissue while nickel was higher in the Squawfish. Chromium content was nearly the same for all fish liver tissues ranging between 1.3 and 1.9 mg/kg. Antimony and cobalt were present in quantities less than 1.0 mg/kg. Other metallic elements: Cs, Eu, Hf, Rb, Sc, and Th, were measured in µg/kg quantities in all liver tissues [Figures 53(a) and 53(b)].

Fillet tissues taken from the same fishes were considerably lower in metal composition. Mean Zn values were 33, 55, and 54 mg/kg in Perch, Bullhead, and Squawfish tissues, respectively. Iron was 408, 231, and 128 mg/kg in fillet tissues of the Perch, Bullhead, and Squawfish, respectively. Nickel was not detected. Hafnium was 7.5 and 8.0 µg/kg in the Bullhead and Squawfish, respectively. Hafnium was not measured in Perch tissues. Thorium was not detected in any of the tissues tested. Selenium measurements were .6 mg/kg in the tissues of Bullhead and Squawfish, and .8 mg/kg in Perch.

Chromium content was 2.09 mg/kg in Bullhead, 2.02 mg/kg in Squawfish, and .7 mg/kg in Perch tissues. Cobalt was .33, .4 and .06 mg/kg respectively in the Bullhead, Squawfish, and Perch fillet tissues. Antimony occurred in

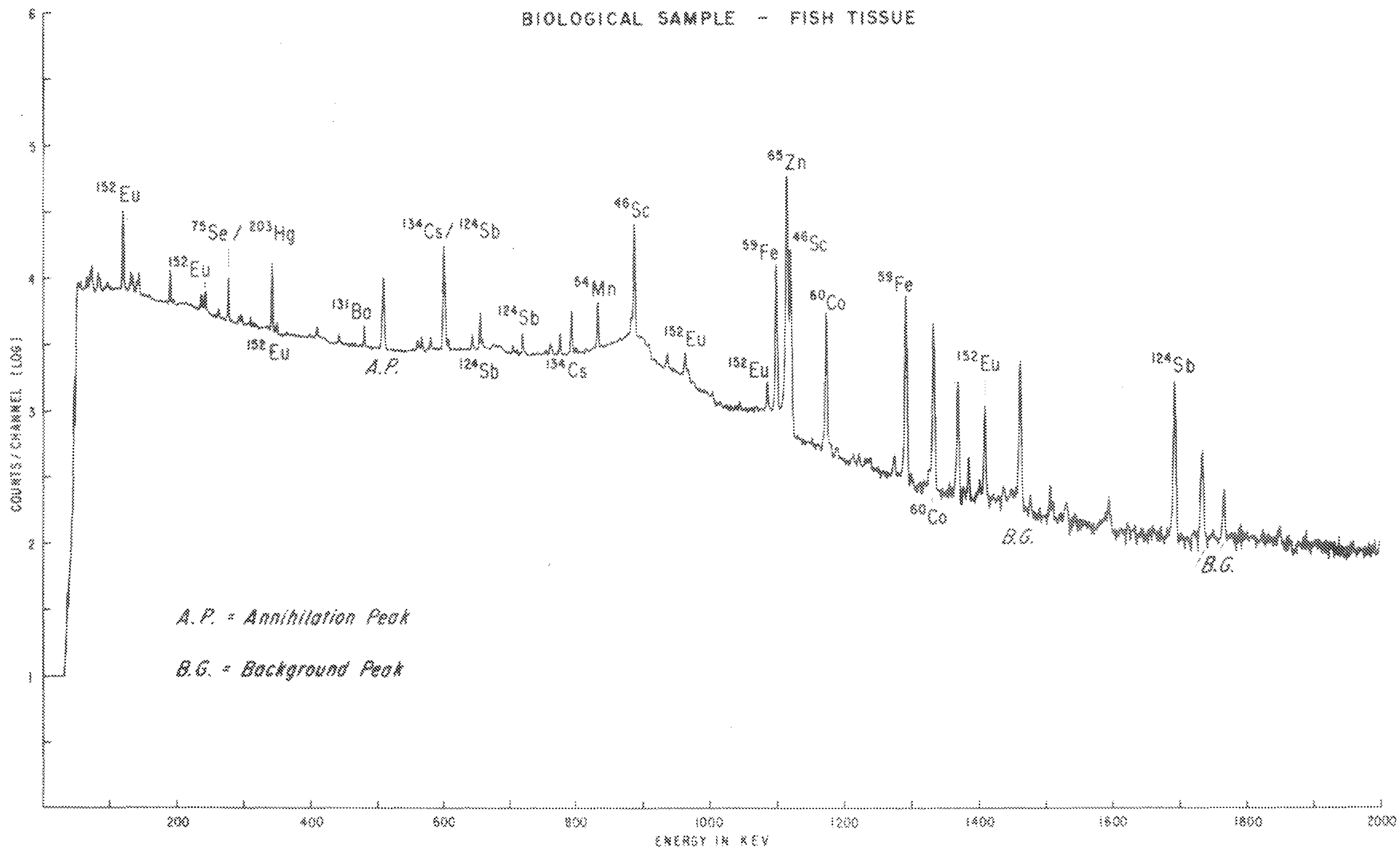


Figure 52. Neutron Activation Spectra showing Metallic Element Concentration in Fish Tissue. (Funk, et al., 1973.)

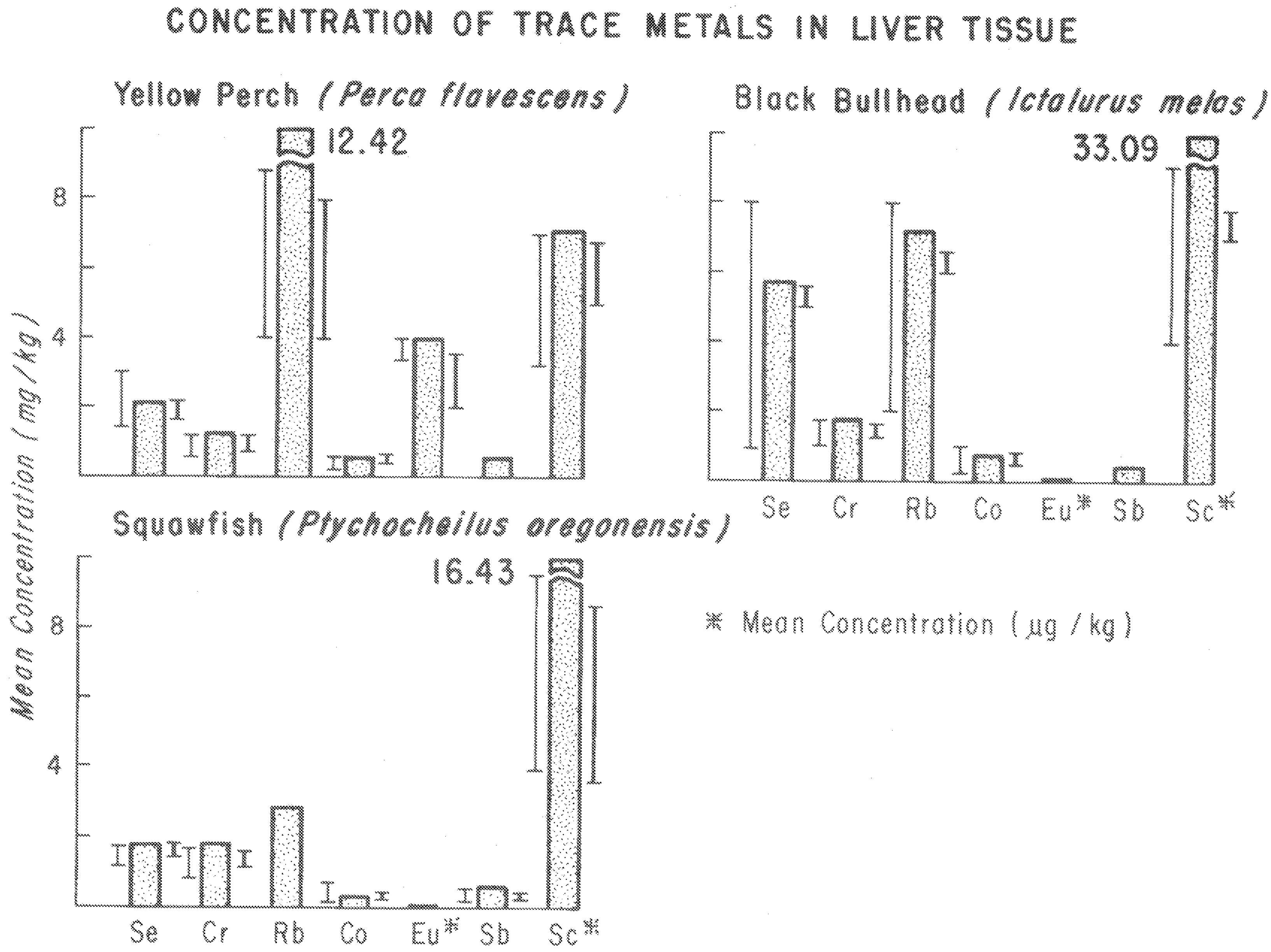


Figure 53(a). Trace Metal Concentration in Fish Liver Tissue. (Light line indicates range of three specimens, dark line represents the confidence limits at the 95% level.) (Funk, *et al.*, 1973.)

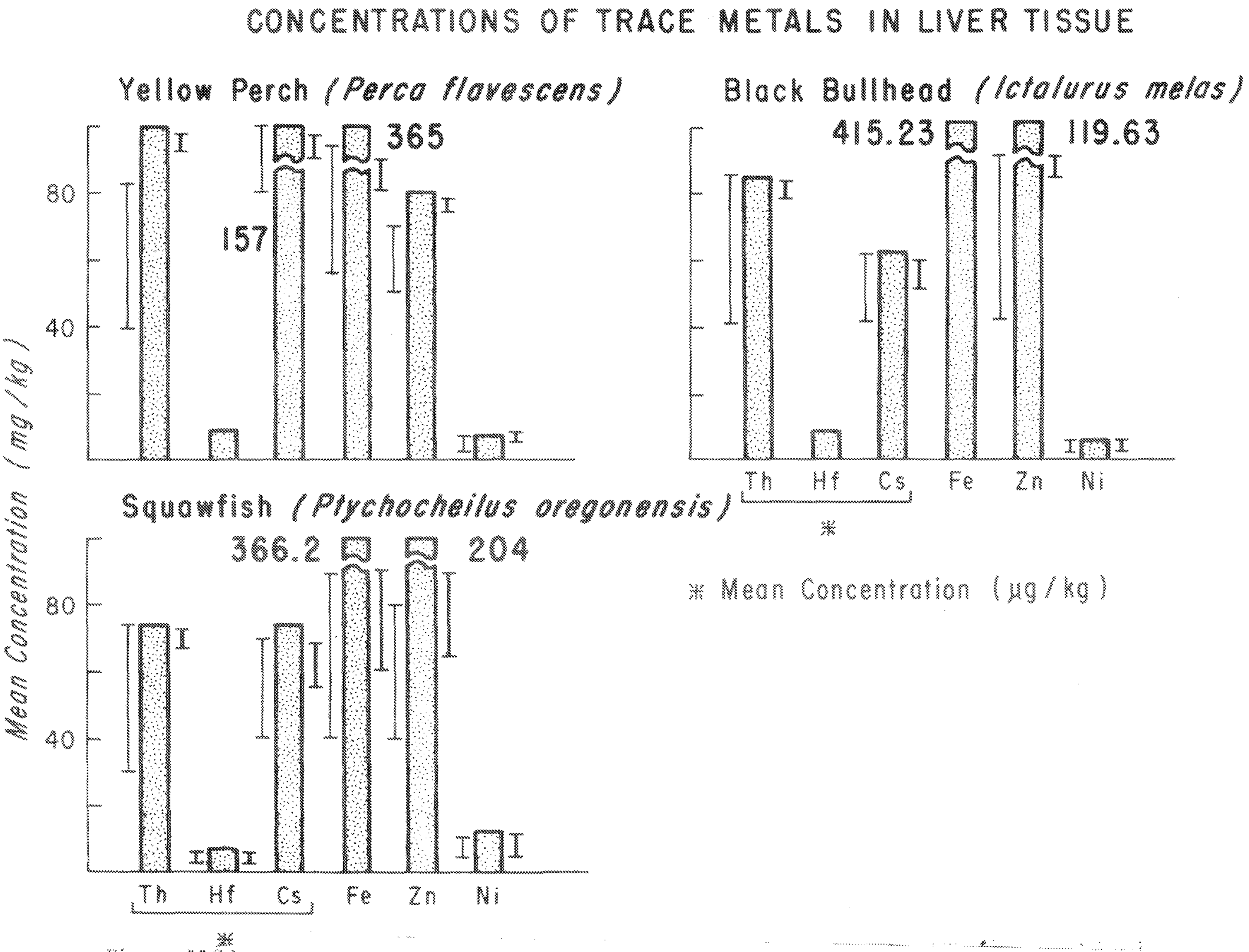


Figure 53(b). Trace Metal Concentration in Fish Liver Tissue. (Light line indicates range of three specimens, dark line represents the confidence limits at the 95% level.) (Funk, et al., 1973.)

.06, .31, and .19 mg/kg respectively in the Perch, Bullhead, and Squawfish. Rubidium occurred in quantities of 9.9, 10, and 9.8 mg/kg respectively in the Perch, Bullhead, and Squawfish. Europium and Sc occurred in the μg/kg range. Simultaneous analysis of Fe and Zn by atomic absorption methods on subsamples of the same tissues were within 20% of those reported here. Two exceptions occurred where results were 50% different, with neutron activation analysis being considerably higher for analyses on Bullhead fillet and liver tissue. The results of the activation analyses of these fish tissues are also presented graphically in Figures 54(a) and 54(b). Comparison of elemental composition of the fat tissues of the Bullhead and Squawfish are shown in Figure 55. Comparison of whole fish analysis of the pool areas of Ross Point and Long Lake of the Spokane River are shown in Figure 56.

Specific conclusions should not be drawn from the fish tissue analyses presented in these sections. At this point, only some 25 fish samples have been analyzed to date and far more need to be analyzed. Zinc and other metal constituents seem high in relation to some previous analysis by the Washington State Department of Ecology (Haggarty, personal communication). This may be due to the fact that our data are reduced to a dry weight basis. Another question may also be--what form are these metals in? The fish appeared healthy, robust, and not under stress when collected. As Cushing and Rancitelli (1972) point out in the analysis of the algae in the Columbia River, there is a paucity of data on the direct analysis of the elemental composition of organisms. Wiessner (1962) has also aptly pointed out that organisms may concentrate elements in direct abundance to their availability in the surrounding media.

