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A WATER QUALITY STUDY OF THE FLATHEAD RIVER BASIN IN BRITISH COLUMBIA PRIOR TO PROPOSED COAL MINING

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JULY, 1980

Inland Waters Directorate
Pacific and Yukon Region
Vancouver, B.C.

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SUMMARY

Since 1972 Rio Algom mines has been exploring coal deposits in the Cabin Creek Region of the Flathead River Valley in Southeast British Columbia. Cabin Creek is located approximately 16 kilometers from the B.C. - Alberta border and 10 kilometers north of the International Boundary. Because of the potential for adverse transboundary effects from such a development, the Water Quality Branch, Inland Waters Directorate, and the Environmental Protection Service of the Pacific and Yukon Region undertook on behalf of the Canadian Government, a joint water quality study in the Flathead River Basin in Canada.

1) The nutrients, major ions, suspended sediment and organic levels in the water of the Flathead River are indicative of an oligotrophic or ultra-oligotrophic system. Metal levels found in the water and biota are indicative of a non-toxic aquatic environment. The alkalinity levels and pH in the Flathead River System appear to be similar to those in the Elk River above the Fording-Sparwood-Fernie area where the effect of coal mine effluents on receiving waters are minimal. The measurements taken do not represent those of an undeveloped watershed since logging, exploration of coal, and the construction of roads were in progress during the study period.

2) Periphytic biomass in this Rocky Mountain River is representative of oligotrophic and even ultra-oligotrophic systems. Diatoms, represented by 86 species, were the main constituents of the flora, *Hannaea arcus* the dominant diatom is common in many other mountainous, cool water, systems. Other periphytic dominants include the chrysophyte *Hydrurus foetidus* and the Blue-green *Nostoc verrucosum* both of which are adapted to live in cool, low nutrient, flowing waters.

   The sparsity of planktonic algae, probably derived from sloughed-off periphytic algae, has been documented. Planktonic cell numbers were low and 97 percent of the free floating species were usually found in the periphytic assemblages in the river.

3) Benthic macroinvertebrates collected in the Flathead River Basin during four sampling periods were mainly of the class Insecta. The macroinvertebrate density varied from 200 individuals to 7500 individuals per square meter. Each site sample contained between 24 and 26 major taxa. The macroinvertebrate fauna were dominated by large numbers of pollution sensitive macroinvertebrate species which characterize healthy pristine water conditions.

RÉSUMÉ SUR L'ÉTUDE DE LA QUALITÉ DE L'EAU DU BASSIN DE LA RIVIÈRE FLATHEAD

Depuis 1972, la firme minière Rio Algom extrait des gisements de charbon dans la région de Cabin Creek dans la vallée de la rivière Flathead au sud-est de la Colombie-britannique. Cabin Creek est situé à environ 16 kilomètres de la limite entre la C.B. et l'Alberta et à 10 kilomètres au nord de la frontière internationale. Par suite de la possibilité de conséquences frontalières adverses provenant d'un tel développement, la Direction de la qualité des eaux, Direction générale des eaux intérieures, et le Service de la protection de l'environnement de la Région du Pacifique et du Yukon ont entrepris, au nom du Gouvernement canadien, une étude conjointe sur la qualité de l'eau dans le bassin de la rivière Flathead au Canada.

1) Les substances nutritives, les ions majeurs, les sédiments en suspension et les niveaux des substances organiques des eaux de la rivière Flathead indiquent l'existence d'un système oligotrophique ou ultra-oligotrophique. Les niveaux de minerai trouvés dans l'eau et dans la biota dénotent un environnement aquatique non-toxique. Les niveaux d'alkalinité et de pH dans le système de la rivière Flathead semblent être semblables à ceux de la riviere Elk, au-dessus de la région Fording-Sparwood-Fernie, où l'effet des effluents de la mine de charbon sur les eaux réceptrices sont minimes. Les mesures prises ne représentent pas celles d'un bassin hydrographique non développé, puisque le déboisement, l'exploration du charbon et la construction de routes étaient en cours lors de la période d'étude.

2) La biomasse périphytique de la rivière Rocky Mountain possède les caractéristiques des systèmes oligotrophiques et même ultra-oligotrophiques. Les diatomées, qui comprennent 86 espèces, constituaient la majeure partie de la flore. On y retrouve *Hannaea arcus*, la diatomée la plus répandue dans plusieurs autres systèmes montagneux ou d'eau douce. D'autres périphytiques assez répandus comprennent le chrysophyte *hydrurus festidus* et le *Nostoc verrucosum* bleu-vert, tous deux adaptés à la vie en eau vive, fraîche et faible en substances nutritives.

La distribution éparse des algues planctoniques, celles-ci provenant possiblement de débris d'algues periphytiques, a été documentée. Le nombre de cellules planctoniques était peu élevé et 97 pourcent des especes libres ont été retrouvées ordinairement dans les assemblages périphytiques de la rivière.

3) Les macro-invertébrés benthiques ramassés dans le bassin de la rivière Flathead durant quatre périodes d'échantillonnage faisaient partie principalement de la catégorie Insecta. La densité des macro-invertébrés variait entre 200 et 7500 individus par mètre carré. Chaque échantillon contenait entre 24 et 26 groupes majeurs. La faune macro-invertébrée était dominée par un grand nombre d'especes de macro-invertébrés sensibles a la pollution, ce qui caracterise des conditions d'eau saine primitive.

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I INTRODUCTION

Coal exploration in the Cabin Creek region of the Flathead River, Southeast B.C., has been underway since 1972. Cabin Creek is a tributary of Howell Creek which enters the Canadian reach of the Flathead River some 10 kilometers north of the International Boundary (see Figure 1). In view of the potential adverse transboundary effects from a coal development on Cabin Creek, the Water Quality Branch, Inland Waters Directorate, and the Environmental Protection Service were asked to examine the water quality of the Canadian portion of the Flathead River Basin.

In November 1974, the Water Quality Branch reviewed water quality information which was available for the Flathead River. A preliminary study of the Flathead Basin in Canada was initiated in July 1975. Colour, false colour, infrared aerial photographs which covered approximately 65 kilometers of flight line were taken at an altitude of 1220 meters. The photographs were used in planning a sampling network for the basin. A ground survey was conducted in August 1975 to assess these pre-selected sampling sites and to provide background data for planning a more detailed study. The proposed study was reviewed with interested provincial and federal agencies and with the consultant to the company interested in developing the coal properties.

The Water Quality Branch prepared a proposal which defined the objectives and scope of a Flathead River study. The primary objective of the Flathead River study was to determine the existing transboundary movement of nutrients, pollutants, and other materials as well as the present character and sensitivity of the aquatic environment. In meeting this objective this report documents the density and diversity of existing aquatic communities and the existing levels of selected chemical parameters in water, sediment and biota so that possible future changes in water quality associated with coal development can be determined.

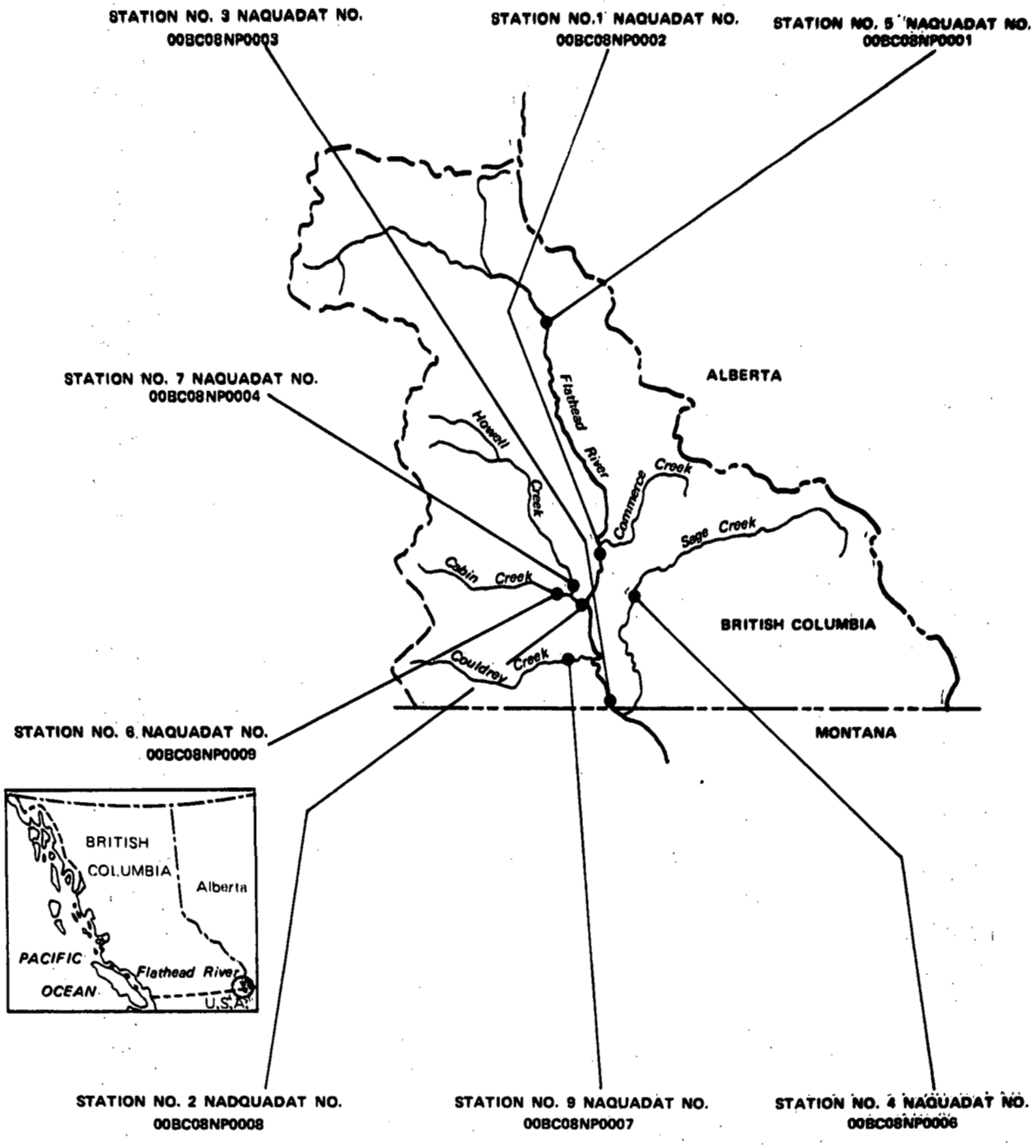

Fig. 1. STATION LOCATION AND NAQUADAT STATION NO.

II STATION SELECTION AND DESCRIPTION (Ref. Fig. 1)

Flathead River, 1.5 kilometers east of Marl Lake Station 1 (NAQUADAT No. 00BC08NP0002)

This water quality station is located 50 meters upstream of the main bridge which crosses the Flathead River in Canada. This site is just upstream of the proposed coal development and was selected in order to document the density and the diversity of the existing aquatic communities and the existing levels of selected chemical parameters in water, sediment, and biota (Table 1).

Howell Creek, 750 meters upstream of the Flathead River-Howell Creek confluence Station 2 (NAQUADAT No. 00BC08NP0008)

This site which is located downstream of the bridge that crosses Howell Creek is 750 meters upstream of the Flathead River-Howell Creek confluence and downstream of the Howell-Creek - Cabin Creek confluence. This site is just downstream of the north and south coal hills which are proposed for development. (Table 1).