The direct applicability of laboratory toxicity tests (as pointed out earlier in this report) may not always describe what will happen in the field as indicated by the fish catches made in the area of the Coeur d'Alene River delta. These results do, however, cause concern and for that reason additional fish will be tested during the next OWRR study--Phase II under Title II funds.

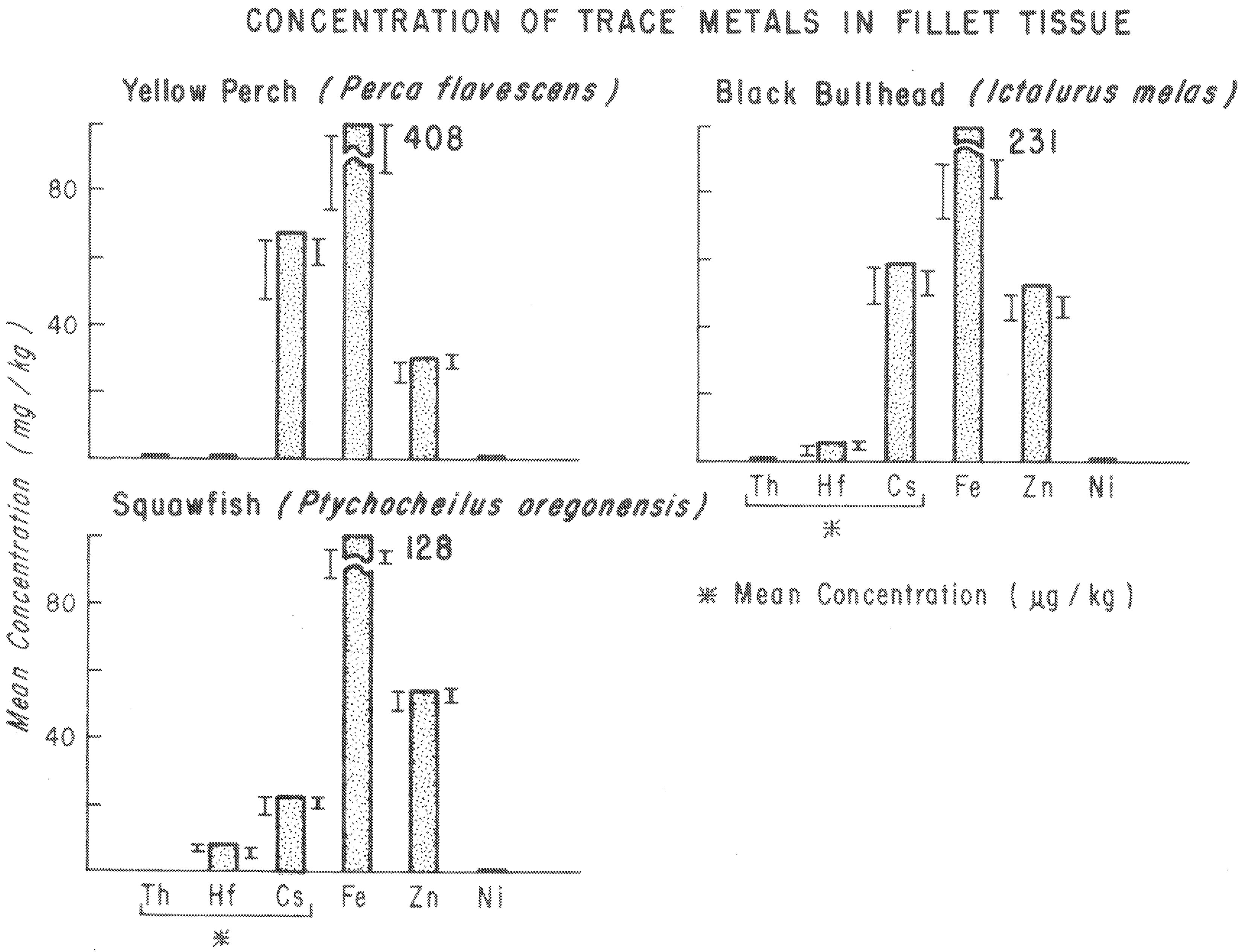


Figure 54(a). Trace Metal Concentration in Fish Fillet Tissue. (Light line indicates range of three specimens, dark line indicates confidence limits of 95% level.) (Funk, et al., 1973.)

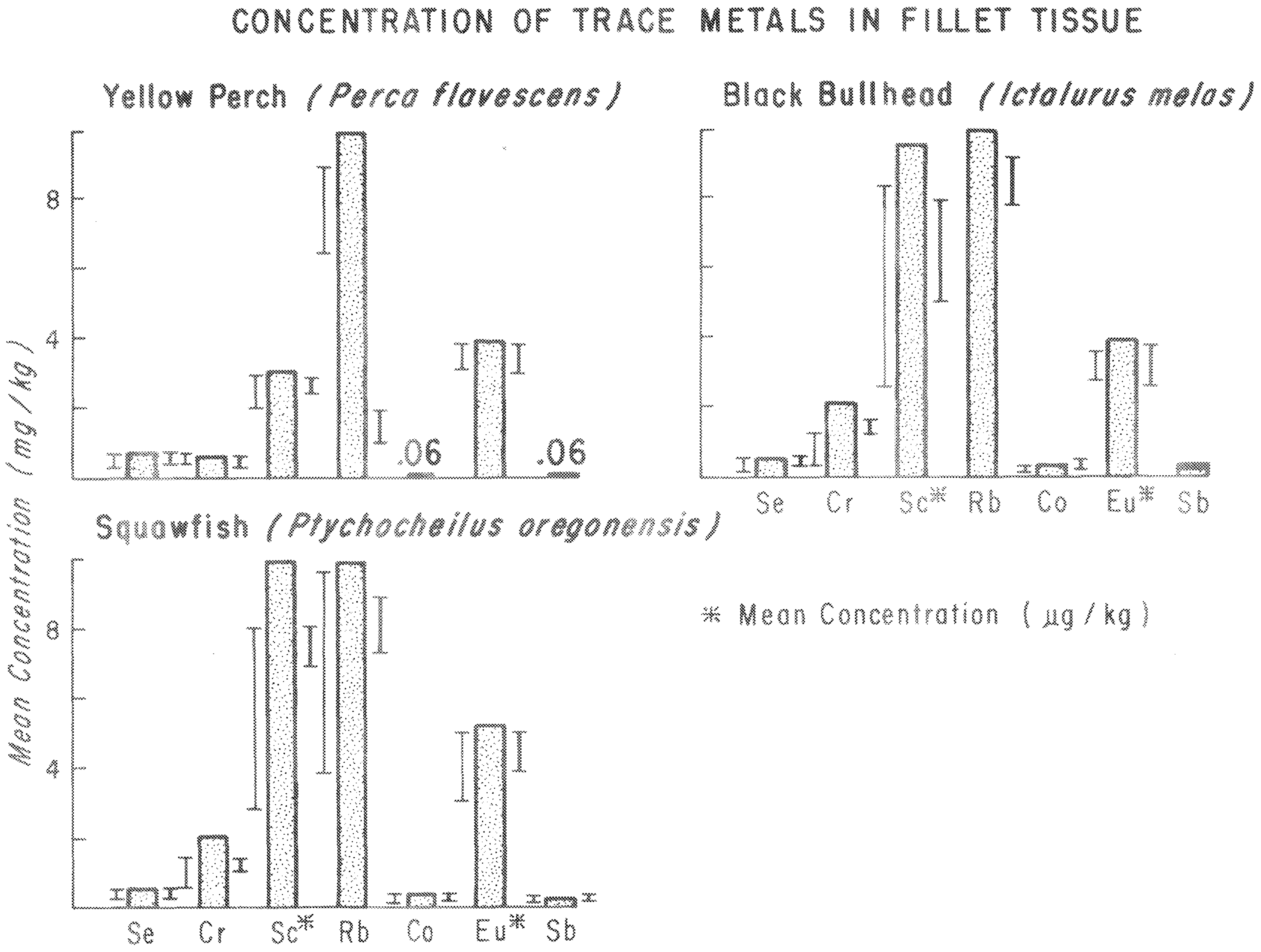


Figure 54(b). Trace Metal Concentration in Fish Fillet Tissue. (Light line indicates range of three specimens, dark line indicates confidence limits of 95% level.) (Funk, *et al.*, 1973.)

FAT TISSUE

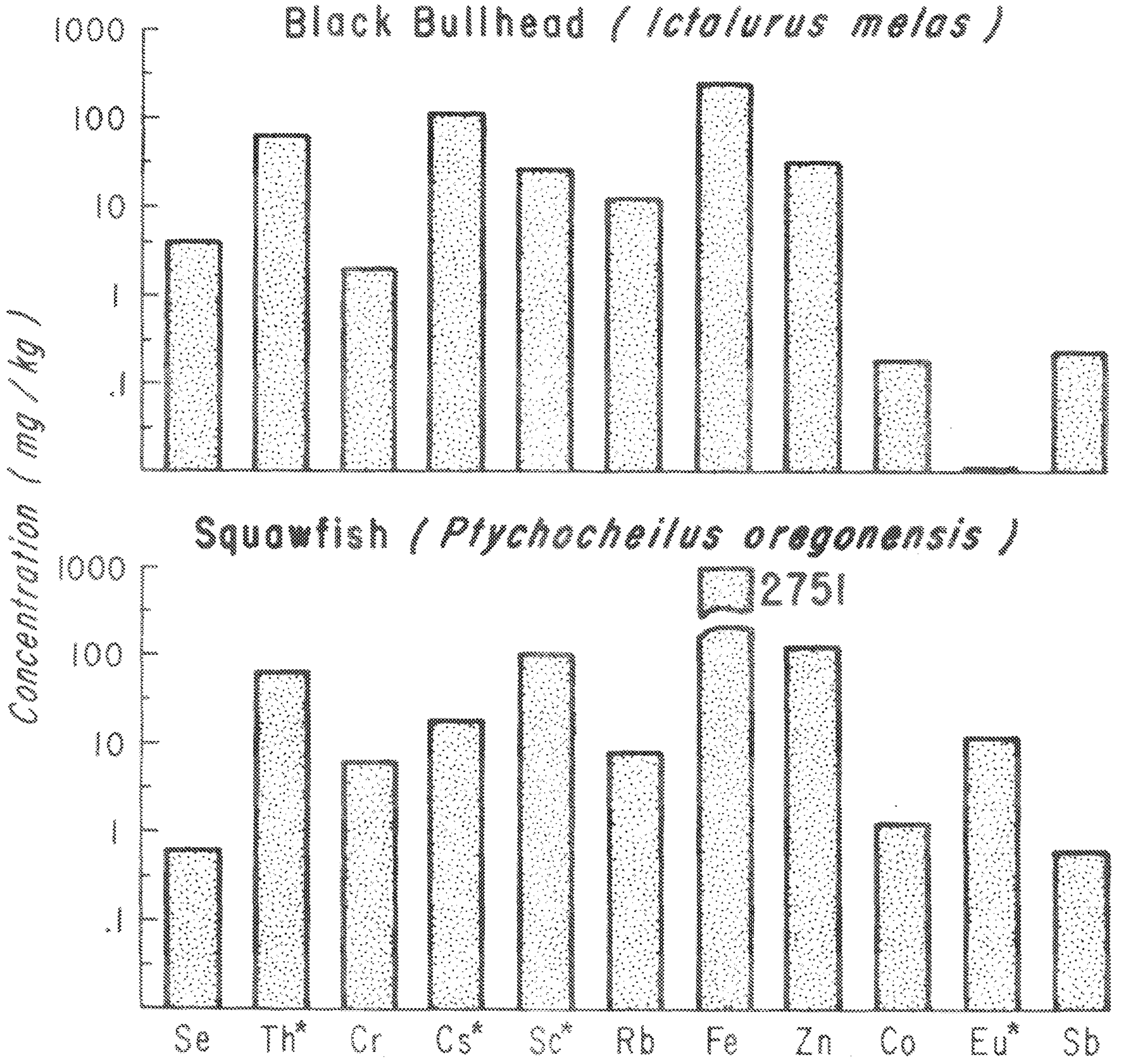
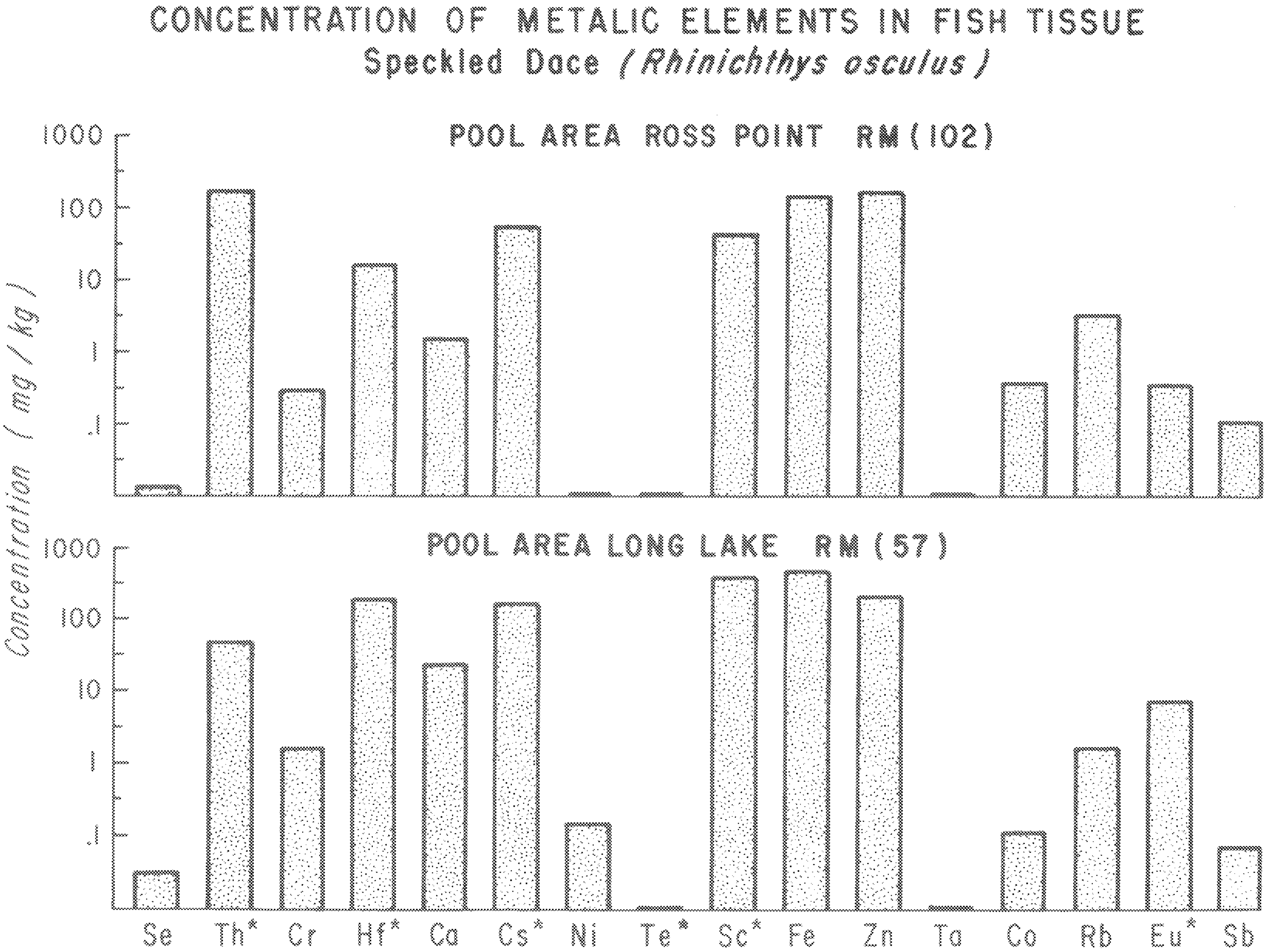


Figure 55. Metallic Concentration in Fat Tissues of Two Species of Fish. Asterisk indicates the reported value is in µg/kg. (Results are composite samples from three fish of each species). (Funk et al., 1973.)



CONCENTRATION OF METALIC ELEMENTS IN FISH TISSUE
Speckled Dace (*Rhinichthys osculus*)

POOL AREA ROSS POINT RM (102)

POOL AREA LONG LAKE RM (57)

Figure 56. Metallic Concentrations in Speckled Dace From Two Areas of the Spokane River. Asterisk indicates the reported value is in µg/kg. (Each value is the result of analysis of three fish in each area). (Funk, et al., 1973.)

SUMMARY

Comprehensive limnological, water quality, and productivity investigations were undertaken in an attempt to satisfy study objectives of determining some of the effects of heavy metal and organic pollution upon the Coeur d'Alene Lake, Coeur d'Alene River and the Spokane River. The following paragraphs summarize the major findings of the joint investigators.

Water quality data show that the heavy inflow of nutrients occur in late spring, largely from the St. Joe and Coeur d'Alene Rivers and Plummer Creek. Although no waters devoid of oxygen have been detected in the lake system, levels below 2.0 mg/l have been measured off Chatcolet and less than 4.0 mg/l have been detected in the hypolimnion areas of Conkling Park south to the Hidden Lake area during the late summer.

Coeur d'Alene Lake functions at several trophic levels along its lengthwise axis.

The southern portion--from Shingle Bay to Rocky Point--receives considerable nutrient loading from river and creek discharges. This portion of the lake has responded to enrichment by dense growths of aquatic macrophytes which cover about 50-60% of the water surface of the area by midsummer and probably accounts for most of the autotrophic production in the southernmost area of the lake system. Phytoplankton productivity in this area averaged 275 mg/C/m^3/4 hr incubation period. It is thought that this relatively low productivity in comparison to the mid- and northern-areas of the lake is in large part due to competitive interference with the very abundant aquatic macrophytes. Extensive blue-green algae growth also occurs in this area in late summer.

The middle portion of the lake--from Rockford Bay south to Conkling Park--is comparatively rich in nutrients and supports heavy diatom growth with seasonal development of blue-green algae populations. Carbon 14 studies indicate an average of 520 mg/C/m^3/4 hr incubation period. This portion of the lake would be classified as strongly mesotrophic.

The open waters of the northern portion of Coeur d'Alene Lake support a relatively low population of diatoms; some bays, however, support moderately heavy diatom growth with some blue-green growth in late summer.

Carbon 14 measurements for this area averaged 400 mg/C/m^3/4 hr incubation period.

Simultaneous studies were made upon the macrobenthic invertebrates of Lake Coeur d'Alene and of the lake sediments in which they were found. These organisms can be used as indicators of water quality because their presence or absence may reflect physical or chemical changes in the aquatic system over a considerable length of time. The larvae of these invertebrates are relatively sedentary and have complex life cycles--in many cases over several years. Chironomid larvae and oligochaetes made up 90% of the 62 taxa of invertebrates collected and identified. The most commonly collected organisms were chironomids--found mostly in the open water regions of the Round Lake and Chatcolet area. The particular forms identified reflect the eutrophic nature of the southern end of the lake and the oligotrophic nature of the northern portion.

Macroinvertebrates were most abundant in shallow water where aquatic macrophytes were common. Diversity was generally low at stations deeper than 20 m in depth; however, more than 2,500 *Chironomus*/m^2 were observed in the Cougar Bay area at depths greater than 20 m.

High concentrations of zinc and other heavy metals occur in the sediments over the entire length of the lake north of the Coeur d'Alene River delta. However, those concentrations decrease in bays protected from the main flow of the lake. Metal concentrations in the sediments decrease south of the Coeur d'Alene River delta and are relatively low in the Round and Chatcolet regions of the lake.

The distribution of benthic chironomids or oligochaetes did not seem to be substantially affected by 1,000-7,000 mg/kg Zn as well as considerable amounts of other metals in the sediments.

Benthic studies of the Coeur d'Alene River have been made for a period of four years in an attempt to determine possible stream improvement after impoundment of mine tailings in 1968. Since 1968 major changes have been noted in substrate conditions. After reduction of turbid conditions, dense blue-green algal growth (*Oscillatoria sp.*) has occurred at two stations where few or no bottom organisms previously existed. Several resistant species have now become established and colonization of the area is underway.

Diversity (Shannon diversity index) values are still low--less than 1.0 probably as a result of the prodigious amounts of Zn (4.2-21.0 mg/l) and macronutrients (NO_3 and PO_4) still flowing down the river. In the delta region (where the river enters the lake) 11 genera of Chironomidae, 4 Hydracarina, 4 Trichoptera, and 1 Turbellaria were observed during this investigation. It is therefore thought that the previous inhibition and extremely low diversity of organisms within this area may be due as much to inundation by the formerly high sedimentation rates of mine tailings and silts as to the presence of heavy metals.

Sediment cores were taken across the width of the lake from the Coeur d'Alene River delta to 1.6 km off Camp Easterseal on Cottonwood Bay. Most of the cores with the exception of core 3 penetrated the sediment to depths beyond the layers containing high levels of metallic elements. Using these metallic concentrations as evidence of the flow of mine tailings into the river-lake system (which began in 1884) average sedimentation rates were developed for each coring area. Those rates ranged from .86 to .28 cm per year. Metallic constituents of the sediments were determined in most cases at every 5 to 10 cm increment of the core sample by neutron and atomic absorption analysis. A 1.0 cm subsample was also extracted at the same time for diatom analysis. Diatom shifts occurred at the same levels as the metallic constituents changed. It is believed this phenomenon occurred as a consequence of metallic toxicity and increased turbidity of the waters.

Laboratory evaluation of the toxic effects of Cu, Cd, and Zn alone and in combination with Coeur d'Alene River and Lake waters were made as part of this research program. Of the six water collection sites, only waters from Shoshone Park and the North Fork of the Coeur d'Alene River would support growth of the EPA test alga, Selanastrum capricornutum. At the other four collection sites, Zn was present in amounts of 0.55 to 19.1 mg/l while other heavy metals (Cu, Cd) were present in the same range (μg/l) as those waters successfully supporting growth. For this reason Zn was chosen as the dominant metal for combination toxicity tests. It did appear, however, that Cu and Cd were antagonistic in combined laboratory tests. Incipient and complete inhibition occurred in Zn tests at 30 and 120 μg/l respectively. Zinc and Cd in combination at 50 and 20 μg/l, respectively, allowed S. capricornutum to grow at twice the maximum growth rate of Zn at 60 μg/l. It appeared that these metals were mildly antagonistic to each other. Incipient inhibition of S. capricornutum occurred at 50 μg/l of Cd. Tests with combinations of Cd, Cu, and Zn resulted in growth similar to that of Zn alone. It appeared from these tests that S. capricornutum is extremely sensitive to certain heavy metals such as Zn, Cd, and Cu. It was also shown that the amount of Zn normally present in the Coeur d'Alene Lake and River and the Spokane River would be inhibitory to S. capricornutum.

Nine to 10 physicochemical water quality parameters were monitored weekly from October to December 1971 on the Spokane River. Of the original seven stations, five sampling sites were maintained for monthly checks for an additional nine months. As the water passed from the outlet at Coeur d'Alene Lake to the last station downstream (Upriver Drive) some water quality degradation occurred. Biochemical and chemical oxygen demand slightly increased and conversely dissolved O_2 ranged from 108% to 81% of saturation. However, the dissolved O_2 above 100% in this case was thought to represent summer time periphyton and plankton productivity between RM 107-90. Bacterial analysis over this portion of the river indicated the stream to be generally of good to excellent quality. It would be given a Class A rating from RM 107-94 and a Class B rating from RM 94-80 based upon the Water Quality Standards for Interstate and Coastal Waters of the State of Washington and a Plan for their Enforcement (1970). Nutrient analysis indicated that a trace to 3.0 mg/l CO_2 was found in the river in the fall. None was detected during the summer. Orthophosphate phosphorus ranged from .01 to .12 mg/l and probably became limiting to further phytoplankton growth in the late summer. Nitrate nitrogen, on the other hand, ranged from .01 to .11 mg/l and was considered limiting during late summer and fall. Other forms of utilizable nitrogen were virtually non-existent at this time. Diatoms made up most of the algae population throughout the year and were generally the same forms that occupied the northern portion of Coeur d'Alene Lake. Blue-green algae such as Aphanizomenon flos-aquae dominated the fall populations. Their numbers, however, never exceeded 500 standard units/ml.

Analysis of the metallic content in tissues of the organisms populating the Spokane River indicated that the algae were the prime concentrators of metals such as Zn, Cd, Pb, Hg, Fe, and Mn. Algae and detritus consumers such as the larva of the caddis fly, Hydropsyche sp. and the nymphs of the may fly Baetis sp. showed a correspondingly high level of the metals tested for, especially Zn, Cd, Pb, and Fe. A similar high concentration of metals was exhibited by the snail Physa sp. which also injests algae and detritus. However, the chironomid, Glyptotendipes sp., another detritus consumer living in the river sediments showed a somewhat lower concentration of the metallic elements. Higher aquatic plants such as Potomegeton crispus and the moss, Amblystegium juratzkanum, had relatively high concentrations of Zn and Pb in their tissues but these amounts were somewhat lower than that found in the algae and algae consumers.

Analysis of fish tissues (fillet, fat, liver, and kidney) were also made as part of this investigation. As one would expect, the filter bodies (kidney and liver tissues) showed the highest concentration of the metallic elements. Zinc, for example, ranged from over 80 mg/kg in the Perch (Perca flavescens) to over 119 and 200 mg/kg respectively in the Black Bullhead (Ictalurus melas) and Squawfish (Ptychocheilus oregonensis) in liver tissue. Fillet tissues taken from the same fishes were considerably lower. Mean Zn values were 33, 55, and 54 mg/kg in the Perch, Bullhead, and Squawfish, respectively. Fatty tissue values for the same fishes lay generally between the higher liver and the lower fillet tissue measurements.

Other metallic elements such as Fe, Ni, Sb, Se, Cr, Co, Rb, Em, Cr, and Sc followed a similar pattern with the exception of Rb and Cs which were higher in the fatty tissues than either the liver or fillet tissues.

In conclusion it may be said that the upper Spokane River's productivity in regard to plankton and bottom organisms is largely controlled by the water quality of Coeur d'Alene Lake. For the most part it is of good to excellent quality except for metallic content. There is still, however, a considerable amount of Zn, Pb, and Cu and other metals continually being supplied through the Coeur d'Alene River - Lake system. These metals are concentrated by the algae and other aquatic plants in the river and passed on to aquatic insects and fish feeding upon the plants. There appears to be relatively large quantities of metallic elements in the tissues of aquatic insects and fishes from the upper Spokane River. It also appears, however, that most of the metallic elements must be in a relatively innocuous form since the fishes are swimming in waters containing as much or more than that quantity necessary to injure them under laboratory conditions.

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APPENDICES

APPENDIX A

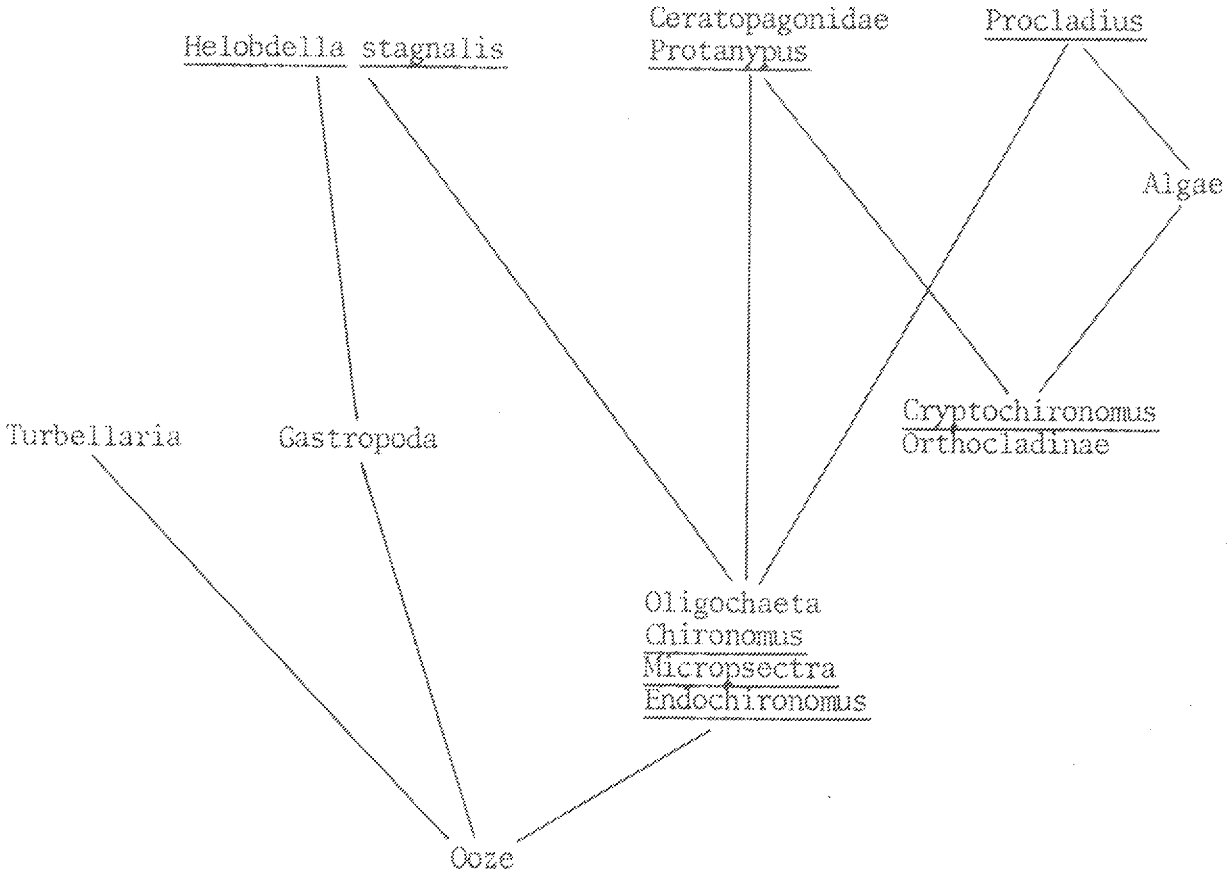

Chart A-1. A simplified food web of taxa from Lake Coeur d'Alene based on collected data and observations. (Winner, 1972)

Table A-1. Macrobenthic taxa collected from Lake Coeur d'Alene, Chatcolet Lake, and Round Lake. (Winner, 1972)

- Turbellaria
  - Tricladida
    - Planariidae ?[a]

- Oligochaeta

- Hirundinea
  - Rhynchobdellida
    - Glossiphosiidae
      - *Helobdella stagnalis*

- Crustacea
  - Amphipoda
    - Gammaridae
      - *Gammarus* sp.