Flathead River at the International Boundary Station 3 (NAQUADAT No. 00BC08NP0003)

This station is located 100 meters upstream of the International Boundary and was selected to document the aquatic ecology and the levels of chemical parameters immediately upstream of the International Boundary (Table 1). A Water Survey of Canada gauging station is located at the International Boundary.

Sage Creek, 1.0 kilometers north of Proctor Lake Station 4 (NAQUADAT No. 00BC08NP0006)

This site is located at the bridge which crosses Sage Creek, approximately 1.0 kilometer south of Proctor Lake. The site was selected to take into account geological differences in the eastern section of the Flathead River Basin. Sage Creek drains an area immediately adjacent to the Flathead River in Canada and enters the Flathead on the U.S. side (Table 1).

Flathead River above Pollock Creek Road Bridge Station 5 (NAQUADAT No. 00BC08NP0001)

This site is located in the headwaters of the Flathead River upstream from Pollock Creek bridge. The site was selected to document the density and diversity of the existing aquatic community and the levels of selected chemical parameters in the water and the biota. (Table 1).

Cabin Creek, 4.5 kilometers above the confluence with Howell Creek Station 6 (NAQUADAT No. 00BC08NP0009)

The Cabin Creek site is located upstream from the north and south hill coal deposits. The site was selected in order to determine the chemical concentration levels and the condition of the aquatic community before the water traverses the proposed development area (Table 1).

Because this station was not easily accessible under certain weather conditions the exact sampling location varied over a stretch of approximately 2 kilometers.

Howell Creek, 250 meters above the confluence of Cabin Creek and Howell Creek Station 7 (NAQUADAT No. 00BC08NP0004)

This site is located just downstream from the bridge which led to the exploration campsite. The site was selected in order to determine the inputs coming from the Howell Creek watershed. The watershed includes the north side of the north hill coal deposit. (Table 1).

Cabin Creek, 9.0 kilometers above confluence with Howell Creek Station 8 (NAQUADAT No. 00BC08NP0010)

This station is located upstream of the main logged area in the Cabin Creek watershed. This site was sampled only once because it was not easily accessible (Table 1), and station 6 served to be representative of the headwater quality conditions on Cabin Creek.

Couldrey Creek above confluence with Burham Creek Station 9 (NAQUADAT No. 00BC08NP0007)

The water quality sampling site on Couldrey Creek is located approximately 1.5 kilometers upstream of the confluence with the Flathead River. The Couldrey Creek watershed includes the south hill coal deposit. A Water Survey of Canada gauging station is located approximately one kilometer upstream of this Water Quality site (Table 1).

Latest Development

Water Survey of Canada installed gauging stations in 1977 at the Howell Creek water quality station 2 and on Cabin Creek upstream of the confluence with Howell Creek.

TABLE 1

STATION DESCRIPTION

Station No.	River Bank Description (i.e. Physical Characteristics, Vegetation Coverage)	Approximate light Reaching Water Surface (percent)	Approximate Mean Depth Water Over the Period June-September (meters)	Velocity and/or Discharge	Stream bed Composition *
1	The east bank has a drop of 50 meters and an 85^{0} slope. Trees are present at the top of the bank. The west bank is a gravel bar with a grove of trees. (Flathead River)	95-100	1-2		39% small gravel 20% large gravel 40% large rubble 1% boulder
2	The banks which form gradual slope are comprised of willows and small bushes interspersed with patches of grass. (Howell Creek)	80-95	0.75	1 m sec^{-1} in June and .5 m sec^{-1} in August The uniform flow at the site exhibits rapids and boils	5% silt/course sand 10% small gravel 30% small rubble 20% large gravel 30% large rubble 5% boulder
3	The east and west banks are characterized as having low bush spotted with an occasional tree. (Flathead River)	95-100	0.50	The velocity on Aug. 4/76 was approximately 1.5 m sec^{-1} The discharge varies from 3.7 m^3 sec^{-1} on March 3, 1976 to 232.7 m^3 sec^{-1} on May 11, 1976 at the Water Survey Site which is located 200 meters south of the Water Quality Station.	15% coarse sand 25% small rubble 15% large gravel 35% boulder 10% bedrock and block
4	The banks which are composed of a gravel and sand are unstable and erosion is evident particularly on the east bank. (Sage Creek)	100	0.50	The velocity measured .40 m sec^{-1} August, 1 m sec^{-1} in June, and .75 m sec^{-1} in September 1976	5% coarse sand 15% small gravel 30% small rubble 20% large gravel 30% large rubble

* The stream bed composition was determined by visual observation and reference to the Fish and Wildlife report entitled "An inventory of the Flathead River and tributaries" See Stream Parameter Terms - page 9.

TABLE I (Continuation)

STATION DESCRIPTION

Station No.	River Bank Description (i.e. Physical Characteristics, Vegetation Coverage)	Approximate light Reaching Water Surface (percent)	Approximate Mean Depth Water Over the Period June-September (meters)	Velocity and/or Discharge	Stream bed Composition
5	The north bank which has a 45^{0} slope and a vertical drop of 9 meters and the south bank which has a vertical drop of 2 meters are composed of gravel and sand. The banks are covered with scrub vegetation and patches of grass. (Flathead River)	85-100	0.3	0.75 m sec^{-1} in June and .40 m sec^{-1} in August.	10% small gravel 30% small rubble 15% large gravel 40% large rubble 5% boulder
6	The site is located in a canyon which has a south bank with a vertical height of approximately 20 meters and a north bank with a vertical height of 12 meters (Howell Creek)	45-55	0.3	2 m sec^{-1} in August and 1-1½ m sec^{-1} in September	20% boulder 80% bedrock
7	The low banks are composed of glacial till with scrub vegetation. (Howell Creek)	100	0.5	A riffle pattern describes the flow. The velocity was approximated as 1 m sec^{-1} on June 15, 1976 and 2 m sec^{-1} on September 12, 1976	9% sand 10% small gravel 30% small rubble 20% large gravel 30% large rubble 1% boulder
8	This site was only sampled once due to the fact that it was not easily accessible. An accurate description could not be given at that time as 1-2 meters of snow formed the banks (Cabin Creek)				

TABLE 1 (Continuation)

STATION DESCRIPTION

Station No.	River Bank Description (i.e. Physical Characteristics, Vegetation Coverage)	Approximate light Reaching Water Surface (percent)	Approximate Mean Depth Water Over the Period June-September (meters)	Velocity and/or Discharge	Stream bed Composition
9	The banks at the Water Quality site which are covered with willows and small scrub are composed of glacial till.	75-90	0.5	The flow which can be described as being a uniformed riffle varied from a mean discharge of 1.0 m^3 sec^{-1} on January 28 1976 to a discharge of 23.5 m^3 sec^{-1} on May 11, 1976. The velocity measured on June 15, 1976 was 1.25 m sec^{-1}, and on September 12, 1976 it was 2 m sec^{-1}.	5% coarse sand 20% small gravel 25% small rubble 25% large gravel 20% large rubble 5% boulder
	(Couldrey Creek)				

TABLE 2

STREAM PARAMETER TERMS

GRADIENT - SUBSTRATE

Gradient in % slope

Substrate

Bedrock
Boulder 30 cm.
Large Rubble 15-30 cm.
Small Rubble 7-15 cm.
Large Gravel 2-7 cm.
Small Gravel .5-2 cm.
Sand
Silt
Mud
Clay

FLOW PATTERN

- uniform (no turbulance)
- uniform (rapids and boils)
- pool riffle sequence
- tumbling flow
- cascading flow

BANK MATERIAL

(est. % of each)

Bedrock
Boulder
Glacial till
Sand Gravel
Silt sand
Clay silt
Organic

UPLAND SOILS

Glacial till
Colluvium
Outwash
Alluvium
Marine
Lacustrine
Organic

TEXTURE OF SOIL

Fine, Medium, Coarse

BANK AND HILLSIDE STABILITY

Upland soil type and depth, texture
Slumping banks and hillsides
Slope (%) of hillsides; Banks
Terracing
Erosion
Windfall

Reference Caw (1976).

III SAMPLING SCHEDULE

The chemical sampling schedule was designed to measure the levels for the parameters during pre-freshet, freshet, and post freshet periods (see Fig. 2). The biological sampling program was also scheduled to correspond with the different parts of the hydrologic cycle.

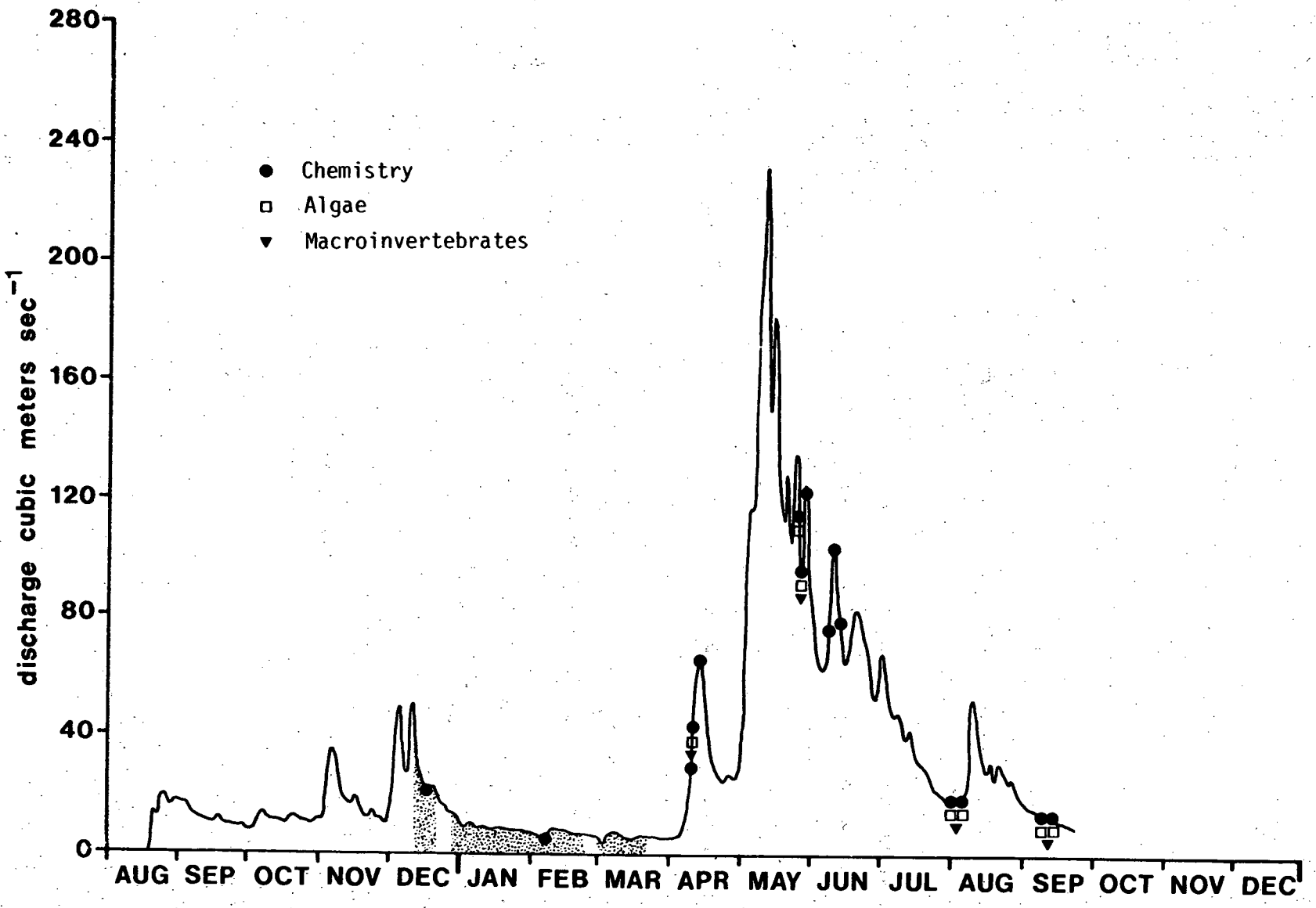

Fig. 2 Sampling schedule for period August, 1975 - October, 1976 in the north fork of the Flathead River Basin north of the U.S.-Canada border. Sampling dates are superimposed on the Flathead River hydrograph measured at the U.S. - Canada border station 3. Shaded portions of hydrograph represent ice cover conditions.