- Arachnoidea
  - Hydracarina
    - Limnesiidae
      - *Limnesia* sp.
    - Hygrobatidae
      - *Hygrobates* sp.
    - Libertiidae
      - *Libertia* sp.
    - Unionicolidae
      - *Neumania* sp.
      - *Unionicola* sp.
    - Pionidae
      - *Piona* sp.
      - *Unk.*
    - Protziidae
      - *Calonys* sp.
    - Arrenuridae
      - *Arrenurus* sp.

- Insecta
  - Ephemeroptera
    - Heptigeniidae
      - *Epeorus* sp.[b]
    - Baetidae
      - *Ephemerella serrata levis*
      - *Caenis* sp.
  - Odonata
    - Coenagrionidae
      - Enallagma sp. (possibly *E. clausam*)
  - Plecoptera
    - Perlodidae
      - *Isoperla* sp.[b]

- Trichoptera
  - Rhyacophiladae
    - *Rhyacophila* sp.
    - *Glossosoma* sp.
    - *Agapetus* sp.
  - Leptoceridae
    - *Mystacides* sp.
  - Hydroptilidae
    - *Agraylea* sp.
    - *Dibusa* sp.
  - Hydropsychidae
    - *Hydropsyche*[b]
  - Limnophilidae
    - Unk.
  - Psychomyiidae[b]
    - Unk.
- Coleoptera
  - Elmidae
    - *Zaitzevia* sp.[b]
  - Cicindelidae
    - *Megacephala* sp.[c]

Table A-1. (Cont.)

- Diptera
  - Ceratopagonidae
    - *Palpomyia* group (four spp.)
  - Chaoboridae
    - *Chaoborus* sp.
  - Tipulidae
    - *Tipula* sp.
  - Rhagionidae
    - *Athrix variagata*
  - Chironomidae
    - *Procladius* (two spp.)
    - *Psectrotanypus* sp.
    - *Guttipelopia* ? sp.
    - *Thienemannimyia* grp, one sp.
    - *Protanypus* sp.
    - *Odontomesa* sp.
    - *Psectrocladius* sp.
    - *Heterotrissocladius* sp.
    - *Cricotopus* sp.
    - *Corynoneura* sp.
    - *Chironomus* (three spp.)
    - *Paratendipes* sp.
    - *Cryptochironomus fulvus*
    - *Cryptochironomus* (two spp.)
    - *Polypedilum* sp., *Tripodura* grp.
    - *Paracladopelma* sp.
    - *Phaenopsectra* sp.
    - *Endochironomus* sp.
    - *Einfeldia* sp.
    - *Glyptotendipes* sp.
    - *Stictochironomus* sp.
    - *Tanytarsus* sp.
    - *Micropsectra* sp.
- Gastropoda
  - Planorbidae
    - Unk.
- Pelecypoda
    - *Pisidum* sp.

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[a] ? = unconfirmed.

[b] Probable drift from river or stream.

[c] Terrestrial.

Table A-2. Density estimates of *Procladius* and *Psectrotanypus* (sub-family Tanypodinae), *Psectrocladius* (Orthocladinae), and *Protanypus* (Diamesinae) collected on three dates in the Coeur d'Alene Lake system. (Winner, 1972)

Station	Depth (m)	Genus	Number Collected/m^2		
			July	Sept.	March
1A	2	*Procladius*	215	430	43
		Psectrotanypus	86	...	...
		Psectrocladius	43	215	...
1B	5	*Procladius*	560	86	430
		Psectrocladius	43	...	43
		Protanypus	43	43	...
1C	10	*Procladius*	43	...	43
		Psectrotanypus	560	...	...
		Psectrocladius	43	...	...
2A	2	*Procladius*	43	43	...
2B	5	*Procladius*	215	517	215
		Psectrocladius	215	43	...
2C	10	*Procladius*	129	172	732
		Psectrocladius	172	...	...
2D	>20	*Procladius*	...	...	43
		Psectrocladius	...	43	86
3A	2	*Procladius*	172	517	344
		Psectrocladius	...	215	...
3B	5	*Procladius*	344	172	517
		Psectrocladius	43	...	...
		Protanypus	86	...	43
3C	10	*Procladius*	86	...	...
		Psectrocladius	...	...	43
		Protanypus	172	129	129
3D	>20	...	...	...	...
4A	2	*Psectrotanypus*	43	...	...
		Psectrocladius	301	86	...
4B	5	*Psectrocladius*	43	...	...
4C	10	*Procladius*	43	172	...
		Protanypus	43	...	...
4D	>20	...	...	...	...

Table A-3. Density estimates of Trichoptera collected on three dates in the Coeur d'Alene Lake system. (Winner, 1972)

Station	Depth (m)	Taxon	Number Collected/m^2		
			July	Sept.	March
1A	2	Dibusa	430	...	...
		Limnephilidae	...	43	...
		Glossosoma	...	...	129
1B	5	Limnephilidae	43	...	...
		Glossosoma	...	...	129
1C	10	...	...	...	...
2A	2	Psychomyiidae	43	...	...
		Glossosoma	...	43	...
2B	5	Limnephilidae	...	...	43
		Glossosoma	86	172	...
		Rhyacophila	...	...	43
2C	10	Limnephilidae	...	...	474
		Glossosoma	...	...	43
		Rhyacophila	...	...	172
2D	>20	...	...	...	...
3A	2	Agraylea	215	990	...
		Agapetus	...	129	...
		Rhyacophila	...	43	...
3B	5	...	...	...	...
3C	10	...	...	...	...
3D	>20	...	...	...	...
4A	2	Mystacidaes	...	603	...
4B	5	Agapetus	...	43	...
		Rhyacophila	...	...	43
4C	10	Glossosoma	...	...	43
		Limnephilidae	...	...	86
4D	>20	...	...	...	...

Table A-4. Density estimates of each genus of Hydracarina collected on three dates in the Coeur d'Alene Lake system. (Winner, 1972)

Station	Depth (m)	Genus	Number Collected/m^2		
			July	Sept.	March
1A	2	*Limnesia*	86	430	301
		Hygrobates	...	...	43
		Arrenurus	...	...	43
1B	5	*Limnesia*	...	...	43
		Arrenurus	43	43	43
		Piona	...	43	86
1C	10	*Limnesia*	43	...	...
		Unionicola	...	...	43
2A	2	...	...	...	...
2B	5	*Limnesia*	...	43	...
		Piona	...	43	...
2C	10	*Limnesia*	...	...	43
		Piona	...	43	...
		Pionidae	...	43	...
		Neumania	...	...	43
2D	>20	*Limnesia*	43	...	...
3A	2	*Limnesia*	...	43	...
		Pionidae	...	43	...
3B	5	*Limnesia*	86	129	86
		Arrenurus	...	172	...
		Libertia	...	43	...
		Hygrobates	...	...	43
3C	10	*Hygrobates*	...	43	86
3D	>20	...	...	...	...
4A	2	...	...	...	...
4B	5	*Limnesia*	...	43	...
		Hygrobates	...	43	...
4C	10	*Limnesia*	43	43	43
4D	>20	...	...	...	...

TABLE A-5. CHEMICAL DATA COEUR D'ALENE LAKE 1971-2

(Measurements were taken at 1.0 M and are expressed as mg/l except where noted.)

Date Location	NO_3-N	NH_3-N	PO_4-P	SO_4	BOD	COD	CO_2	HCO_3	DO	Temp. °C	pH Units	Conductivity Micro-mhos at 25°C
August 27, 1971												
Mid Lk off Harrison	.01		.01			1.61		26.0			7.2	50
Cd'A Lk Outlet	.015		.02	7.0		3.0		28.0				50
Echo Bay	.03		.01			1.5		27.0				50
Carlin Bay	.02		.01			3.4		26.0				50
Mica Bay	.05		.01			3.6		29.0				50
Rockford Bay	.04		.01			3.1		28.0				50
Cave Bay	.025		.01			1.6		28.0				50
Cd'A River Mouth	.015		.03	4.0		6.5		24.0				65
E. Shore off Conk	.025		.01			3.25		24.0			7.15	50
Mid Lake off Conk	.03		.02			3.4		23.0				50
Chat Outlet	.04		.002	9.2		5.17		24.0			7.15	50
Chat off Rocky Pt.	.025		.001	7.9		4.36		29.0			7.2	50
September 23, 1971												
Rockford Bay	.075	.0	.00	8.0	.7	3.75	2.0	23.0	8.8	15	7.8	75
Cd'A River	.025	.0	.02	9.5	1.7	5.13	2.0	21.0		14	7.1	81
Cd'A River Delta	.05	.0	.40	44.5	1.05	---	2.0	24.0	9.1	15	7.2	65
Cd'A Outlet	.010	.0	.00	6.5	2.1	4.67	2.0	22.0	8.8	16	7.2	50
Chat Outlet	.02	.0	.02	9.2	2.1	5.15	1.0	24.0	8.9	16	7.6	60
October 13, 1971												
Mid Lk off Harrison			.020									
Cd'A Lk Outlet	.07	.0	.010	8.0			2.0	22.0	9.1		7.8	50
Echo Bay	.03	.0	.005									

Cd'A = Coeur d'Alene, Conk = Conkling, Chat = Charcolet, Lk = Lake

Table A-5. Continued

Date Location	NO_3-N	NH_3-N	PO_4-P	SO_4	BOD	COD	CO_2	HCO_3	DO	Temp. °C	pH Units	Conductivity Micro-mhos at 25°C
October 13, 1971												
Carlin Bay												
Mica Bay												
Rockford Bay	.04	.0	.0				2.0	23.0	8.8		7.1	
Cave Bay	.02	.0	.0					21.0			7.2	
Cd'A River Mouth	.01	.0	.020	9.5			2.0	22.0	8.9		6.9	80
E. Shore off Conk	.01	.01	.0						8.8			
Mid Lake off Conk	.01	.0	.010						8.8			
Chat Outlet	.01	.0	.010						10.1			
Chat off Rocky Pt.	.01	.0	.010						10.2			
October 16, 1971												
Mid Lk off Harrison	.027	.06	.100						9.7			
Cd'A Lk Outlet	.025	.07	.0						10.2			
Echo Bay	.027	.08	.0						10.1			
Carlin Bay	.015	.08	.01						10.2			
Mica Bay	.003	.08	.01						10.1			
Rockford Bay	.044	.09	.0			6.0			10.1			
Cave Bay	.017	.01	.015						10.2			
Cd'A River Mouth	.006	.04	.070						10.2			
E. Shore off Conk	.030	.03	.030						11.0			
Mid Lake off Conk	.027	.03	.030			2.5	5.00		10.1			
Chat Outlet	.021	.01	.040			3.5	8.00		11.0			
Chat off Rocky Pt.	.027	.01	.010			3.0	7.62		10.8			

Cd'A = Coeur d'Alene, Conk = Conkling, Chat = Chatcolet, Lk = Lake

Table A-5. Continued

Date Location	NO_3-N	NH_3-N	PO_4-P	SO_4	BOD	COD	CO_2	HCO_3	DO	Temp. °C	pH Units	Conductivity Micro-mhos at 25°C
November 29, 1971												
Mid Lk off Harrison	.03		.032									
Cd'A Lk Outlet	.05		.015	8.0								
Echo Bay	.025		.008									
Carlin Bay	.05		.014									
Mica Bay	.045		.011									
Rockford Bay	.025		.008									
Cave Bay	.045		.083									
Cd'A River Mouth	.040		.029									
E. Shore off Conk	.055		.030									
Mid Lake off Conk	.035		.073									
Chat Outlet	.045		.016									
Chat off Rocky Pt.	.030											
February 8, 1972												
Cd'A River	.025		1.525	41.0								
St. Joe River	.14		.050	35.0								
Bennewah Creek	.17		.100	10.0								
Rocky Point	.30		.125	7.5								
Plummer Creek	1.75		.350	9.5								
Chat Lk Outlet	.26		.100	10.5								
March 8, 1972												
Cd'A River	.125		.050	18.5					11.7	5.5		
St. Joe River	.115		.050	5.5					11.8	5.0		
Bennewah Creek	.130		.075	11.0								
Rocky Point	.170		.100	10.5					11.7			
Plummer Creek	.650		.150	11.5					11.7			
Chat Lk Outlet	.165		.175	11.5					11.6	6.0		
Cottonwood Cr. West	2.850		.225	31.5								

Table A-5. Continued

Date Location	NO_3-N	NH_3-N	PO_4-P	SO_4	BOD	COD	CO_2	HCO_3	DO	Temp. °C	pH Units	Conductivity Micro-mhos at 25°C
March 18, 1972												
Cd'A River	.06		.175							5.5	6.8	
St. Joe River	---		---								6.7	
Bennewah Creek	.07		.125									
Rocky Point	.13	.150								5.5		
Plummer Creek	.15		.225							5.7		
Chat Lk Outlet	.07		.175	10.5					10.0		6.8	
Cottonwood Cr. West	1.25	.275										
Cd'A Outlet							1.0	34.0	10.0	5.5	6.7	50
June 8, 1972												
Beetle Point	.030		.025	4.0	1.50	4.36	2.0	17.0	10.0	19.2	7.0	50
Carlin Bay	.040		.025	14.5	.90	2.71	9.0	16.0	9.9	18.4	7.0	50
Cd'A Outlet	.030		.025	15.0	1.00	2.53	6.0	14.0	9.5	19.0	7.0	50
Mica Bay	.040		.030	13.5	.85	3.26	6.0	14.0	9.5	18.1	6.7	50
Mid Lk off McDonald Pt	.045		.025	12.5	1.20	2.98	6.0	15.0	9.9	18.1	7.0	50
Chat lk outlet	.045		.025	4.0	.78	4.09	4.0	15.0	9.7	18.0	7.0	50
Windy Bay	.030		.040	13.5	.70	2.76	4.0	20.0	11.5	18.0	7.1	50
Rockford Bay	.05		.025	13.5	.88	2.71	4.0	15.0	9.3	19.0	7.1	50
Cd'A River Delta	.040		.050	12.0	.65	2.66	6.0	20.0	9.5	18.0	7.0	62
E. End of Wolf Lodge Bay	.03		.012	14.5	1.25	4.59	2.0	16.0	9.0	18.0	7.0	52
July 12, 1972												
Cd'A River Delta	.065		.175	20.0		1.77	4.0	18.0	11.0	17.0	6.9	97
Cottonwood Bay	.010		.075	6.0		2.06	4.0	20.0	10.8	17.1	7.2	50