IV STUDY OBJECTIVES

The primary intent of the Flathead River Study was to document existing levels of chemical parameters in sediment, water and biota and to provide a qualitative and quantitative analyses of the existing algal and invertebrate communities on the Canadian portion of the Flathead River. Specific objectives of the study were to:

a) Determine the existing transboundary movement of nutrients, pollutants and other materials;

b) Determine the concentrations of several metals, nutrients, organics, and other chemical parameters in the Flathead River Basin and attempt to identify important parameters by comparing results with Canadian drinking water standards;

c) Quantify the existing content of metals in algal, macroinvertebrates, and fish tissue;

d) Attempt to determine the limiting nutrients for algal growth by examining N:P ratios and measuring phosphorus reserves in algae;

e) Establish the species composition, species diversity, and abundance of algae and benthic macroinvertebrates in the Flathead River Basin north of the U.S. border;

f) Identify and determine the sensitivity of the aquatic biota in the boundary reach to changes in water quality by reviewing both Canadian data and data available for the U.S. portion of the Flathead River Basin.

V CHEMICAL METHODS

Chemical methods and analytical procedures for both the field and laboratory chemistry program are presented in Tables (3 - 10).

TABLE 3

METHODS-HEAVY METALS IN WATER SAMPLES

Parameter	Field collection, sampling procedures sampling bottles, preservatives etc.	Analytical Procedures	National Water Quality Data (Method No. NAQUADAT)
Ba	Single samples were collected in the main flow at the station site in 1-liter teflon sampling bottles. Samples were preserved with 2 ml HNO_3 per liter. Sub-samples were analyzed for the following metals: Ba, Cd, Co, Cu, Fe, Pb, Mn, Ni, and Zn. The extractable method used measures the dissolved fraction and that portion of materials associated with suspended particles which is dissolved by the action of the extractant. This procedure does not generally release metal which is with in refractory particles or combined with insoluble organics.	Atomic emission - direct	56302 P
Cd		Atomic absorption - solvent extraction	48302 P
Co		Atomic absorption - solvent extraction	27302 P
Cu		Atomic absorption - solvent extraction	29305 P
Fe		Atomic absorption - direct Atomic absorption - solvent extraction	26304 P 26305 P
Pb		Atomic absorption - solvent extraction	82302 P
Mn		Atomic absorption - direct	25304 P
Ni		Atomic absorption - solvent extraction	28302 P
Zn		Atomic absorption - solvent extraction	30305 P
Hg	Single samples were collected in the main flow at the station site in 100 ml teflon bottles. The samples were preserved with 1 ml of H_2SO_4.	Automated flameless atomic absorption	80301 P
As	Single samples were collected in the main flow at the station sites in 2 liter polyethylene bottles. No preservatives were added: sub-samples were taken for analysis of arsenic and selenium.	Automated flameless atomic absorption	33304 L
Se		Automated flameless atomic absorption	34302 L

TABLE 4

METHODS - HEAVY METALS IN SEDIMENTS AND ALGAE

	Field Collection, Sampling Procedures, Sampling Bottles, Preservatives, etc.	Analytical Procedures	National Water Quality Data (Method No. NAQUADAT)
Settled Sediment	Polyethylene pickle jars were filled with pea gravel and dug into the river bed. The placement of the pickle jars formed a random pattern in the river bed. The pickle jars trapped sediment which had settled out of the river water. The pickle jars were left in the river for a stated period of time. The sediment which was separated from the pea gravel in the laboratory was analyzed.	Non-residual metal in a sediment is defined as the fraction of the metal that is not part of the silicate matrix of the rock from which the sediment is derived. This includes metal absorbed on organic matter, and in the form of insoluble salts (Analytical Methods Manual, 1979). The analysis was completed on three size fractions for Cu, Fe, Pb, Mn, Zn, Cd, Co, and Ni (Agemian and Chan, 1976).	
Bed Sediment	Bed sediment samples were scooped by hand and placed in polyethylene whirl-pak double sterilized bags. Samples were taken at random in the wadeable portion of the river.	Total metal analysis requires complete destruction of sample in order to release all forms of metal. These include metal in the rock matrix, metal absorbed on the sediment particles and metal in the form of insoluble salts and organic complexes (Analytical Methods Manual, 1979). The analysis was completed for Cu, Fe, Pb, Mn, Zn, Cd, Co and Ni on dried sediment that had passed through a 270 mesh size sieve. Open digestion utilizing pyrex beakers. To .5 gms of dried sediment add 5 mls HNO_3 and 2 mls HCl, make sure all sediment is wetted down, then add 2 mls $HClO_4$. Heat at medium heat on hot place for 1 hour. Cool and bulk to 50.0 mls in a volumetric flask, then read using an atomic spectrometer - direct aspiration. Blanks and standards were analyzed along with samples. Standard reference materials such as orchard leaves were used to act as reference samples and to determine the digestion efficiency.	
		Hg in sediment - total	80050
Algae	Algae samples were collected by hand from natural substrates and placed in HNO_3 washed polyethylene bags. The samples were frozen until analysis for Cu, Fe, Pb and Zn were undertaken. Just prior to chemical analysis algae were separated from sediment and invertebrates. The algae were washed several times in D.I. water to remove contaminants on the outside of the cells.	Metals in algae - total. To 1.0 gm (dry wt.) 60°C add 5 ml HCl and 5 ml HNO_3, digest on hot plate for several hours, then read by atomic absorption - direct aspiration.	

TABLE 5

METHODS - HEAVY METALS IN SLIMY SCULPINS

	Field Collection Sampling Procedures, Sampling Bottles, Preservatives, etc.	Analytical Procedure
Slimy Sculpins	Slimy Sculpins were caught by personnel from the Cranbrook regional office of the Fish and Wildlife Branch. An electroshocker was used to capture the fish. The Slimy Sculpins were frozen until analysis for metals was undertaken. Prior to analysis whole Slimy Sculpins usually 5 or 6 were ground up into a paste. Analysis for metals was done on subsamples taken from the paste.	Metals in Slimy Sculpins - total. The analysis for Cu, Fe, Pb and Zn was done on the subsamples. To 5.0 gm (wet wt.) add 10 ml D.I. H_2O, 10 ml HNO_3 and 2 ml $HClO_4$, cover with watch glass and digest on a hot-plate for approximately 4 hours. Cool, filter if necessary and make up to 50 ml. Then read using atomic spectrometer - direct aspiration.
		Hg in Slimy Sculpins - total to 5.0 gm (wet wt.) add 15 ml H_2SO_4-HNO_3 (2:1) 15 ml $KMnO_4$ - 6% 5 ml $K_2S_2O_8$ - 5% Hydroxylamine sulfate - 6% 10 ml Sodium Chloride - 6% Samples are read on a Pharmacia (mercury monitor utilizing 10% $SnCl_2$ as a reductant). The technique used is known as mercury cold vapour.

TABLE 6

METHODS - NUTRIENTS IN SEDIMENT

Substrate	Field Collection, Sampling Procedures, Sampling bottles, Preservatives, etc.	Analytical Procedures	National Water Quality Data (Method No. NAQUADAT)
Bed Sediment	Polyethylene pickle jars were filled with pea gravel and dug into the river bed. The placement of the pickle jars formed a random pattern in the river bed. The pickle jars trapped sediment which had settled out of the river water. The pickle jars were left in the river for a stated period of time. The sediment which was separated from the pea gravel in the laboratory was analyzed.	Analysis for total phosphorus (ignition method) was conducted on three size fractions (Water Quality Branch, Analytical Method Manual, 1979).	15050
		Analysis for particulate carbon was conducted on three size fractions. Samples were dried and weighed into a combustion boat containing MnO_2 and ignited at 950°C. The resulting CO_2 was measured by thermal conductivity using a HP-185 CHN analyzer. The detection limit is 5 µg g^{-1}.	06902
		Analysis for particulate nitrogen was conducted on three size fractions. Method identical to that described for particulate carbon. The detection limit is 5 µg g^{-1}.	07902

TABLE 7

METHODS - NUTRIENTS IN WATER

	Field Sampling Procedures, Sampling bottles, Preservatives, etc.	Analytical Procedures	National Water Quality Data (Method No. NAQUADAT)
Water	The analysis for NH_4^+, $NO_2^- + NO_3^-$, total dissolved nitrogen (TDN) was conducted on water taken from a 250 ml polyethylene bottle. Six samples were taken at each site using a replicate sampler developed by the Water Quality Branch (Oguss and Erlebach, 1976). All samples which were analyzed for NH_4^+, $NO_2^- + NO_3^-$ and TDN were cooled with ice until they reached the Water Quality Laboratory. The analysis for total dissolved nitrogen is conducted on a decanted portion of the sample. The sample was not filtered.	Ammonia - NH_4^+ The detection limit is 2 µg l^{-1}. The sample is treated with alkaline phenol, alkaline hypochlorite, and sodium nitroprusside. The absorbance is then read at 640 nm on an autoanalyzer.	07557
		Nitrite + Nitrate - $NO_2^- + NO_3^-$ A decanted aliquot of the samples is allowed to mix with NH_4Cl - NH_4OH buffer (pH - 8.5), pass through a column of Cu - Cd, and react with solutions of sulphamilamide, N-1- napthylethylenediamine dihydrochloride and H_3PO_4 to form an azo dye which is read at 550 nm on an autoanalyzer. The detection limit is 2 µg l^{-1}.	07110
		Total Dissolved Nitrogen - TDN A decanted aliquot of the sample is acidified, irradiated in a quartz coil by UV, and made alkaline and irradiated again. The solution is then mixed with disodium EDTA and passed through a column of Cd filings to react with solutions of sulphamilamide, N-1-napthylethylenediamine dihydrochloride to form an azo dye which is read at 550 nm on an autoanalyzer. The detection limit is 25 µg l^{-1}.	07651
		Dissolved Organic Nitrogen (DON) Calculated value DON = TDN - NH_4 -($NO_2 + NO_3$)	

TABLE 7 (Continuation)