Cd'A = Coeur d'Alene, Chat Lk = Chatcolet Lake, Conk = Conkling

Table A-5.Continued

Date Location	NO_3-N	NH_3-N	PO_4-P	SO_4	BOD	COD	CO_2	HCO_3	DO	Temp. °C	pH Units	Conductivity Micro-mhos at 25°C
July 12, 1972												
Mid Lk off Harrison	.000		.100	10.0		1.48	2.0	25.0	10.8	17.1	7.1	50
Mid Lk off Conk	.010		1.875	6.0		2.18	4.0	21.0	10.0	18.0	7.2	50
Main Channel-Cous Bay	.050		.075	4.0		2.67	3.0	17.0	10.5	18.7	7.2	50
Chat lk Outlet	.025		.100	2.0		1.23	6.0	21.0	11.5	18.9	7.2	50
Browns Bay	.055		.100	2.0		3.29	2.0	25.0	11.0	19.0	7.2	52
Carlin Bay	.050		.150	8.0		.617	5.0	15.0	9.5	18.0	7.2	50
Rockford Bay	.010		.100	11.0		3.41	2.0	15.0	10.8	17.7	7.4	50
Cd'A Outlet						2.00	2.0	20.0	9.0	19.0	7.2	50
August 18, 1972												
Cd'A River	.05		.40	37.0		9.71	10.0	38.0	9.0	22.1	6.4	125
Cd'A River Delta	.04		.10	13.0		6.92	6.0	24.0	10.0	22.1	7.0	71
Hidden Lake	.055		.055	6.0		3.75	4.0	28.0	12.0	22.0	7.2	50
Cougar Bay	.03		.075	12.0		6.81	---	30.0	10.2	22.1	7.8	61
Long Bay	.015		.10	12.0		5.75	5.0	25.0	12.5	22.0	7.0	52
Conklin Park	.030		.10	15.0		6.81	2.0	32.0	12.0	21.0	7.0	50
St. Joe River	.055		.12	2.0		5.34	6.0	42.0	11.5	22.0	6.5	50
Chat Lk Outlet	.035		.10	1.0		22.93	2.0	32.0	11.0	22.8	7.0	50
Twin Beach	.030		.70	10.5		6.41	2.0	22.0	11.0	22.4	7.1	50
Cd'A Outlet	.035		.77	12.0		6.94	7.0	27.0	8.9	22.3	7.6	50
October 17, 1972												
Cd'A River Delta	.05		.0005	10.6		5.07	4.0	26.0	12.0	14.0	6.7	72
No. End Mid Lake	.025		.0003	10.4		4.36	1.0	24.0	85	14.0	7.0	50
Chat Outlet	.025		.007	.10		5.05	2.0	23.0	9.5	14.0	7.1	50
Cd'A Lake Outlet	.05		.0003	11.0		5.07	1.0	22.0	9.0	13.9	7.15	50

APPENDIX B[*]

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[*] Most of the data contained within this appendix was derived from Dunigan (1972).

TABLE B-1. Chemical data for Core 1. Delta 9.14 m
all except pH, % Water Content, and % Total-Carbon are expressed as mg/kg

depth		% Water			Atomic Absorption Analysis									
cm	pH	Content	Total-P	Total-C	As	Cd	Cu	Fe	Mg	Mn	Mo	Ni	Pb	Zn
0.0	-	113.34	3360.	2.98	0.00	21.0	56.4	10200.	1064.	1140.	2.5	296.	1588.	800.
10.0	5.9	35.53	3440.	2.99	0.00	26.3	8.2	11500.	1224.	1300.	3.0	370.	232.	920.
20.0	6.1	35.16	4777.	3.03	0.23	25.7	59.2	10400.	1210.	1140.	2.8	378	1978.	850.
30.0	-	35.08	4388.	2.90	0.19	13.2	38.2	10800.	1260.	1500.	3.4	326.	1430.	672.
36.0	7.05	54.89	4388.	2.58	0.19	13.6	64.2	13200.	1550.	1600.	2.76	494.	1632.	750.
57.75	6.2	54.05	3142.	2.81	0.08	10.7	89.0	16200.	1640.	1900.	3.4	574.	1854.	1020.
70.0	6.1	54.83	3483.	2.87	0.10	8.4	43.4	16700.	1640.	1800.	4.26	554.	1886.	830.
79.5	5.3	53.98	2440.	1.36	0.00	4.5	17.2	4700.	290.	335.	2.0	172.	1574.	255.

TABLE B-1 continued. Chemical data for Core 1. Delta 9.14 m
all expressed as mg/kg

depth cm	Al	Co	Cr	Cs	Fe	Mn	Rb	Sb	Sc	V	Zn
0.0	33011.9	21.59	47.18	10.24	103000.	29390.5	35.29	96.86	6.9165	9.0799	4363.
10.0		19.05	27.8	6.3	102200.		118.80	248.50	6.770		3400.
20.0		12.34	28.04	5.5	63270.		90.17	121.63	7.43		3430.
30.0		18.01	30.10	7.114	101500.		124.30	280.4	7.54		3150.
36.0	24992.0	24.44	40.85	8.399	140650.	38058.0	34.33	101.22	6.22	7.63	4192.
57.75	31967.0	16.03	37.79	9.569	117700.	35169.5	37.84	68.625	6.90	12.79	7563.
70.0		10.46	68.09	18.29	45290.		271.9	261.4	19.7		5040.
79.5	46526.0	11.385	61.57	11.81	38250.	1744.05	40.58	1.976	12.50	19.09	

TABLE B-1 continued. Chemical data for Core 1.
all expressed as mg/kg

depth	Neutron Activation Analysis									
cm	Ag	Ba	Eu	Ha	Se	Ta	Tb	Th	Y	Zr
0.0										
10.0	10.27	15.60	0.87	1.28		0.211	0.63	1.9	1.00	513.5
20.0	10.13	15.25	0.97	1.34	5.30	0.15	0.384	2.19	1.00	70.5
30.0	10.62	15.54	0.88	1.04		0.75		1.863	1.03	572.1
36.0										
57.75										
70.0	23.34	36.06	0.85	2.17		1.36	1.00	4.96	2.39	707.1
79.5										

TABLE B-1. (continued) Chemical data for Core 1
all expressed as mg/kg

depth	Neutron Activation Analysis										
cm	Al	Co	Cr	Cs	Fe	Mn	Rb	Sb	Sc	V	Zn
0.0	33011.9	21.59	47.18	10.2355	103000.	29390.5	35.29	96.86	6.9165	9.0799	4363.
10.0	-	19.05	27.80	6.342	102200.	-	118.8	248.50	6.770	-	3400.
20.0	-	19.53	28.045	5.574	110700.	-	90.16	239.40	7.435	-	3430.
30.0	-	18.01	30.10	7.114	101500.	-	124.3	280.4	7.542	-	3150.
36.0	24992.0	24.44	40.85	8.399	140650.	38058.0	34.33	101.22	6.2215	7.6325	4192.
57.75	31967.0	16.025	37.79	9.569	117700.	35169.5	37.84	68.625	6.899	12.7873	7563.
70.0	-	10.46	68.09	18.29	45290.	-	271.9	261.40	19.70	-	5040.
79.5	46526.0	11.385	61.57	11.81	38250.	1744.05	40.58	1.976	12.495	19.093	-

TABLE B-1. (continued) Chemical data for Core 1
all expressed as mg/kg

depth cm	Neutron Activation Analysis Ag	Ba	Eu	Ha	Se	Ta	Tb	Th	Y	Zr
0.0	-	-	-	-	-	-	-	-	-	-
10.0	10.27	15.60	0.871	1.283	-	0.211	0.627	1.854	0.995	513.5
20.0	10.13	15.25	0.968	1.343	5.295	0.147	0.384	2.193	0.996	70.48
30.0	10.62	15.54	0.825	1.036	-	0.248	-	1.863	1.034	572.1
36.0	-	-	-	-	-	-	-	-	-	-
57.75	-	-	-	-	-	-	-	-	-	-
70.0	23.34	36.06	0.851	2.167	-	1.364	0.996	4.958	2.378	702.1
79.5	-	-	-	-	-	-	-	-	-	-

TABLE B-2. Chemical data for Core 2, center off Delta, 18.28 m
all except pH, % Water Content, and % Total-Carbon are expressed as mg/kg

depth		% Water				Atomic Absorption Analysis								
cm	pH	Content	Total-P	Total-C	As	Cd	Cu	Fe	Mg	Mn	Mo	Ni	Pb	Zn
0.0	6.0	375.57	3905.	3.29%	0.15	27.7	75.0	11600.	1320.	1300.	4.2	328.	1650.	786.
10.0	6.15	208.01	3332.	2.93%	0.10	18.4	75.0	12500.	1390.	1450.	3.2	344.	1750.	870.
25.0	6.3	64.03	2929.	2.31%	0.37	8.4	43.0	9440.	1360.	1250.	2.8	222.	1588.	730.
40.0	6.3	45.59	2449.	2.35%	0.10	11.0	84.0	17420.	1480.	3280.	2.2	570	1756	1100.
47.5	6.0	65.74	3108.	2.83%	0.36	8.6	53.6	14400.	1480.	1580.	2.7	444.	1554.	820.
62.5	5.9	76.45	3099.	2.56%	0.34	15.6	14.0	15600.	1610.	1580.	2.8	548.	1960.	1420.
72.5	5.1	54.49	3007.	2.16%	0.32	11.5	11.8	5600.	260.	210.	0.174	134.	364.	86.

TABLE B-2. (continued) Chemical data for Core 2

all expressed as mg/kg

depth		Neutron Activation Analysis of oven-dried samples (freeze-dried samples)											
cm	Ag	Al	Co	Cr	Cs	Fe	Mn	Rb	Sb	Sc	Se	V	Zn
0.0	20.3	30678.	23.19	38.6	7.634	125800.	40126.5	176.6	109.1	8.247	-	16.8741	4516.
25.0	11.84 (12.42)	38209. (30636.)	15.04 (18.03)	32.9 (31.65)	6.938 (8.491)	84520. (88480.)	39995.5 (30998.)	90.19 (108.1)	39.44 (50.53)	6.106 (7.225)	(21.82)	16.894 (13.625)	3011. (3681.)
40.0	11.48	-	11.67	30.80	9.521	85590.	-	150.5	202.2	8.378	-	-	4440.
47.5	17.42 (18.11)	(35295.)	15.67 (18.77)	33.01 (38.32)	9.006 (10.67)	93670. (106200.)	(44363.5)	153.1 (110.3)	88.66 (71.82)	7.744 (7.717)	20.99 (19.95)	(20.184)	4281. (4217.)
62.5	75.35 (81.63)	34415. (47572.)	10.85 (9.746)	44.34 (40.21)	12.98 (13.98)	82390. (80550.)	18779.4 (23751.)	116.6 (175.5)	209.3 (215.3)	11.96 (15.54)	-	15.567 (23.647)	12690. (13210.)
72.5	3.074 (3.166)	50853. (46908.)	9.168 (8.079)	42.56 (37.74)	9.217 (9.029)	31530. (32470.)	3839.4 (5990.05)	143.3 (128.6)	6.577 (7.041)	11.21 (10.86)	6.402 (2.283)	25.824 (21.268)	527.7 (547.9)

TABLE B-3. Chemical data for Core 3, 189 m off Delta, 18.28 m
all except pH, % Water Content, and % Total-Carbon expressed as mg/kg

depth		% Water						Atomic Absorption Analysis						
cm		Content	Total-P	Total-C	As	Cd	Cu	Fe	Mg	Mn	Mo	Ni	Pb	Zn
0.0	5.0	32.93	2590.	2.59%	0.11	42.5	74.2	8360.	382.	705.	2.8	294.	1594.	900.
10.0	5.45	44.53	2471.	3.64%	0.01	17.5	53.6	6400.	390.	710.	2.2	200.	1628.	620.
20.0	5.68	41.84	2294.	2.79%	0.19	16.0	38.0	6800.	780.	797.	2.76	332.	1760.	660.
30.0	5.86	54.74	2468.	2.80%	0.02	17.4	56.4	10000.	1240.	1120.	3.0	328.	1606.	792.
40.0	5.68	36.40	1616.	2.88%	0.09	7.0	25.4	5260.	380.	564.	2.2	198.	1260.	275.
50.0	5.95	41.25	2132.	2.45%	0.12	9.5	43.8	9340.	1580.	1120.	2.8	312.	1596.	675.
58.2	6.06	34.52	2425.	2.75%	0.06	13.6	60.0	10100.	1500.	1190.	3.0	332.	1596.	760.