METHODS - NUTRIENTS IN WATER

	Field Sampling Procedures Sampling bottles, Preservatives, etc.	Analytical Procedures	National Water Quality Data (Method No. NAQUADAT)
Water	The analysis of total phosphate was done on samples collected in 50 ml sovirel glass bottles. Six samples were collected using the replicate sampler.	Total Phosphorus - TP The total phosphorus method utilized the colour producing procedure developed by Murphy and Riley (1962) with modifications by Menzel and Corwin (1965) and Gales *et al.*(1966). These modifications incorporated the use of persulfate oxidation to liberate organically bound fractions. Colourimetry on an autoanalyzer with ammonium molybdate, ascorbic acid, and potassium antimonyl tartrate. To a sample, $K_2S_2O_3$ and H_2SO_4 solution were added to a sample, which is then autoclaved 30 minutes at 121°C. If turbid, the treated sample is decanted. The sample is then mixed with a reagent solution containing H_2SO_4, $NH_4MO_7O_{24}$, potassium antimonyl tartrate, and ascorbic acid. The resulting colour is measured spectrophotometrically at 880 nm, and compared with those of identically prepared standard PO_4 ion solutions. Interference: High Fe concentrations. The limit of detection is 2 μg^{-1}.	15406
	Three 100 ml sovirel glass bottles were filled using the replicate sampler. Samples were filtered through 0.45 µm millipore filters within 30 minutes after collection.	Dissolved Phosphorus - Diss P Analytical procedure same as that used to determine total phosphorus.	15406

TABLE 8

METHODS - DETECTION OF MAJOR IONS IN WATER

	Field Sampling, Procedures, Sampling bottles, Preservatives, etc.	Analytical Procedures	National Water Quality Data (Method No. NAQUADAT)
Water	One 2 liter polyethylene bottle was filled with water and aliquots were taken for analysis.	Conductivity Field measurements (in situ) were conducted.	02041
		Hardness Samples were titrated with EDTA, using Eriochrome Black as an indicator.	10603
		Alaklinity total phenolphthalin The samples were titrated with standard acid.	10101 10151
		Calcium The samples were titrated with EDTA, Calver II indicator.	20101
		Magnesium The amount of magnesium in water was derived by calculation.	12101
		Potassium Sodium An automated, flame photometric method was used to measure the levels. Technicon Auto Analyzer II methodology. Sodium and Potassium in water, methodology No. 20b.	19103 11103

TABLE 8 (Continuation)

METHODS - DETECTION OF MAJOR IONS IN WATER

	Field Sampling, Procedures, Sampling bottles, Preservatives, etc.	Analytical Procedures	National Water Quality Data (Method No. NAQUADAT)
Water	One 2 liter polyethylene bottle was filled with water and aliquots were taken for analysis.	Chloride Technicon Auto Analyzer II methodology - Chloride in water and waste water, industrial methods No. 99-70 W, (1974).	17206
		Fluoride A specific ion electrode was used.	09105
		Silica The detection range for silica is 0.2 - 20.0 ppm SiO_2. The water quality branch uses 25 mls of acetone instead of 50 mls. Technicon Auto Analyzer II methodology. Silicates in water and sea water, industrial method No. 186-72 W, (1973).	14105
		Sulphate The method used is the result of alterations and adaptations of the Technicon Industrial Method 118-71 W, Nov. 1971 with manifold No. 116-DO 96. The water quality laboratory makes use of Technicon Auto Analyzer II methodology, Automated sulphate by methylthymol blue indicator, industrial method No. 118-71 W, (1972), with modifications to the methylthymol blue procedure developed by McSwain and Watrous (1974).	16306

TABLE 9

METHODS - DETECTION OF ORGANICS IN WATER
AND THE METHODS USED TO DETERMINE RESIDUES
IN WATER

	Field Sampling, Procedures Sampling bottles, Preservatives, etc.	Analytical Procedures	National Water Quality Data (Method No. NAQUADAT)
Sediment	Samples were taken in one 2 liter polyethylene bottle. The samples were shaken in the laboratory prior to decanting aliquots.	Residue	
		Non-filterable	10401
		Filterable	10451
		Fixed non-filterable	10501
		Fix filterable	10551
	Samples were filtered through a watman glass fiber filter. The time lag between collection and filtering was always less than four hours. The filters were kept in petri dishes and the filtrate was analyzed for dissolved nitrogen.	Particulate carbon	06901
		Particulate nitrogen	07901

TABLE 10

METHODS - PHENOLS IN WATER

	Field Sampling, Procedures Sampling bottle, Preservative, etc.	Analytical Procedures	National Water Quality Data (Method No. NAQUADAT)
Water	Teflon bottles were used to collect the samples.	Phenols The automated 4-Aminoantipyrine method was used.	06536

VI ALGAL METHODS

A. Periphyton

1. Algal Collections

a) Natural Substrates

Rocks approximately 20 cm in diameter (sometimes much larger) were collected from a depth of about 0.5 m and sampled quantitatively for attached algal growth. One of the quantitative sampling methods employed a nylon brush sampler (Stockner and Armstrong, 1971) to remove algae from the rocks. The nylon brush sampler was made from a modified 50 cc syringe. Two samples were taken from a rock (combined sample area of 11.5 cm^2) in order to account for variation in abundance and species composition of algae on each rock. Two rocks were sampled at each location in order to account for algal variance between rocks.

As the study progressed it became obvious that algal growth on individual rocks was patchy (unevenly distributed) and low in abundance. Therefore another quantitative sampling method was developed to remove algae from entire rocks thereby compensating for within rock patchiness and low algal biomass. The method involved scraping the entire rock with a tooth brush and, when necessary, removing encrusted forms with forceps or a razor blade. A distilled water squeeze bottle was also used to transfer the algae from the rock into the collecting bin. Collected algae were transferred using a funnel, into *circa* 120 ml glass jars. After sampling, the rock area available for algal growth was measured. Aluminium foil was tightly wrapped around the exposed part of the rock (top and sides above river bottom), then this foil template representing the rock area was pressed flat (sides were cut when necessary) on a large sheet of paper and the outline of the rock traced. This outline was later measured with a polar planimeter to estimate the rock area sampled. In addition to these quantitative samples unusual growths were sometimes qualitatively sampled for species identification and immediately preserved in acid Lugol's or 4 percent formalin solution.

b) Artificial Substrates

Artificial substrates were installed at stations 1, 2, 3, 4, 5, 7, and 9 to measure the growth rates of attached algae (method of Castenholz, 1960). These substrates consisted of sanded plexiglass plates with a surface area of either 150 cm^2 or 450 cm^2 . Ropes fastened this substrate to a concrete reinforcing rod which had been driven into the river bottom. A polyproplyene float and small brick were also attached to the plexiglass plate. The installation was arranged so that the floating plexiglass plate would align itself with the current such that only the narrow edge faced the current, with the main surface area of the plate being parallel to the direction of the current. After the immersion period the algae were transferred from the plexiglass plate to a sample jar by use of razor blade and wash bottle.

Artificial substrates were installed to provide information on algal abundance and to provide algae for heavy metal analysis. The use of artificial substrates resulted in recognizable collection deficiencies. The orientation of the plexiglass plates in the water lead to fast flow across the plexiglass plates, apparently restricting algal growth. Also, the immersion period was 6-9 weeks (the time between field trips), far longer than the recommended 3 week period (Castenholz 1960; Patrick *et al.* 1954). In these long incubation periods algal competition can seriously affect production rates. These long incubation periods also encouraged invertebrate growth, particularly the Simuliidae which interfere with a measure of the algal growth rates. The algal abundance data collected from the artificial substrates is not presented in this report. The species that grew on the artificial substrates were identified and have been included.

2. Sample Preservation and Treatment

After the algae were sampled and put in glass jars they were placed in a cold, dark cooler for transportation. That evening the day's samples were wet filtered onto 5.5 cm or 10 cm Whatman$^{(R)}$ GF/C glass fibre filters.

Then, the filter was cut (subdivided) with a razor blade: 1/3 for chlorophyll analysis, 1/3 for organic weight analysis, 1/6 for diatom counts, and 1/6 to estimate the percent abundance of the major algal groups and to identify non-diatom species. Chlorophyll *a* subsamples then had a magnesium carbonate slurry added, were dry filtered, placed in tight fitting petri dishes and frozen in the dark until laboratory analysis. Subsamples to be analyzed for organic weights were dry filtered, placed in tight fitting petri dishes frozen and kept in the dark until laboratory analysis. Diatom and non diatom subsamples were washed off the filter with a distilled water squeeze bottle and preserved in separate glass jars with acid Lugol's solution.

3. Algal Analytical Procedures

a) Biomass

Biomass determinations were performed on every sample by measuring the organic weight and chlorophyll *a* content of the algae. The organic weight, sometimes referred to as ash-free dry weight or loss on ignition, is the difference between a dry weight (at 60°C) and an ash weight (at 500°C). This procedure effectively weighs only cell contents or organic detritus, not silicified materials such as diatom cell walls or rock crystals. Samples for chlorophyll *a* biomass determinations were extracted in 90 percent acetone with a High-Speed Polytron Homogenizer. Then, debris and particulate matter were removed by filtering the sample through a Whatman GF/F filter. The residue was re-homogenized and filtered again. Both filtrates were combined and made up to 15 ml with 90 percent acetone. Chlorophyll *a* content was then measured on a technicon antoanalyzer Kan (1980) and corrected for phaeophytin using the extinction values and formula of Lorenzen (1967) as presented in Strickland and Parsons (1968).

b) Diatom Enumeration

Diatom identification and frustule (cell wall) counts were made on subsamples which were cleaned in nitric acid (Patrick and Reimer 1966) and then mounted on microscope slides with Hyrax media. It was impossible to tell if the prepared diatom frustules represented

living cells, but preliminary observations of unpreserved material indicated that most cells present in the samples were alive.

To enumerate the diatom frustules on the slide, 36 stratified random fields were counted with a phase contrast microscope at 1000 times magnification (Ennis, MS 1972). This method resulted in a mean of about 200 frustules being enumerated per slide. In samples of very low abundance, especially the April samples, it was not always possible to count 200 frustules, and samples with very low counts ($\lesssim$ 10 frustule counts) are excluded from the data presentation. Counts of about 200 frustules are well below the 8000 specimens that Patrick and her co-workers (Patrick *et al.* 1954) enumerated for their time consuming 'detailed readings'. According to Williams (1964), counts of 300 individuals accurately represent the proportional abundance of the major species. Furthermore, diversity indicies such as the Shannon-Wiener function can be reliably calculated from counts of 200-300 frustules.

Numerous references were consulted for identification of diatoms Patrick and Reimer (1966), Cleve-Euler (1951-1955), Hustedt (1930, 1931-1959), Huber-Pestalozzi (1942), Sreenivasa and Duthie (1973) and Weber (1966). Bourrelly's (1968) taxonomic scheme was followed to place the diatoms into orders and where applicable (diatom genera A-M) the species classification outlined by Van Langingham (1967-1971) was followed except that *Cymbella caespitosa* was recognized as a distinct species. For genera not covered by Van Landingham (starting after the genus *Melosira*), the species taxonomy of Patrick and Reimer (1966), Cleve-Euler (1951-1955), Hustedt (1930) and Huber-Pestalozzi (1942) was followed.

c) Algal Phyla Abundance

The relative abundance of each algal phyla was measured with an inverted microscope using methods detailed in Northcote *et al.* (1975). In the inverted microscope sample, non-diatom species abundance was

qualitatively measured and identified using Prescott (1962). Hoek (1963), and Bourrelly (1966, 1968, 1970).