TABLE B-3. (continued) Chemical data for Core 3
all expressed as mg/kg

depth cm	Neutron Absorption Analysis Ag	Ba	Co	Cr	Cs	Eu	Fe	Ha	Rb	Sb	Sc
0.0	13.86	-	19.43	41.46	7.253	0.946	116700.	1.839	606.5	219.2	8.725
10.0	15.84	27.58	27.25	47.88	8.341	1.119	159900.	1.980	230.9	433.1	9.664
20.0	9.351	15.53	15.38	24.97	6.890	0.837	78850.	1.307	123.5	357.3	7.334
30.0	15.90	-	23.82	38.50	7.456	0.987	136700.	1.472	-	328.2	7.875
40.0	7.515	16.49	14.54	26.24	7.017	0.886	81480.	1.598	130.9	146.7	7.741
50.0	18.19	30.29	24.21	44.31	10.25	1.097	135500.	2.081	207.3	250.1	10.13
58.0	16.53	27.89	24.97	48.95	11.68	1.173	125400.	1.972	228.6	218.5	11.39

TABLE B-3. (continued) Chemical data for Core 3
all expressed as mg/kg

depth	Neutron Activation Analysis					
cm	Ta	Tb	Th	Y	Zn	Zr
0.0	0.238	0.651	2.726	1.792	5730.	540.0
10.0	0.326	0.727	3.167	1.956	5160.	122.9
20.0	0.176	-	1.921	0.983	4270.	66.74
30.0	-	0.481	2.371	1.654	3520.	742.9
40.0	0.265	-	2.240	0.973	3270.	78.85
50.0	2.109	0.769	3.308	2.157	5690.	614.8
58.0	0.325	0.881	3.666	2.227	5760.	195.0

TABLE B-4. Chemical data for Core 4, 1.6 km off Easterseal, 19.8 m
all except pH, % Water Content, and % Total-Carbon expressed as mg/kg

depth cm	pH	% Water Content	Total-P	Total-C	As	Cd	Cu	Fe	Mg	Mn	Mo	Ni	Pb	Zn
					Atomic Absorption Analysis									
0.0	5.3	46.82	2917.	2.93%	0.13	25.6	75.2	11620.	980	1500	3.2	410.	1640	625.
10.0	5.6	49.41	1886.	2.02%	0.09	10.6	84.0	12900.	1410	1480	2.7	430.	1632	2080.
20.0	5.6	53.73	2297.	2.61%	0.05	9.9	62.0	17400.	1760	-	2.8	512.	1690	1120.
30.0	5.2	85.52	2551.	2.54%	0.00	13.6	58.6	8360.	396	1820	2.8	216.	1470	1100.
40.0	5.2	95.72	2613.	2.05%	0.00	0.32	8.6	4160.	200	735	0.15	172.	61	17.4
50.0	5.6	108.0	2781.	2.33%	0.20	0.55	11.8	6100.	300	316	2.4	148.	113	3280.
60.0	5.7	118.89	2253.	2.14%	0.12	0.32	5.2	4640.	250	118	0.16	126.	31.2	14.
70.0	5.8	102.10	2720.	1.99%	0.00	0.25	6.0	3500.	190	105	0.17	148.	38.4	13.
79.5	5.5	127.10	3411.	1.93%	0.00	0.68	10.4	4400.	220	116	2.7	156.	85.4	17.5

TABLE B-4. (continued) Chemical data for Core 4.

all expressed as mg/kg

depth cm	Neutron Activation Analysis Ag	Ba	Co	Cr	Cs	Eu	Fe	Ha	Rb	Sb	Sc
0.0	110.08	-	5.315	28.67	6.323	0.663	79580.	0.787	107.6	248.7	6.751
10.0	9.004	-	15.85	25.32	5.945	0.629	71420.	0.774	112.4	212.0	6.784
20.0	20.54	46.25	23.86	50.36	16.11	1.325	125000.	1.342	280.8	250.5	12.05
30.0	43.13	-	10.44	34.36	11.77	1.229	62380.	0.855	155.1	482.6	11.58
40.0	-	33.75	12.99	64.94	13.56	0.866	40500.	2.890	221.0	9.948	19.44
50.0	-	13.28	7.845	30.33	7.415	0.516	22570.	1.366	107.2	5.312	11.21
60.0	-	-	12.25	49.18	10.69	0.739	34490.	1.639	165.7	5.346	16.54
70.0	-	19.23	10.21	41.51	10.39	0.782	30800.	2.207	155.0	6.775	15.67
79.5	-	17.02	0.164	44.86	10.74	0.820	32070.	2.096	147.2	11.07	15.91

TABLE B-4. (continued) Chemical data for Core 4.
all expressed as mg/kg

depth	Neutron Activation Analysis						
cm	Se	Ta	Tb	Th	Y	Zn	Zr
0.0	-	-	0.569	1.550	0.664	2350.	517.7
10.0	-	0.150	-	1.433	0.825	2660.	445.2
20.0	-	0.371	0.870	3.216	1.718	5040.	642.1
30.0	-	0.207	-	2.289	1.011	10510.	96.13
40.0	-	5.437	0.927	5.451	3.018	-	149.6
50.0	-	0.232	0.439	2.384	1.126	-	56.06
60.0	-	0.356	0.945	4.135	2.163	-	129.3
70.0	1.556	0.403	0.238	3.699	1.614	-	97.91
79.5	-	0.404	0.805	3.603	1.649	-	92.78

TABLE B-5. Chemical data for Core 5, 274 m off Camp Easterseal, 17.98 m
all except pH, % Water Content, and % Total-Carbon are expressed as mg/kg

depth		% Water				Atomic Absorption Analysis								
cm	pH	Content	Total-P	Total-C	As	Cd	Cu	Fe	Mg	Mn	Mo	Ni	Pb	Zn
0.0	5.6	43.07	2355.	2.64%	0.08	9.4	40.4	-	1370.	-	2.5	-	-	-
10.0	5.5	43.36	2079.	2.41%	0.11	12.4	74.0	19500.	1380.	1580.	3.0	574.0	1746.0	98.0
20.0	5.4	52.89	2107.	2.75%	0.15	9.0	82.0	11600.	1300.	1260.	2.76	326.0	1674.0	102.0
30.0	4.4	43.07	1969.	1.94%	0.00	1.07	11.5	4500.	250.	185.	2.0	152.0	342.0	105.0
40.0	4.6	84.00	1159.	1.57%	0.06	0.36	8.4	3680.	216.	134.	2.7	32.8	113.6	25.0
50.0	4.6	108.39	2840.	2.46%	0.36	0.154	8.4	4200.	210.	126.	2.2	47.6	59.0	18.4
60.0	4.8	103.80	2933.	2.22%	0.00	0.35	8.2	4700.	220.	140.	2.7	194.0	47.8	15.0
69.0	5.3	101.94	2564.	2.07%	0.00	-	7.6	-	-	-	-	-	-	-

TABLE B-5. (continued) Chemical data for Core 5.
all expressed as mg/kg

depth	Neutron Activation Analysis									
cm	Ag	Co	Cr	Cs	Fe	Rb	Sb	Sc	Se	Zn
0.0	-	56.49	74.62	10.66	56360.	163.0	34.71	16.01	-	32810.0
10.0	-	31.86	32.15	4.438	27590.	73.47	12.37	8.054	2.747	12120.0
20.0	1.648	32.17	10.75	1.338	10520.	-	7.045	1.841	1.048	2995.0
30.0	-	9.607	38.22	4.772	26540.	101.9	1.463	9.448	3.07	709.5
40.0	3.954	15.11	46.06	3.501	18480.	-	10.23	4.791	14.88	5772.0
50.0	-	3.336	7.921	0.667	1650.	-	0.909	0.327	1.862	1915.0
60.0	-	10.95	-	-	3424.	-	6.019	-	1.953	-
69.0	-	8.634	44.42	-	3628.	-	10.50	-	2.185	-

APPENDIX C[*]

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[*] Certain data (October-December, 1971) contained within Table C-1 derived from Thompson (1972).

TABLE C-1. CHEMICAL AND PHYSICAL DATA SPOKANE RIVER 1971-72

(Expressed as mg/l except as noted)

Date Location	River Mile	Temp. °C	pH	02 mg/l	02 % Sat.	CO_2 mg/l	CO_3 mg/l	HCO_3 mg/l	T.D.S. mg/l	Conductivity Micro-mhos at 25°C
October 10, 1971										
Lake Outlet	107	14.0	7.0	9.1	88	2.0	---	21	39.0	58
Spokane Yacht Club	106	14.0	7.0	9.1	88	2.0	---	22	41.1	59
Ross Point	102	14.0	7.1	9.1	88	1.0		28	40.0	61
Post Falls	100	15.1	7.1	9.4	92	2.5		25	39.0	60
Corbin Park	97	16.0	7.2	9.8	96	2.5		24	39.4	60
State Line	94	16.0	7.2	9.8	98	---		24	39.6	61
Harvard Road	90	16.0	7.9	9.8	98	---	1.0	23	41.6	64
October 14, 1971										
Lake Outlet	107	14.0	7.0	9.1	91	1.0		24	37.5	56
Spokane Yacht Club	106	14.0	7.0	9.0	87	1.0		24	35.5	53
Ross Point	102	14.0	7.1	9.0	87	2.0		25	36.1	54
Post Falls	100	14.0	7.2	9.4	90	2.0		25	37.5	56
Corbin Park	97	14.0	7.2	9.4	90	Tr		25	38.9	57
State Line	94	14.0	7.2	9.8	94	---	1.0	23	39.5	59
Harvard Road	90	14.0	7.4	9.8	94	---	1.0	23	42.0	62
October 17, 1971										
Lake Outlet	107	12.0	7.1	9.0	83	1.0		20	37.8	60
Spokane Yacht Club	106	12.0	7.0	9.0	83	1.0		20	38.4	61
Ross Point	102	12.0	7.1	9.0	83	1.0		18	37.9	60
Post Falls	100	12.0	7.3	9.3	83	2.0		18	39.1	62
Corbin Park	97	11.0	7.3	9.7	88	2.0		18	40.3	64
State Line	94	11.0	7.3	9.3	88	2.0		18	41.2	65
Harvard Road	90	11.0	7.4	10.3	93	2.0		18	42.0	67

Table C-1. (Continued)

Date Location	River Mile	Temp. °C	pH	02 mg/l	02 % Sat.	CO_2 mg/l	CO_3 mg/l	HCO_3 mg/l	T.D.S. mg/l	Conductivity Micro-mhos at 25°C
November 4, 1971										
Lake Outlet	107	7.0	7.0	10.3	85	1.0		20	36.6	60
Spokane Yacht Club	106	8.0	7.0	10.3	87	1.0		20	37.8	62
Ross Point	102	8.0	6.8	10.5	88	1.0		20	37.2	61
Post Falls	100	7.0	6.9	10.0	83	1.0		21	38.3	61
Corbin Park	97	7.0	6.9	12.0	98	1.0		20	38.4	63
State Line	94	7.0	7.0	12.2	100	1.0		20	39.4	64
Harvard Road	90	7.0	7.0	12.0	98	2.0		20	44.0	72
November 11, 1971										
Lake Outlet	107	8.0	6.9	10.0	84	1.0		21	44.4	66
Spokane Yacht Club	106	8.0	6.9	10.4	87	1.0		18	46.0	67
Ross Point	102	8.0	6.8	10.4	87	1.0		20	46.7	68
Post Falls	100	8.0	6.9	10.4	87	1.0		20	46.0	68
Corbin Park	97	7.5	6.9	11.0	92	1.0		21	44.0	66
State Line	94	7.5	6.9	11.0	92	1.0		20	46.8	66
Harvard Road	90	7.5	6.9	11.3	94	1.0		20	47.1	67
November 18, 1971										
Lake Outlet	107	6.9	6.9	10.0	82	Tr		19	37.8	54
Spokane Yacht Club	106	6.9	6.9	10.1	82	Tr		21	42.2	54
Ross Point	102	6.7	6.9	10.1	82	1.0		23	38.3	59
Post Falls	100	6.7	6.9	9.0	73	1.0		22	39.1	59
Corbin Park	97	7.3	6.8	11.0	91	---		23	41.5	59
State Line	94	7.2	6.8	11.0	91	---		22	40.9	60
Harvard Road	90	7.4	6.9	12.0	99	---		24	41.0	61

Table C-1. (Continued)

Date Location	River Mile	Temp. ^{o}C	pH	02 mg/l	02 % Sat.	CO_2 mg/l	CO_3 mg/l	HCO_3 mg/l	T.D.S. mg/l	Conductivity Micro-mhos at 25°C
<u>December 2, 1971</u>										
Lake Outlet	107	4.7	7.2	11.0	89	1.0		22	51.0	64
Spokane Yacht Club	106	4.5	7.2	11.0	92	1.0		23	52.0	64
Ross Point	102	4.5	7.2	10.7	84	2.0		21	45.0	64
Post Falls	100	4.6	7.2	10.6	85	3.0		22	45.0	60
Corbin Park	97	4.7	7.2	11.0	89	---		24	50.0	64
State Line	94	4.8	7.3	11.2	92	---		24	55.0	69
Harvard Road	90	4.7	7.3	11.3	91	1.0		23	55.0	65
<u>January 10, 1972</u>										
Lake Outlet	107	3.3	7.0	11.9	89	1.0		17	38.9	54
Ross Point	102	3.4	7.1	11.7	87	2.0		19	39.9	57
Post Falls	100	3.3	6.9	11.0	83	3.0		24	39.9	57
Harvard Road	90	3.1	7.1	12.1	90	2.0		29	42.0	58
Upriver Drive Felts	80	3.1	7.1	11.4	85	3.0		30	44.1	59
<u>February 5, 1972</u>										
Lake Outlet	107	3.1	7.0	11.9	89	---		21	42.0	60
Ross Point	102	2.9	7.2	11.9	88	---		22	45.0	61
Post Falls	100	2.9	7.2	11.3	83	---		24	41.5	62
Harvard Road	90	2.1	7.2	12.4	90	---		24	48.0	64
Upriver Drive Felts	80	2.1	7.3	11.8	92	---		27	47.6	70

Table C-1. (Continued)

Date Location	River Mile	Temp. °C	pH	02 mg/1	02 % Sat.	CO_2 mg/1	CO_3 mg/1	HCO_3 mg/1	T.D.S. mg/1	Conductivity Micro-mhos at 5°C
March 1, 1972										
Lake Outlet	107	3.0	6.6	10.9	82	1.0		27		50
Ross Point	102	3.1	6.7	11.2	84	1.0		27		50
Post Falls	100	3.2	7.0	10.8	81	Tr		31		56
Harvard Road	90	4.0	7.1	11.1	83	Tr		34		58
Upriver Drive Felts	80	4.0	7.1	10.8	82	Tr		36		58
April 1, 1972										
Lake Outlet	107	5.5	6.5	10.0	83	1.0		34		50
Ross Point	102	7.2	6.6	11.8	96	1.0		29		50
Post Falls	100	7.1	6.6	12.0	98	3.0		22		52
Harvard Road	90	6.0	7.2	12.5	100	3.0		24		54
Upriver Drive Felts	80	8.4	7.1	10.6	84	2.0		20		58
May , 1972										
Lake outlet	107	9.2	6.6	10.1	86					
Ross Point	102	10.0	6.6	9.0	80					
Post Falls	100	11.0	6.7	10.0	90					
Harvard Road	90	10.1	7.1	11.0	98					
Upriver Drive Felts	80	11.0	7.4	9.4	85					

Table C-1. (Continued)

Date Location	River Mile	Temp. °C	pH	02 mg/l	02 % Sat.	CO_2 mg/l	CO_3 mg/l	HCO_3 mg/l	T.D.S. mg/l	Conductivity Micro-mhos at 25°C
<u>August 30, 1972</u>										
Lake Outlet	107	23.0	7.3	9.4	108	2.0		29	32.0	52
Ross Point	102	22.8	7.3	9.35	107	2.0		29	41.6	58
Post Falls	100	23.0	7.3	9.1	105	2.0		28	43.4	59
Harvard Road	90	23.5	7.95	9.4	109	---	1.0	28	35.0	60
Upriver Drive Felts	80	23.8	8.1	12.0	139	---	1.0	34	47.0	66
<u>September 14, 1972</u>										
Lake Outlet	107	17.0	7.2	9.0	93	1.0		30	35.1	54
Ross Point	102	17.0	7.4	8.5	88	1.0		32	39.7	56
Post Falls	100	16.8	7.6	8.8	89		1.0	34	45.0	60
Harvard Road	90	15.0	7.6	10.0	98		1.0	31	42.8	61
Upriver Drive Felts	80	15.0	7.85	11.0	108		1.0	38	47.1	67
Desmet House		15.0	7.9	11.0	108		1.0	40	46.0	66

TABLE C-1. CHEMICAL DATA SPOKANE RIVER 1971-72

(Expressed as mg/1)

Date Location	River Mile	NO_3-N	NH_3-N	PO_4-P	SO_4	$S^=$	BOD	COD	Cu	Zn	Fe	Mn
October 10, 1971												
Lake Outlet	107	.07	.000	.02	8.4	.01	1.5	5.1	.01	.26	.1	.01
Spokane Yacht Club	106	.08	.000	.02			1.6	5.0	.01	.23	.1	.01
Ross Point	102	.09	.000	.07	8.2		1.4	5.5	.01	.23	.02	.01
Post Falls	100	.015	.007	.05	7.5	.005	1.2	5.75	.01	.22	.015	.01
Corbin Park	97	.000	.000	.031		.007	1.2	5.35	.01	.21	.01	.01
State Line	94	.010	.002	.025	8.0		.6	5.3	.01	.20	.01	.01
Harvard Road	90	.010	.002	.025	8.0	.001	.7	4.87	.01	.20	.01	.01
October 14, 1971												
Lake Outlet	107	.02	.000	.05	6.0	.005	1.4	3.4	.01	.26		.01
Spokane Yacht Club	106	---	.000	.05			1.45	3.5	.01	.26		.01
Ross Point	102	.04	.01	.07			1.60	3.7	.01	.24		.01
Post Falls	100	.010	.000	.05	8.0	.005	1.55	3.0	.01	.24	.02	.01
Corbin Park	97	.005	.000	---			----	3.0	.01	.21	.015	.01
State Line	94	.000	.002	.025	8.0		1.2	3.1	.01	.20	.01	.01
Harvard Road	90	.010	.002	.025	7.0	.001	1.25	3.1	.01	.20	.005	.01
October 17, 1971												
Lake Outlet	107	.010	.000	.001	6.8	.000	1.6	3.8	.01	.23	.02	.01
Spokane Yacht Club	106	.005	.000	.001	7.0	.001	1.8	4.1	.01	.24	.01	.01
Ross Point	102	.020	.000	.002		.001	1.9	4.4	.01	.25	.01	.01
Post Falls	100	.030	.016	.025	7.3	.0007	1.8	3.6	.01	.24	.02	.01
Corbin Park	97	.020	.000	.000			1.4	3.2	.01	.24	.01	.01
State Line	94	.035	.000	.000	8.0	.001	1.0	3.2	.01	.21	.011	.01
Harvard Road	90	.010	.016	.000	8.0	.001	1.0	3.0	.01	.20	.005	.01

Table C-1. (Continued)

Date Location	River Mile	NO_3-N	NH_3-N	PO_4-P	SO_4	$S^=$	BOD	COD	Cu	Zn	Fe	Mn
November 4, 1971												
Lake Outlet	107	.00	.052	.000	7.6	.001	1.35	3.26	.01	.28	.01	.01
Spokane Yacht Club	106	.00	.031	.015	10.2		1.2	3.04	.01	.27	.01	.01
Ross Point	102	.05	.000	.021	8.9		1.4	3.04	.01	.27	.02	.01
Post Falls	100	00	.000	.005	7.5	.001	1.5	2.6	.01	.30	.01	.01
Corbin Park	97	.00	.031	.01	7.5		1.4	3.48	.01	.29	.01	.01
State Line	94	.10	.003	.01	8.3	.001	1.4	3.2	.01	.29	.01	.01
Harvard Road	90	.20	.003	.005	8.8		1.0	2.8	.01	.28	.01	.01
										.27	.01	.01
November 11, 1971												
Lake Outlet	107	.005	.005	.00	7.0	.001	1.6	4.72	.01	.30	.01	.01
Spokane Yacht Club	106	.000	.000	.00	6.5	.001	1.3	8.20	.01	.30	.01	.01
Ross Point	102	.000	.036	.05	6.0	.02	1.8	5.15	.01	.30	.005	.01
Post Falls	100	.070	.007	.05	6.5	.001	1.2	4.72	.01	.30	.01	.01
Corbin Park	97	.075	.000	.025	6.5	.001	1.6	4.29	.01	.28	.01	.01
State Line	94	.001	.000	.02	6.1	.001	1.7	4.29	.01	.28	.01	.01
Harvard Road	90	.200	.007	.02	5.5	.001	1.6	4.29	.01	.26	.01	.01
									.01		.01	.01
November 18, 1971												
Lake Outlet	107	.075	.000	.03	7.0		.3	5.9	.01	.30	.01	.01
Spokane Yacht Club	106	000	.000	.02	---		.7	5.9	.01	.30	.01	.01
Ross Point	102	.000	.000	.07	7.1		.8	5.9	.01	.30	.01	.01
Post Falls	100	.010	.021	.06	6.2		.2	5.9	.01	.31	.01	.01
Corbin Park	97	.000	.000	.02	6.2		.2	5.9	.01	.30	.01	.01
State Line	94	.005	.000	.00	6.0		.5	6.5	.01	.28	.01	.01
Harvard Road	90	.070	.002	.00	5.8		.3	6.3	.01	.27	.01	.01

Table C-1. (Continued)

Date Location	River Mile	NO_3-N	NH_3-N	PO_4-P	SO_4	$S^=$	BOD	COD	Cu	Zn	Fe	Mn
December 2, 1971												
Lake Outlet	107	.050	.000	.01			.6	5.4	.01	.29	.01	.01
Spokane Yacht Club	106	.050	.000	.02	9.1		.5	---	.01	.29	.01	.01
Ross Point	102	.006	.001	.005	9.0		.7	5.4	.01	.29	.01	.01
Post Falls	100	.09	.008	.015	11.0		.9	5.1	.01	.29	.01	.01
Corbin Park	97	.07	.002	.001	10.0		.8	5.07	.01	.29	.01	.01
State Line	94	.07	.001	.001	10.0		.2	4.13	.01	.27	.007	.005
Harvard Road	90	.07	.001	.002	10.0		.4	4.2	.01	.28	.007	.005
January 10, 1972												
Lake Outlet	107	.04	.000	.010	10.0		.8	5.1	.01	.42	.2	.01
Ross Point	102	.09	.000	.02	11.0		.9	7.2	.01	.31	.2	.01
Post Falls	100	.06	.002	.04	12.0		1.1	7.5	.01	.33	.3	.01
Harvard Road	90	.04	.001	.01	11.0		.7	6.9	.01	.32	.3	.01
Upriver Drive(Felts)	80	.04	.003	.01	8.2		1.2	7.8	.01	.33	.3	.01
February 5, 1972												
Lake Outlet	107	.03	.000	.02	12.0	.01	1.1	6.41	.01	.62	.06	.01
Ross Point	102	.06	.000	.02	12.3	.01	1.2	6.19	.01	.50	.065	.01
Post Falls	100	.07	.001	.03	11.9	.01	1.4	6.21	.01	.43	.06	.01
Harvard Road	90	.04	.000	.04	11.4	.01	1.2	5.63	.01	.40	.035	.01
Upriver Drive (Felts)	80	.06	.004	.04	10.8	.01	1.3	6.7	.01	.40	.03	.01
									.01	.50	.02	.01

Table C-1. (Continued)

Date Location*(RM)	NO_3-N	NH_3-N	PO_4-P	Total P	SO_4	$S^=$	BOD	COD	Cu	Zn	Fe	Mn
March 1, 1972												
Lake Outlet (107)	.105	.01	.05	.11	15.5	.01		5.65	.01	.50	.065	.02
Ross Point (102)	.125	.01	.075	.12	17.0	.01		6.30	.01	.42	.025	.025
Post Falls Pool (102)	.095	.02	.075	.12	16.5	.01		6.18	.01	.38	.04	.025
Post Falls Dam (98)		.02	.050	.14		.01		5.40	.01	.33	.02	.022
Harvard Road (90)	.120	.00	.075	.14	16.0	.01		6.18	.005	.31	.06	.021
Upriver Drive Felts (80)	.125	.01	.100	.16	16.0	.01		7.52	.005	.33	.05	.015
March 12, 1972												
Below Upriver Dam	.18		.10									
Above Green Street Bridge	.15		.050									
Spokane Linen	.16		.050									
Below Gonzaga	.18		.075									
Black Angus	.52		.050									
Above Ft. Wright	.52		.050									
Adj. Rivercrest	.16		.050									
Above Sewage Plant	.05		.050									
March 31, 1972												
Below Upriver Dam	.12		.10		22.0							
Above Green Street Bridge	.13		.075		20.0							
Spokane Linen	.12		.10		20.0							
Below Gonzaga	.12		.075		21.0							
Black Angus	.12		.075		20.0							
Above Ft. Wright	.30		.050		19.0							

*(RM = River Mile)

Table C-1. (Continued)

Date Location (RM)	NO_3-N	NH_3-N	PO_4-P	Total P	SO_4	$S^{=}$	BOD	COD	Cu	Zn	Fe	Mn
March 31 (Continued)												
Adj. Rivercrest	.15		.050		21.0							
Above Sewage Plant	.15		.075		20.0							
Below Sewage Plant			.050		20.0							
April 1, 1972												
Lake Outlet (107)	.14	.02	.05	.10	19.0	.01	3.15	7.71	.01	.54	.33	.03
Ross Point (102)	.13	.02	.05	.10	19.0	.01	2.15	7.67	.01	.48	.28	.03
Post Falls (100)	.11	.03	.05	.12	19.0	.01	2.55	8.07	.01	.44	.26	.03
Harvard Road (90)	.12	.01	.05	.11	18.0	.01	3.55	8.47	.01	.37	.31	.035
Upriver Drive Felts (80)	.14	.01	.095	.16	19.0	.01	2.90	7.63	.01	.36	.30	.035
May 12, 1972												
Lake Outlet (107)	.10	.00		.14	24.0			7.92		.60		
Ross Point (102)	.09	.00		.12	22.0			7.70		.56		
Post Falls (100)	.09	.02		.10	20.0			8.23		.58		
Harvard Road (90)	.10	.00		.11	21.0			8.08		.39		
Upriver Drive Felts (80)	.08	.03		.12	19.0			7.45		.40		
May 13, 1972												
Below Upriver Dam	.08		.02		21.0							
Above Green Street Bridge	.08		.02		22.0							
Spokane Linen	.05		.01		20.0							
Below Gonzaga	.05		.02		20.0							
Black Angus	.055		.01		21.0							

(RM = River Mile)

Table C-1. (Continued)

Date Location* (RM)	NO_3-N	NH_3-N	PO_4-P	Total P	SO_4	$S^=$	BOD	COD	Cu	Zn	Fe	Mn
May 13 (Continued)												
Above Ft. Wright	.10		.01		19.0							
Adj. Rivercrest	.06		.01		21.0							
Above Sewage Plant	.065		.01		21.0							
Below Sewage Plant	.065		.05		21.0							
June 15, 1972												
Lake Outlet (107)	.010		.25		----		----	4.94	.02			
Ross Point (102)	.025		.30		19.0		1.45	5.42				
Post Falls (100)	.015		.20		10.0		1.27	4.47				
Harvard Road (90)	.020		.22		7.0		.40	4.99				
Upriver Drive Felts (80)	.015		.22		10.5		.90	4.89				
Gonzaga	.030		.25		13.5		1.19	3.61				
July 25, 1972												
Lake Outlet (107)	.03		.08		13.0			2.13				
Ross Point (102)	---		.10		13.0			1.52				
Post Falls (100)	.00		.075		13.5			2.83				
Harvard Road (90)	.09		.10		14.0			2.22				
Upriver Drive Felts (80)	.20		.08		12.0			1.74				
Gonzaga	.295		.10		11.0			1.09				
Bowl & Pitcher	.36		.32		26.0			4.40				

*(RM = River Mile)

Table C-1. (Continued)

Date Location	River Mile	Temp. °C	pH	02 mg/1	02 % Sat.	CO_2 mg/1	CO_3 mg/1	HCO_3 mg/1	T.D.S. mg/1	Conductivity Micro-mhos at 25°C
June 15, 1972										
Lake Outlet	107	15.0	6.7	9.3	91	3.0		21		50
Ross Point	102	16.0	6.9	9.4	94	3.0		21		50
Post Falls	100	16.0	6.9	9.4	94	4.0		21		50
Harvard Road	90	19.0	7.1	9.2	98	410		21		54
Upriver Drive Felts	80	19.0	7.2	8.6	92	Tr		22		58
Gonzaga		19.0	7.2	8.4	89	Tr				
July 25, 1972										
Lake Outlet	107	19.0	7.7	9.0	96	2.0		20		50
Ross Point	102	23.0	7.7	8.5	97	1.0		20		50
Post Falls	100	26.0	7.6	7.0	85	2.0		19		50
Harvard Road	90	26.0	7.7	7.5	91	2.0		19		50
Upriver Drive Felts	80	26.0	7.6	7.5	91	---	2.0	39		56
Gonzaga						---	1.0	41		59
August 18, 1972										
Lake Outlet	107	22.0	7.6	8.9	101	1.0		27	34.0	50
Ross Point	102	21.0	7.6	8.5	98	1.0		27	34.9	52
Post Falls	100	22.4	7.4	8.8	104	---		27	36.0	52
Harvard Road	90	22.0	7.4	8.9	101	---	1.0	30	41.2	54
Upriver Drive Felts	80	22.0	7.2	8.8	100	---	1.0	67	51.8	80

Table C-1. (Continued)

Date Location *(RM)	NO_3-N	NH_3-N	PO_4-P	Total P	SO_4	$S^=$	BOD	COD	Cu	Zn	Fe	Mn
August 18, 1972												
Lake Outlet (107)	.020		.05		10.0		3.05	4.40				
Ross Point (102)	.035		.06		11.0		3.15	3.78				
Post Falls (100)	.025		.07		10.5		3.40	3.90				
Harvard Road (90)	.070		.10		15.0		3.4	3.08				
Upriver Drive Felts (80)	.525		.10		11.0		3.45	2.70				
August 30, 1972												
Lake Outlet (107)	----		---		----		----					
Ross Point (102)	.065		.00		13.0		2.85					
Post Falls (100)	.055		.02		14.0		2.10					
Harvard Road (90)	.075		.00		14.0		2.15					
Upriver Drive Felts (80)	.160		.00		10.0		2.50					
September 14, 1972												
Lake Outlet (107)	.001		---		12.0			5.07				
Ross Point (102)	----		---		----							
Post Falls (100)	----		---		----							
Harvard Road (90)	.003		.01		13.0			6.14				
Upriver Drive Felts (80)	.112		.02		12.0			5.75				
Upriver Drive Below Dam	----		---		14.0							

*(RM = River Mile)

Table C-2. Bacteria of water quality significance in the upper Spokane River. 1971-1972.