4. Algal Chemical Composition

a) Nitrogen and Phosphorus

Total nitrogen and total phosphorus content of algae was measured for samples collected during September. Samples were cleaned of organic debris and sediment and washed several times in distilled water to remove nutrients associated with the outer cell walls. After this treatment, total phosphorus was measured using the analytical procedure outlined in Table 6. Total nitrogen was analyzed on a Hewlett-Packard Model 125 C:H:N analyser.

b) Excess Phosphorus Storage

Algal samples collected during September were tested for surplus stored phosphorus. Most microorganisms contain polyphosphate bodies which are rich in linear condensed phosphates (Adamec *et al.* 1979). This phosphorus is used for metabolic processes when exogenous phosphorus is limiting (Stewart and Alexander, 1971). Fitzgerald and Nelson (1966) developed a practical method which was used to extract the surplus stored phosphorus. The technique involves washing the algae several times in phosphate free water to remove any aqueous phosphorus. The surplus phosphorus is then extracted from the algae in boiling water bath, and analyzed by the same procedure as used for dissolved phosphorus (Table 7). The results, besides determining whether or not phosphorus is limiting to growth, can be used to see if one aquatic environment has more available phosphorus than another region.

B. Phytoplankton

Phytoplanktonic algae were collected by filling a 200 ml bottle with river water near the middle of the river channel. These samples were preserved

in Lugol's solution.

Algae in the river water samples were filtered on to 0.45 µm millipore filters using a maximal vaccum of 18 cm Hg. Filters were then cleaned with cedarwood oil (McNabb 1960) and mounted on microscope slides. Algal cells were counted (400 x) in 28 fields on each slide, distinguishing those with (live cells) and without (dead cells) chloroplasts. Independent tests by filtering live and also preserved algae showed that chloroplasts remained intact with this technique. Suitable conversion factors were used to transform counts to cells per milliliter.

Planktonic diatoms in the samples were identified using the reference works of Patrick and Reimer (1966). Cleve-Euler (1951-1955), Hustedt (1930, 1931-1951), Huber Pestalozzi (1942), Sreenivasa and Duthie (1973), and Weber (1966). The works of Bourrelly (1966, 1968, 1970) and Prescott (1962) were used to identify algae from other classes.

VII MACROINVERTEBRATES METHODS

During each of the four sampling trips (Fig. 2), five quantitative samples for macroinvertebrates were collected at sample stations 1 to 7 using a 0.1 square meter modified Hess sampler which had a 351 micron mesh collection bag. The samples were emptied into *circa* 450 ml glass jars and preserved with a 10 percent formalin solution.

During the August collection trip, four 0.1 square meter multiple plate samplers known as Hester-Dendy samplers (Hester and Dendy, 1962) were installed at each of the seven sample sites. Stainless steel cable (2 mm diameter) was used to attach each sampler to separate 13 mm diameter reinforcing rods which were driven into the stream bed. Each sampler was held submerged by a 454 gram roll of fisherman's pencil lead.

The Hester-Dendy samples were retrieved during the September survey following a seven week colonization period. The samples were dropped into a three liter open mouth polyethylene container. In order to achieve minimal loss of sample this procedure was performed underwater and the samplers were then disassembled on the stream bank. A stiff brush was used to transfer the organisms into an enamel tray. The contents of the enamel tray were sieved using a 354 micron mesh sieve so that data from Hester-Dendy samplers could then be compared to data from the Hess samplers.

All samples which were collected by either a Hess or Hester-Dendy sampler were returned to Vancouver for sorting, identification, and enumeration. Organisms were viewed with a Wild M5 Stereo Microscope and M1 Compound Microscope and identified using the following biological keys: Pennak (1953), Edmondson (1959), and Usinger (1956). The classification of all benthic invertebrates was dependent on maturity of the specimens and agreement between authors in assigning specimens to appropriate classifications. For example, some authors combine the families Glassomatidae with Rhycophilidae under the latter name for the order Tricoptera. Because of these classification difficulties the term "taxa" in this report denotes family level or the lowest identifiable level above family.

After the classification and identification process was completed a composite sample for each station was derived by adding the contents of the five collected samples. The total number of organisms per square meter, the total number of organisms per sample, and the total number of taxa were determined for each sample site and for each season.

The data were analyzed statistically using the Shannon-Wiener "diversity" index (H'). The diversity index (H') which was derived by Shannon-Wiener is shown below:

$$H' = -\sum_{i=1}^{n} P_i \log_2 P_i$$

where H' = diversity per sample

P_i = proportion of the total sample belonging to the i^{th} species

n = total number of taxa

and the "evenness" index (J) as described by Pielou (1966, 1967).

$$J = \frac{-\sum_{i=1}^{n} P_i \log_2 P_i}{\log_2 n}$$

where $J_{max} = 1$ (where all species are present in equal proportions).

Analysis of variance (Sokal and Rohlf, 1969) tests were performed using the Hess sample diversity values to determine whether or not a significant difference existed between sample sites and between sample times. The diversity data from the Hester-Dendy samplers were used to examine the differences in sites. Estimates for missing data were made in accordance with the methods described by Steel and Torrie (1960). A separate analysis was made of the diversities obtained from the two sampling methods (Hester-Dendy and Hess) to determine if the difference between sample methods and sample sites were statistically significant.

VIII CHEMISTRY DATA - RESULTS AND DISCUSSION

The detailed chemistry data not found in this interpretative report can be obtained in the Flathead River Basin data report (Sheehan *et al.* in preparation).

A. Heavy Metals

1. Sediment - Cu, Fe, Pb, Zn, Cd, Co, Ni, Mn

Heavy metal levels in bed sediment were measured in order to document the existing levels since future pH and temperature changes occurring in the river water, could increase the availability of metals to aquatic biota.

a) Non-residual metals (chemical methods, Table 4) in bed sediment collected in pickle jars (Cu, Fe, Pb, Zn, Cd, Co, Ni)

Heavy metal analysis was conducted on settled sediment collected in polyethylene pickle jars for the period April 12, 1976 to August 5, 1976, (Fig. 3 and 4) and August 5, 1976 to September 11, 1976 (Fig. 5 and 6) at stations 1 and 3 respectively. The arithmetic means and standard deviations calculated from the original data (Table 11) for each of the three defined particle size ranges are presented in Fig. 3 - 6. These samples were taken primarily to give an existing heavy metal level associated with recently settled sediment above and below the proposed coal mining development. There appears to be a trend in the data; metal concentrations increase with a decrease in sediment particle size. The large surface area to volume ratio associated with the smaller particles probably accounts for the high concentrations of non-residual metals. It should be noted that the walls of the pickle jars were coated with ferric hydroxide which was not recovered. Thus the levels of iron and other coprecipitated metals could be higher than actually measured.

b) Total metals in bed sediment collected by scraping the sediment into Whirl-pak bags (Cu, Fe, Pb, Zn, Cd, Co, Ni)

The total concentration levels for metals in bed sediment collected at three sampling sites (Fig. 7, Table 12) were measured.

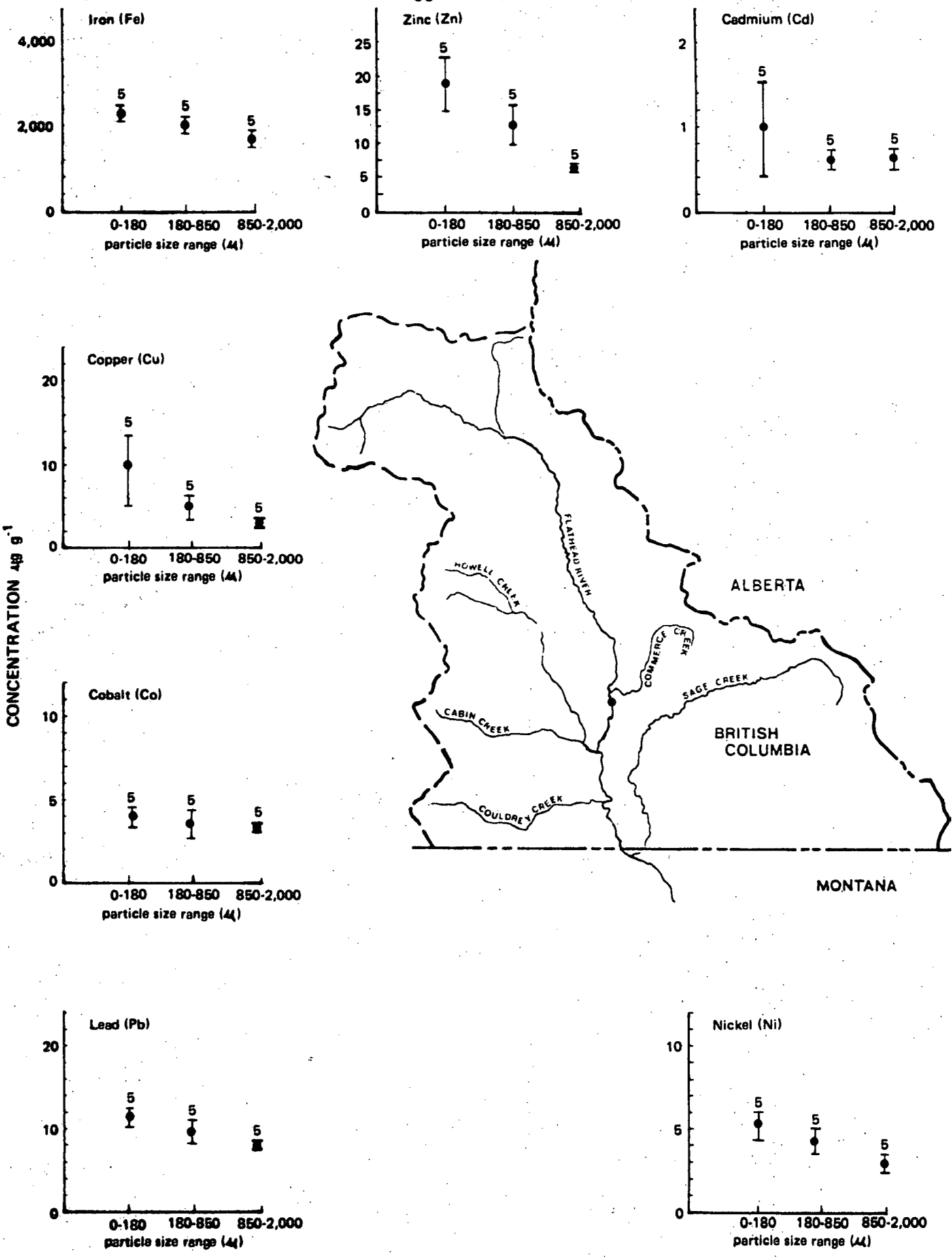

Fig. 3 Non-residual metal concentrations in bed sediment samples collected in pickle jars at station 1 from April 12, 1976 to August 5, 1976. The solid circle and the vertical bars indicate the mean ± one standard deviation. The number above the bar indicates the sample size.

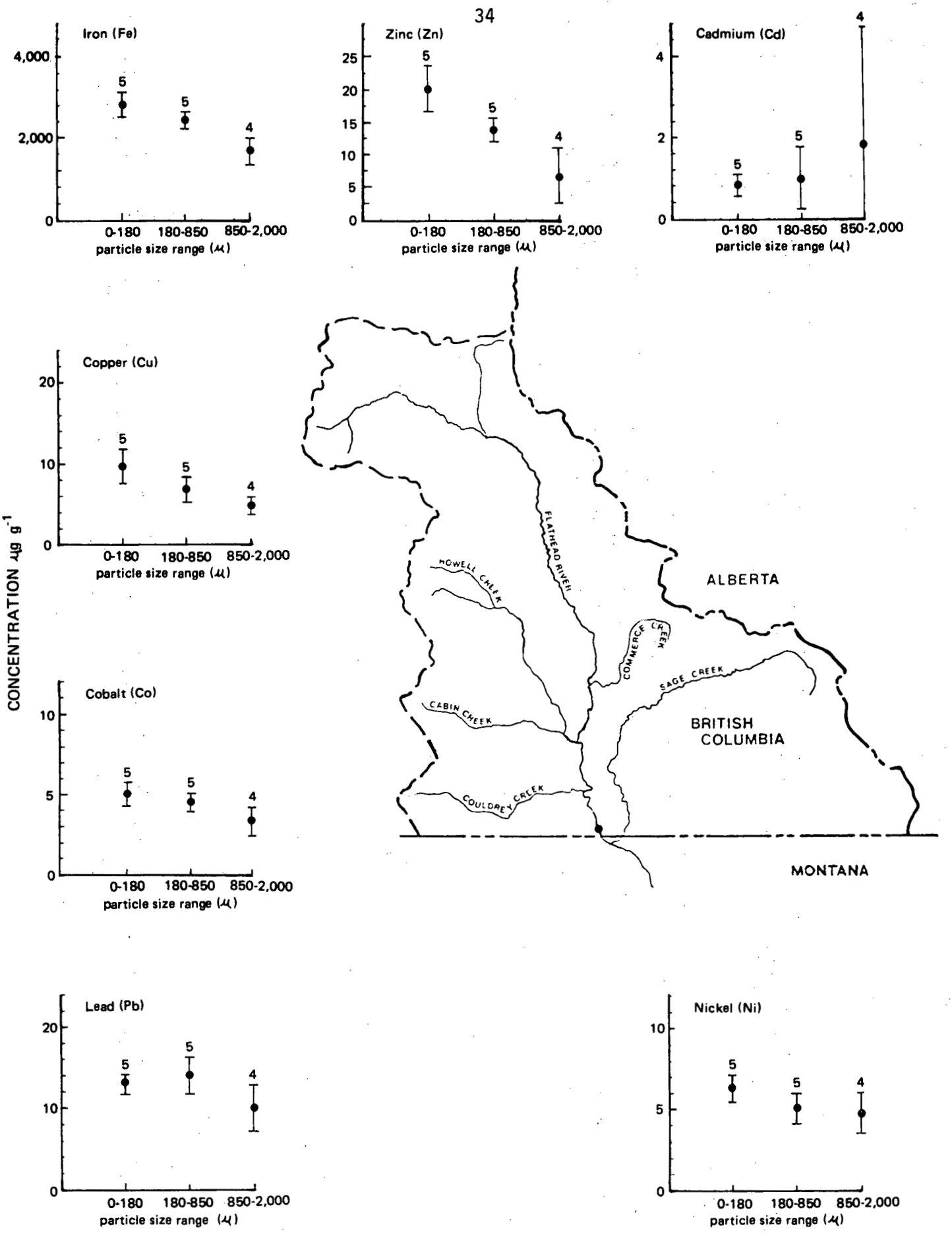

Fig. 4 Non-residual metal concentrations in bed sediment samples collected in pickle jars at station 3 from April 12, 1976 to June 14, 1976. The solid circle and the vertical bars indicate the mean ± one standard deviation. The number above the bar indicates the sample size.

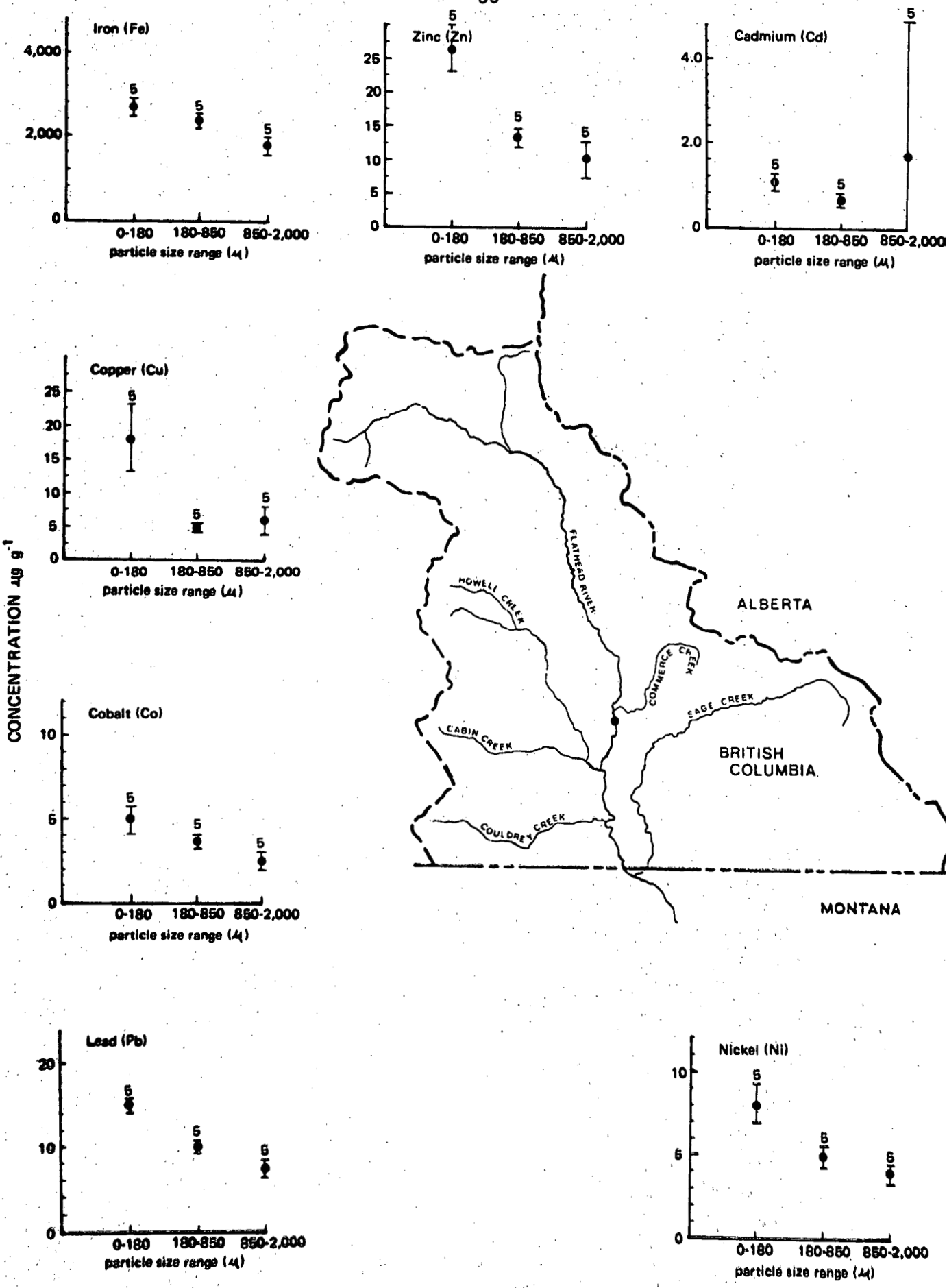

Fig. 5 Non-residual metal concentrations in bed sediment samples collected in pickle jars at station 1 from August 5, 1976 to September 11, 1976. The solid circle and the vertical bars indicate the mean ± one standard deviation. The number above the bar indicates the sample size.

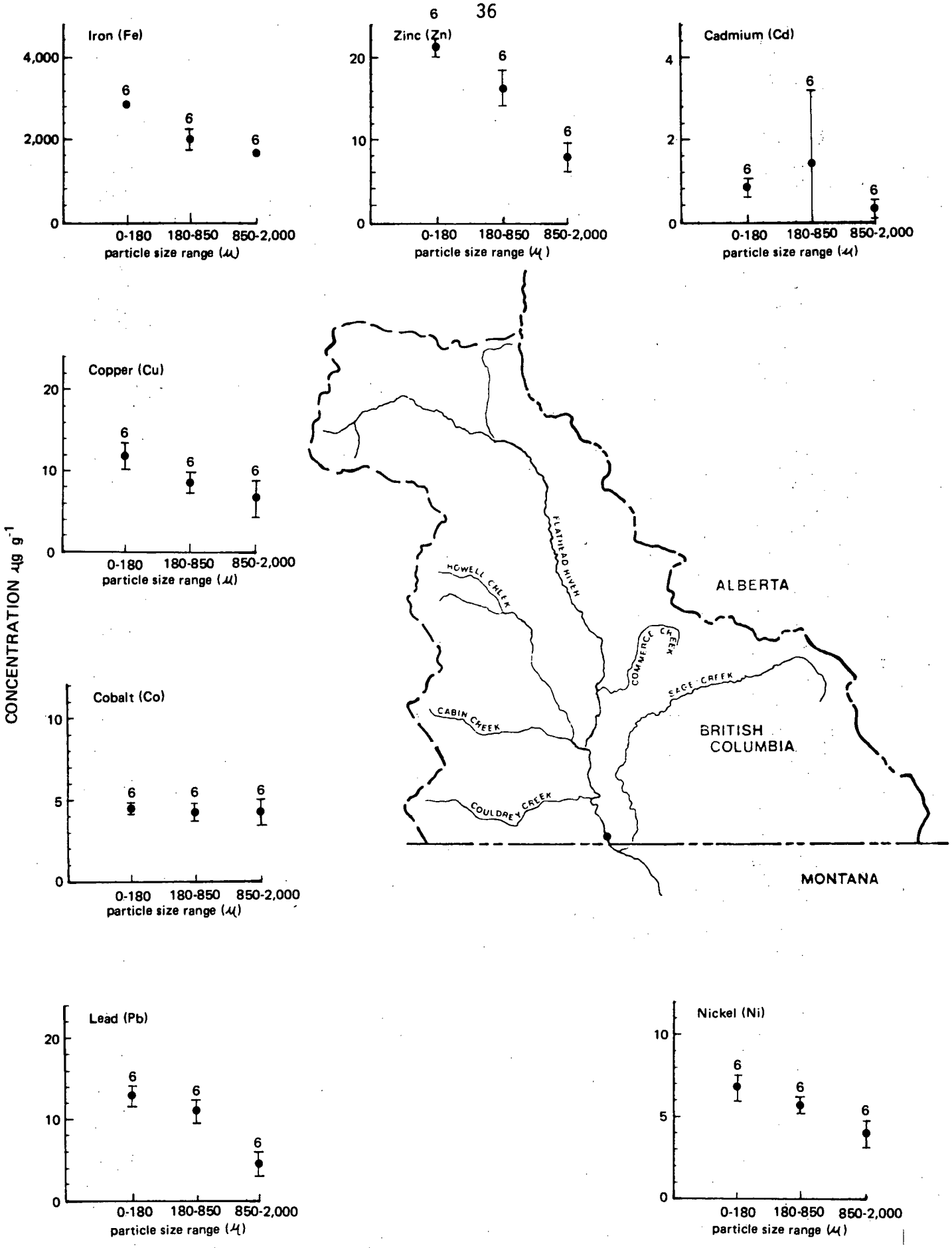

Fig. 6 Non-residual metal concentrations in bed sediment samples collected in pickle jars at station 3 from August 5, 1976 to September 11, 1976. The solid circle and the vertical bars indicate the mean ± one standard deviation. The number above the bar indicates the sample size.