TC(FC)FS[R]*

Station (RM)**	10/10	10/14	10/17	10/21	11/4
Cedars (107)				160(1)11[.09]	260(1)22[.04]
Spokane Yacht Club (106)				130(6)10[.6]	200(1)7[.14]
Ross Point (102)				314(15)9[1.7]	332(48)61[.78]
Post Falls (100)	560(4)45[.08]	880(10)35[.28]	240(6)8[.75]	60(10)2[5.0]	442(35)24[1.46]
Corbin Park (97)				1100(2)4[0.5]	
State Line (94)	1160(1)5[.2]	1430(4)17[.23]	680(1)3[.33]	316(1)1[1.0]	
Harvard Road (90)	280(2)[.33]	1310(21)55[.38]	170(1)4[.25]	200(1)1[1.0]	309(0)10[0]

*TC = Total Coliform Count

FC = Fecal Coliform Count

FS = Fecal Streptococci Count

[R] = Ratio of Fecal Streptococci to Fecal Coliforms

**RM = River Mile

Table C-2. (Cont.)

Station (RM)	11/11	11/18	12/2	12/11	1/ /72
Cedars (107)	440(1)22[.04]	620(1)1[1.0]	280(1)0	100(1)1[1.0]	30(4)2[2.0]
Spokane Yacht Club (106)					
Ross Point (102)	1300(35)18[1.9]	2740(45)24[1.9]	1030(14)0	640(7)14[0.5]	209(11)4[2.0]
Post Falls (100)	431(7)8[.88]	1670(38)6[6.5]		380(1)10[0.1]	141(5)2[2.5]
Corbin Park (97)	550(16)5[3.2]	770(16)4[4.0]			
Harvard Road (90)	327(5)4[1.25]	813(16)4[4.0]	800(42)0	100(2)8[.25]	

Table C-2. (Cont.)

Station (RM)	2/ /72	3/1	4/1	5/13	6/15
Cedars (107)	100(2)1[1.0]	20(4)2[2.0]	140(4)4[0]	20(2)0[0]	12(5)0[0]
Spokane Yacht Club (106)					
Ross Point (102)	530(18)6[3.0]	320(4)2[2.0]	400(18)6[3.0]	700(16)4[4.0]	114(96)27[3.5]
Post Falls (100)	1000(22)4[5.5]	100(2)4[.5]	250(18)[4.5]	500(4)4[1.0]	25(5)1[4.0]
Corbin Park (97)					
Harvard Road (90)	420(6)2[3.0]	102(4)8[.5]	146(12)[4.0]	352(2)4[.5]	140(2)4[.5]
Upriver Drive (80)		220(2)10[.2]	168(4)[2.0]	110(2)[.33]	148(28)4[7.0]
Gonzaga (76)					1680(800)180[4.45]

Table C-2. (Cont.)

Station (RM)	7/14	8/30	9/14	11/9
Cedars (107)	50(10)2[5.0]			
Ross Point (102)	1400(15)2[7.5]	1100(0)13[0]	180(6)7[.85]	1140(32)36[.8]
Post Falls (100)	1120(28)7[4.0]	900(10)4[2.5]	610(6)6[1.0]	600(53)15[3.5]
Harvard Road (90)	1290(32)6[5.3]	1000(2)13[.15]	2100(4)10[.4]	210(0)5[0]
Upriver Drive (80)		1900(10)3[3.3]	400(11)2[5.5]	2600(0)3[0]
Gonzaga (76)				6300(0)2[0]

Table C-3

ALGAE COMPOSITION OF THE SPOKANE RIVER (part 1)
1971-1972

	LAKE OUTLET																	
DIATOMS (CHRYSOPHYTA)	10/1	10/21	11/4	11/11	11/18	12/2	12/11	1/10	2/5	3/1	4/22	5/6	5/13	6/15	7/25	8/16	8/30	9/14
Achnanthes sp.										4			4			4		
Amphora sp.										4								
Asterionella sp.		12	32	12	28	44	120											
Asterionella formosa										88	48	48	80	16	22			
Cocconeis sp.																		
Cyclotella sp.																		
Cymbella sp.											4							
Diatoma sp.																		
Eunotia sp.																		
Fragilaria sp.			8		8					16	4		32	10	18	36		
Fragilaria crotonensis																		
Frustulia sp.																		
Gomphonema sp.																		
Gyrosigma sp.																		
Melosira sp.											3504	1116	2788			24		18
Melosira crenulata										2552				2	2			
Melosira italica										856								
Melosira varians																		
Meridion sp.													4					
Navicula sp.		4			4	4	16			12	4	4	4					8
Navicula exigua																		
Nitzchia sp.																		
Pinnularia sp.										8								
Pinnularia abaujensis																		
Rhizoselenia sp.																		
Synedra sp.						8	20					8	12			8		24
Synedra delicatissima																		
Synedra incisa																		
Synedra ulna										12								
Surirella sp.																		
Tabellaria sp.		156	200	224	248	364	192							18	24			
Tabellaria fenestrata										36	40		28			124		
Testerionella sp.																		
Tribonema sp.			28	8	12	12	8										136	
GREENS (CHLOROPHYTA)																		
Ankistrodesmus sp.							4			4		12						
Chlamydomonas sp.			12															
Chlorella sp.		4																
Cosmarium sp.																		
Dinobryon sp.																		
Euglena sp.																		
Gloeocystis											4							
Mougeotia sp.		16		12	12													
Penium sp.																8		
Phytoconis sp.																		
Planktosphaeria sp.																		
Rhizoclonium sp.																		
Scenedesmus sp.			4															
Schroederia sp.			4															
Staurastrum sp.							4											8
Ulothrix sp.		36	68	208	356	656	1400											
Volvox sp.																4		
BLUE GREENS (CYANOPHYTA)																		
Anabaena sp.			4															
Aphanizomenon sp.							4											
Nostoc sp.																2		
Ocillatoria sp.																		44
		228	360	452	668	1088	1768			3592	3608	1188	2952	46	66	210	136	102

	ROSS POINT																	
DIATOMS (CHRYSOPHYTA)	10/1	10/21	11/4	11/11	11/18	12/2	12/11	1/10	2/5	3/1	4/22	5/6	5/13	6/15	7/25	8/16	8/30	9/14
Achnanthes sp.										6			8					
Amphora sp.													4					
Asterionella sp.		4	8	28	40	80	124											
Asterionella formosa										116	72	20	68	80	14			
Cocconeis sp.																		
Cyclotella sp.													4					
Cymbella sp.																		
Diatoma sp.																		
Eunotia sp.																		
Fragilaria sp.					12		4					8	32	20	24	20		
Fragilaria crotonensis																		
Frustulia sp.																		
Gomphonema sp.											4		4					
Gyrosigma sp.																		
Melosira sp.											3504	664	2412	2252	1108	8	8	
Melosira crenulata										1812								
Melosira italica										1608								
Melosira varians																		
Meridion sp.																		
Navicula sp.				8		16	28			16	16		16					
Navicula exigua										4								
Nitzchia sp.																		
Pinnularia sp.										8						4		
Pinnularia abaujensis																		
Rhizoselenia sp.																		
Synedra sp.			8			16				20		8	12			20		
Synedra delicatissima																		
Synedra incisa																		
Synedra ulna										12								
Surirella sp.																		
Tabellaria sp.		108	292	280	352	248	136							62	42			
Tabellaria fenestrata										84	52					36	4	
Testerionella sp.					12													
Tribonema sp.		20	4	4		4	8											
GREENS (CHLOROPHYTA)																		
Ankistrodesmus sp.						4	20											
Chlamydomonas sp.		4														4		
Chlorella sp.																		
Cosmarium sp.			4															
Dinobryon sp.																		
Euglena sp.																		
Gloeocystis																		
Mougeotia sp.				12	4													
Penium sp.																32	4	
Phytoconis sp.																		
Planktosphaeria sp.																		
Rhizoclonium sp.																		
Scenedesmus sp.																		
Schroederia sp.																		
Staurastrum sp.																		
Ulothrix sp.		48	140	224	308	496	632											
Volvox sp.																		
BLUE GREENS (CYANOPHYTA)																		
Anabaena sp.																	260	
Aphanizomenon sp.																	12	
Nostoc sp.			4															
Ocillatoria sp.																		
		184	460	556	728	864	952			3686	3648	700	2560	2414	1188	124	288	

	POST FALLS														
DIATOMS (CHRYSOPHYTA)	10/1	10/21	11/4	11/11	11/18	12/2	12/11	1/10	2/5	3/1	3/31	4/22	5/6	5/13	6/15
Achnanthes sp.										20				4	
Amphora sp.															
Asterionella sp.	44	4	8	48	40		76								
Asterionella formosa										52		64	48	124	132
Cocconeis sp.															
Cyclotella sp.															
Cymbella sp.												4			
Diatoma sp.															
Eunotia sp.														52	32
Fragilaria sp.			4							52			8		
Fragilaria crotonensis															
Frustulia sp.															
Gomphonema sp.	8														
Gyrosigma sp.															
Melosira sp.												3560	2748	2512	2406
Melosira crenulata										1848					
Melosira italica										888					
Melosira varians															
Meridion sp.															
Navicula sp.		4					4			8			12	4	
Navicula exigua															
Nitzchia sp.															
Pinnularia sp.															
Pinnularia abaujensis															
Rhizoselenia sp.															
Synedra sp.	4		4	8			4			8		12	32	4	
Synedra delicatissima															
Synedra incisa															
Synedra ulna										24			4		
Surirella sp.															
Tabellaria sp.	36	164	576	276	164		72								
Tabellaria fenestrata										36		20	8	4	84
Testerionella sp.															
Tribonema sp.		8	8	4	8										
GREENS (CHLOROPHYTA)															
Ankistrodesmus sp.	4				4		12			12					
Chlamydomonas sp.	8											4			
Chlorella sp.															
Cosmarium sp.															
Dinobryon sp.															
Euglena sp.															
Gloeocystis															
Mougeotia sp.	16			12	20										
Penium sp.															
Phytoconis sp.															
Planktosphaeria sp.															
Rhizoclonium sp.	28														
Scenedesmus sp.															
Schroederia sp.															
Staurastrum sp.		4			4										
Ulothrix sp.	44	40	84	220	316										
Volvox sp.															
BLUE GREENS (CYANOPHYTA)															
Anabaena sp.	144						4								
Aphanizomenon sp.															
Nostoc sp.															
Ocillatoria sp.															
	336	224	684	568	556		172			2948		3664	2860	2704	2654

Table C-3 continued

ALGAE COMPOSITION OF THE SPOKANE RIVER (part II)
1971-1972

	POST FALLS				HARVARD ROAD																			UPRIVER DRIVE (FELT'S FIELD)																	
DIATOMS (CHRYSOPHYTA)	7/25	8/16	8/30	9/14	10/1	10/21	11/4	11/11	11/18	12/2	12/11	1/10	2/5	3/1	3/31	4/22	5/6	5/13	6/15	7/25	8/16	8/30	9/14	10/1	10/21	11/4	11/11	11/18	12/2	12/11	1/10	2/5	3/1	4/22	5/6	5/13	6/15	7/25	8/16	8/30	9/14
Achnanthes sp.														20				16															20	8							
Amphora sp.																																									
Asterionella sp.	46				16		32	20	68	136	88																														
Asterionella formosa														156		96	44	96	42	72				12	10	22	35	54	100	92	42	90	100	44	28	16	84	62			
Cocconeis sp.														4																											
Cyclotella sp.											4																														
Cymbella sp.														4																											
Diatoma sp.														8																											
Eunotia sp.														4																											
Fragilaria sp.	14	48							4					4			8		30	18	60		4											8	16	16	26	22	40	36	
Fragilaria crotonensis																					40																				
Frustulia sp.																16																	4								
Gomphonema sp.														4							4																		8	8	
Gyrosigma sp.														4																											
Melosira sp.	1294		8											240		3340	1212	3112	1080	554	8		28												1124	992	974	652	8	8	22
Melosira crenulata														2304																			3232	2864							
Melosira italica		8												1364																			1072								
Melosira varians																																	116								
Meridion sp.																																									
Navicula sp.						20	12	20	36	12	24			20			12					8	54	22	2	14	8	1					32			4					16
Navicula exigua																	4																								
Nitzchia sp.														8																			16								
Pinnularia sp.																16						12																		8	
Pinnularia abaujensis																																	12								
Rhizoselenia sp.					28																																				
Synedra sp.		4			12	20	8			28				32			16	4			20		6	12	2	1	2	2					24	8	4	4			12		16
Synedra delicatissima																																									
Synedra incisa																		4																							
Synedra ulna																																	20								
Surirella sp.														4		4																									
Tabellaria sp.	26				8	280	264	320	260	87	148												8	14	16	22	18	19				4									
Tabellaria fenestrata		20	4											88		16			42	28		8		10	250	262	212	150	70	54	32	68	112	8			94	42	28		
Testerionella sp.																																									
Tribonema sp.						8	24	12	4	12	8																														
GREENS (CHLOROPHYTA)																																									
Ankistrodesmus sp.										16	4																														
Chlamydomonas sp.																																									
Chlorella sp.											4																														
Cosmarium sp.					4																																				
Dinobryon sp.																																									
Euglena sp.																																									
Gloeocystis																																									
Mougeotia sp.					156			16	12																																
Penium sp.		48	4											8							4	20																		24	
Phytoconis sp.					4																																				
Planktosphaeria sp.																																									
Rhizoclonium sp.																																							12		
Scenedesmus sp.		16																																							
Schroederia sp.																					4																				
Staurastrum sp.									4													12	2																	8	
Ulothrix sp.					20	28	100	324	416	589	732													40	22	32	120	202	220	300	100	28									
Volvox sp.																																									
BLUE GREENS (CYANOPHYTA)																																									
Anabaena sp.		6	260																																					56	
Aphanizomenon sp.																						136																			
Nostoc sp.		16																				4																			96
Ocillatoria sp.					4																		26																		
	1380	166	276		252	356	440	712	804	880	1012			4206		3488	1296	5332	1194	672	140	200	128	110	302	321	395	428	390	446	174		4760	2940	1172	1032	1178	778	108	148	150