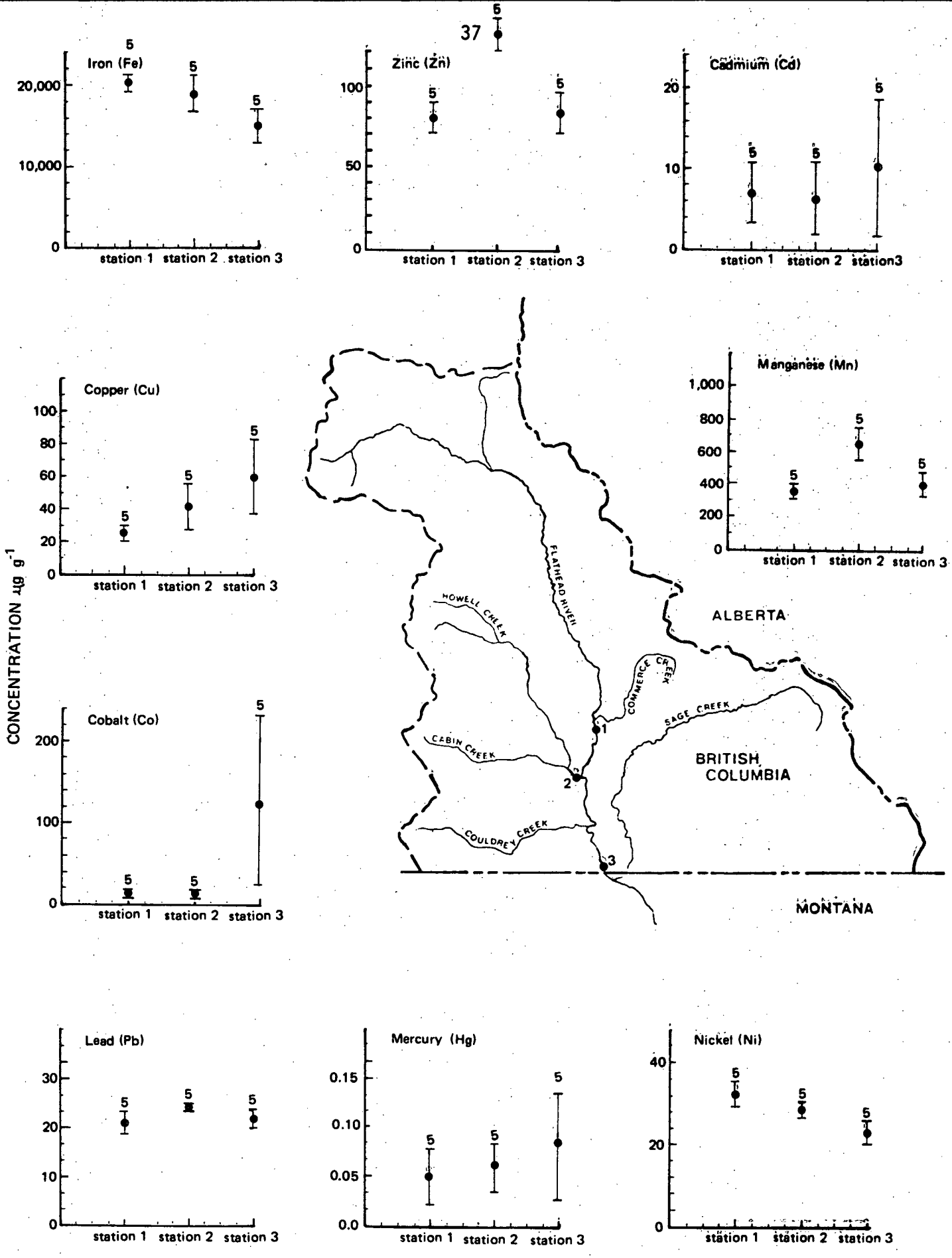

Fig. 7 Total metal concentration µg g^{-1} for bed sediment samples (particle size 0 - 53 µ) taken on September field trip. The solid circle and the vertical bars indicate the mean ± one standard deviation. The number above the bar indicates the sample size.

TABLE 11

METAL CONCENTRATIONS ($\mu g\ g^{-1}$) FOR THE NON-RESIDUAL METAL METHOD FOR BED SEDIMENT COLLECTED IN PICKLE JARS

Exposure Period	Station	Sample No.	MESH SIZE USED TO SEPARATE PARTICLE SIZE (PARTICLE RETENTION SIZE IN BRACKETS)																			
			<80 (<180 Microns)							20-80 (180-850 microns)							>20 (850-2000 microns)						
			Cu	Fe	Pb	Zn	Cd	Co	Ni	Cu	Fe	Pb	Zn	Cd	Co	Ni	Cu	Fe	Pb	Zn	Cd	Co	Ni
April 12 - Aug. 5	1	C-100	9.6	2400	13	20	.79	4.2	6.0	5.2	2400	9.8	13	.59	3.6	4.8	4.0	1500	8.0	7.6	.57	3.1	3.4
	1	C-101	7.5	2000	12	17	.79	3.4	4.5	4.2	2000	9.2	10	.59	3.0	3.4	3.2	1600	8.5	7.6	.59	3.0	3.0
	1	C-102	5.3	2400	10	14	.59	3.6	4.4	6.9	2000	12	17	.79	4.2	5.4	3.8	1600	8.9	7.1	.59	3.4	2.8
	1	C-103	8.9	2000	12	18	.79	4.2	6.8	4.6	2000	9.4	10	.59	3.0	3.8	3.8	1800	7.9	8.2	.39	3.4	3.6
	1	C-104	17	2400	12	24	2.0	4.2	6.0	4.6	2400	10	13	.59	3.4	4.4	3.6	1400	8.9	6.8	.59	3.2	4.0
Aug. 5 - Sept. 11	1	C-105	13	2400	14	22	.99	4.6	7.0	5.4	2400	9.9	14	.59	3.8	4.8	9.8	2000	6.2	13	.39	2.5	4.3
	1	C-106	21	2400	15	26	.99	4.4	7.0	4.9	2400	10.0	13	.59	3.8	4.4	6.5	1900	8.5	11	7.5	3.0	4.0
	1	C-107	16	2700	15	25	.98	5.3	8.8	5.2	2400	10	14	.59	3.2	5.0	4.9	1600	6.8	11	0.39	2.6	4.4
	1	C-108	17	2800	16	28	1.2	6.0	10	4.9	2100	11	13	.79	3.8	5.3	4.6	1600	6.4	7.6	.39	1.8	4.4
	1	C-109	24	2300	15	29	.96	5.0	7.1	5.2	2300	11	13	.59	3.4	5.4	4.5	2000	8.1	8.3	.39	3.0	3.6
April 12 - June 14	3	C-300	11	2700	12	22	.79	5.1	6.1	4.9	2100	12	12	.76	4.8	4.6	3.4	1200	10	8.0	.79	3.6	4.0
	3	C-301	11	3000	13	22	.79	5.3	7.8	6.6	2600	13	16	2.4	4.8	5.8	4.8	2000	13	.12	.22	4.2	5.2
	3	C-302	11	2800	12	20	.79	4.6	6.0	8.5	2400	12	15	.79	4.8	6.1	-	-	-	-	-	-	-
	3	C-303	9.9	3000	13	22	.99	5.8	6.2	6.0	2400	17	14	.59	4.0	4.8	3.9	1400	9.4	8.7	5.8	3.6	3.4
	3	C-304	6.8	2100	11	14	.59	4.0	6.0	4.9	2400	12	13	.59	3.8	4.4	5.4	1700	7.0	8.3	.41	2.1	5.8
Aug. 5 - Sept. 11	3	C-305	14	2800	13	22	.99	4.8	7.0	8.4	2400	10	15	4.8	4.0	5.4	7.6	1600	4.4	9.4	.39	2.4	4.4
	3	C-306	12	2800	13	22	.79	4.4	5.2	9.1	2400	11	14	.79	4.2	5.8	4.9	1600	3.6	6.8	.19	1.8	3.0
	3	C-307	11	2800	13	20	.79	5.0	6.6	9.2	2700	13	20	.99	5.0	6.4	5.1	1600	7.1	7.1	.59	2.8	5.1
	3	C-308	12	2800	13	22	.79	4.4	7.3	9.8	2300	11	16	.79	4.9	6.1	7.2	1600	5.9	8.2	.39	2.8	3.8
	3	C-309	12	2800	13	22	.79	5.0	7.4	6.2	1900	9.9	14	.58	3.8	5.4	4.1	1600	2.8	5.5	.10	1.4	4.5
	3	C-310	9.6	2800	12	19	1.2	4.4	6.4	8.6	2400	11	15	.79	4.0	5.4	9.8	1600	3.3	10	.09	2.7	4.3

TABLE 12

TOTAL METAL CONCENTRATIONS ($\mu g\ g^{-1}$)
FOR BED SEDIMENT SAMPLES TAKEN ON SEPTEMBER TRIP BY HAND
AND PLACED IN WHIRL-PAK BAGS. (SEE METHODS)

STATION	Cu	Fe	Pb	Mn	Zn	Cd	Co	Ni	Hg
1	45	20,000	26	360	85	14	20	40	.08
1	30	20,000	21	350	80	8	20	30	.04
1	33	21,000	20	370	80	5	15	35	.06
1	18	20,000	20	300	65	4	10	30	.01
1	30	22,000	23	430	90	6	10	35	.05
2	40	20,000	25	700	130	4	20	30	.06
2	42	22,000	26	700	130	5	20	30	.07
2	28	20,000	28	720	110	4	15	27	.03
2	65	18,000	25	600	130	15	9	26	.08
2	40	17,000	25	500	130	6	15	26	.06
3	48	15,000	24	350	78	25	210	20	.15
3	72	17,000	24	450	95	9	210	26	.04
3	79	13,000	22	340	90	5	210	20	.04
3	25	13,000	20	360	70	2	10	22	.03
3	80	18,000	26	450	96	10	20	24	.13

The total levels are approximately three to ten times higher than the non-residual levels collected in pickle jars for each metal (Table 11 and 12). The differences in field sampling techniques and analytical methodology (Table 4), associated with non-residual metals and total metals are reflected in the magnitude of the levels measured.

2. Water - Ba, Cd, Co, Cu, Fe, Pb, Mn, Hg, Ni, Zn, As, Se

Canadian Drinking Water Standards are based on criteria which are acceptable to the Department of National Health and Welfare, Canada. Our comparisons with drinking water standards are interpreted with caution. Compliance with drinking water standards doesn't necessarily mean that biota and ungulates are adequately protected as sub-lethal effects on many aquatic organisms and some ungulates are not known.

The mean metal levels for the water samples taken on the Flathead River (stations 1, 3 and 5) for 1975 and 1976 were barium .11 mg l^{-1}, cadmium .003 mg l^{-1}, cobalt .001 mg l^{-1}, copper .001 mg l^{-1}. iron .27 mg l^{-1}, lead .001 mg l^{-1}, manganese .015 mg $^{-1}$, mercury .05 µg l^{-1}, nickel .001 mg l^{-1}, zince .003 mg l^{-1}, arsenic .0003 mg l^{-1}, and selenium .0001 mg l^{-1} (DATA SOURCE NAQUADAT). These levels are also representative of those measured on the tributaries of the Flathead River Basin. These mean levels are all below drinking water standards.

The drinking water standard of .05 mg l^{-1} for manganese (Canadian Dept. National Health and Welfare, 1968) was exceeded on April 12, 1976 at station 8. On that date, the level for a single grab sample was .06 mg l^{-1}. The acceptable standard of .05 mg l^{-1} for manganese in water was measured on April 10, 1976 at station 3 and on April 12, 1976 at stations 3 and 6.

Barium exceeded the drinking water standard of 1.0 mg l^{-1} (Canadian Dept. National Health and Welfare, 1968) on February 5, 1976 at station 2 and 3. The levels were 1.5 mg l^{-1} and 1.6 mg l^{-1} respectively (Fig. 8). The high levels of barium may be accounted for by the fact that there are barite ($BaSO_4$) deposits in the Flathead watershed. High barium concentrations also correspond to period of low discharge when groundwater contributions to base flow appeared to be high.

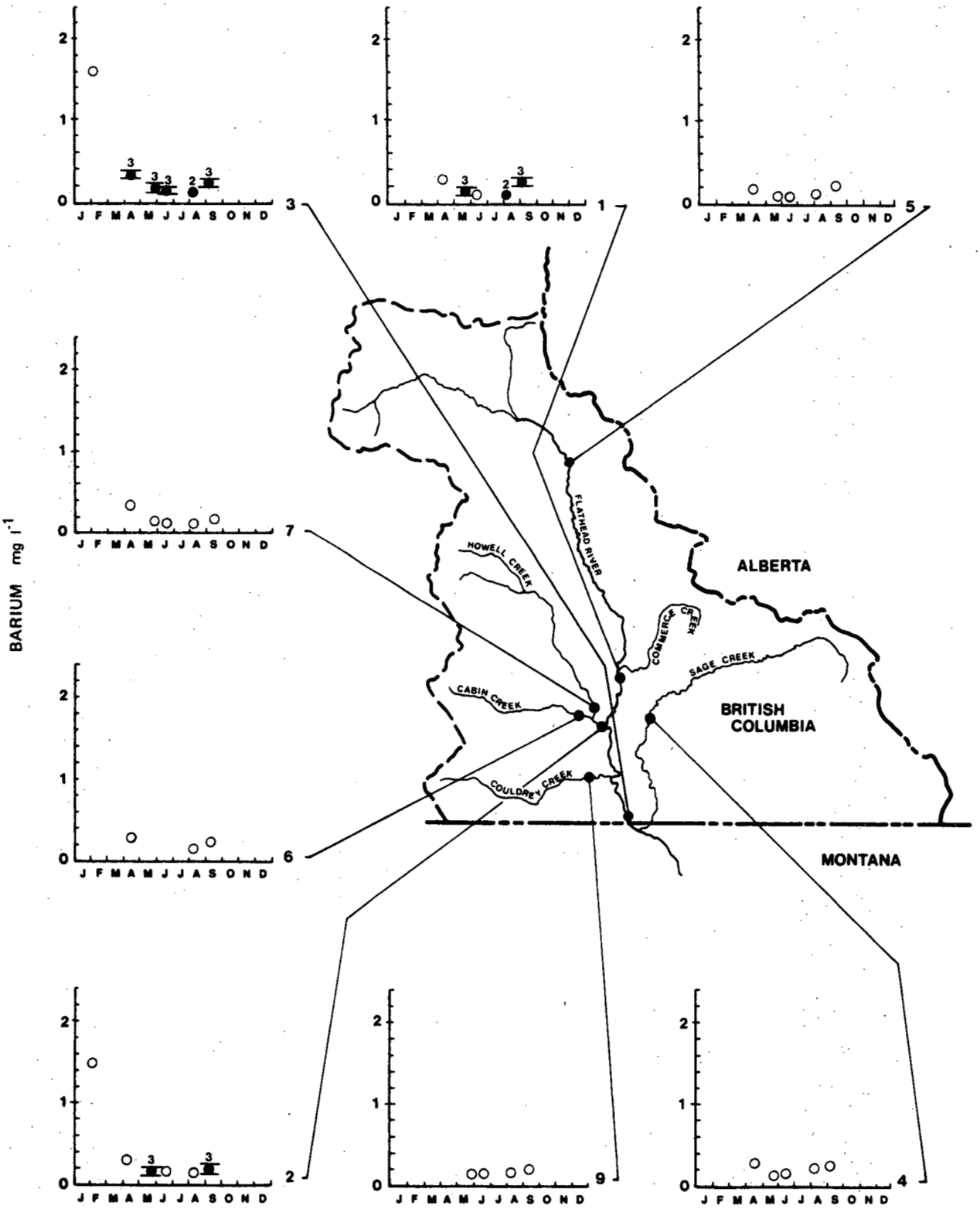

Fig. 8 Concentration of Barium (Ba) in the Flathead River Basin water, January - December, 1976.

Open circle represents single samples. Solid circles with a number above represents an arithmetic mean for those samples. The bars represent ± one standard deviation. No bars indicate a zero standard deviation. The drinking water standard for barium is 1.0 mg l^{-1}.

3. Algae

The levels ($\mu g\ g^{-1}$ dry weight) of copper, iron, lead and zinc in the Flathead River algae are reported in Table 13. The concentrations of these metals are greater in the algae than in the ambient water. The metals in attached algae can be related to uptake at specific locations. The present levels of metals in the Flathead River algae can be considered background levels; concentrations for all samples (Table 13) were low compared to other healthy rivers in the nearby Kootenay River Drainage Basin (Water Quality Report in preparation).

TABLE 13

HEAVY METAL RESULTS FOR ALGAE IN THE FLATHEAD RIVER SYSTEM

Station	Sample No.	Dominant Phyla or Class	Dominant Alga(e) and Percent Abundance	Cu $\mu g\ g^{-1}$ dry wt.	Fe $\mu g\ g^{-1}$ dry wt.	Pb $\mu g\ g^{-1}$ dry wt.	Zn $\mu g\ g^{-1}$ dry wt.
2	C-501	Cyanophyta Chlorophyta	*Nostoc verrucosum* 99% *Stigeoclonium sp.* 1%	12	3500	23	47
2	C-502	Chlorophyta	*Stigeoclonium sp.* 100% *Closterium sp.* trace	97	1800	15	87
3	C-503	Chlorophyta Bacillariophyceae	*Mougeotia sp.* 65% *Cocconeis pediculus* 35%	8.7	1300	5.6	52
3	C-504	Chlorophyta	*Ulothrix zonata* 100%	11	2000	8.8	30
5	C-505	Chlorophyta	*Ulothrix zonata* 100%	28	2000	20	93
6	C-506	Chlorophyta Bacillariophyceae	*Monostroma sp.* 98% *Cocconeis pediculus* 2%	8.5	2300	4.9	39
7	C-507	Cyanophyta	*Nostoc verrucosum* 100%	29	1000	19	46
7	C-508	Chlorophyta	*Ulothrix zonata* 100%	23	3800	14	98
9	C-509	Chlorophyta	*Monostroma sp.* 100%	8.8	1300	2.2	30

4. Macroinvertebrates

Nehring (1976) found that the metal levels in many invertebrates are related by a predictable reproducible factor to metal levels in water. In the present study, methodology problems associated with the collection and preservation of invertebrates invalidated the measured levels of these metals in invertebrates. No further discussion of results is warrented.

5. Fish

The ranges ($\mu g\ g^{-1}$ wet weight) for mercury, copper, iron, lead, and zinc in the Flathead River Basin for Slimy Sculpins, (*Cottus cognatus*) are given in Table 14. There were no observable differences in the metal levels for Slimy Sculpins between stations in the Flathead River Basin. Slimy Sculpins were caught by personnel from the Fish and Wildlife, Nelson Regional Branch and were selected for metal analysis because of their abundance and non-migratory behaviour in the Flathead River. Between 5 and 9 Slimy Sculpins were homogenized for chemical analysis and reported metal levels are for whole fish. Metal concentrations in whole Slimy Sculpins are probably higher than concentrations in fish flesh alone, a pattern observed in other fish species (Rehnoldt *et al.* 1976). The metal levels measured for the Slimy Sculpins are below the Canadian Food and Drug Directorate regulations set for edible fish flesh (see Table 14).

TABLE 14

THE RANGE OF METAL LEVELS IN WHOLE SLIMY SCULPINS (*COTTUS COGNATUS*) IN THE FLATHEAD RIVER BASIN

Collection Date	Station	No. of * samples	Metal ranges (µg g^{-1} wet wt.) Hg	Cu	Fe	Pb	Zn
September 13, 1976	1	6	.03-.04	1.1-1.3	30-51	2.0-2.3	17-22
September 14, 1976	3	7	.03-.04	1.1-1.3	29-120	2.1-2.8	16-25
September 13 and 14, 1976	6	6	.02-.04	1.2-1.6	26-53	2.0-2.5	20-26
September 14, 1976	7	6	.03-.05	1.0-1.5	34-100	2.0-2.5	19-26
			THE CANADIAN FOOD AND DRUG DIRECTORATE STANDARDS FOR EDIBLE FISH FLESH µg g^{-1} WET WT.				
			0.5	100	No STD	10	100

* Each sample had 5 - 9 slimy sculpins digested and analysed for metals.

B. Nutrient - Total Phosphorus, Particulate Carbon Particulate Nitrogen

1. Sediment

Settled sediment, collected by hand from wadeable portions of the river at station 1 (upstream of the proposed coal development) and station 3 (at the International Boundary) were analyzed for total phosphorus, particular carbon, and particulate nitrogen. This data provides only minimal information on total phosphorus, particulate carbon and particulate nitrogen levels present in newly settled sediment.

TABLE 15

TOTAL PHOSPHORUS CONCENTRATIONS ($\mu g\ g^{-1}$)

IN SETTLED SEDIMENT FOR THREE PARTICLE SIZES

*Exposure Period	Station	Mesh size used to separate particle size (particle retention size in brackets)								
		< 80 (< 180 microns)			20-80 (180-850 microns)			> 20 (850-2000 microns)		
		No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ
April 12 - August 5	1	5	470	190	5	650	70	5	750	20
August 5 - September 11	1	4	340	60	5	640	180	5	750	22
April 12 - August 5	3	5	720	10	5	860	120	1	370	0
August 5 - September 11	3	6	670	30	5	520	40	5	420	60

*Exposure period refers to the length of time that the pickle jars were placed in the stream bed.

TABLE 16

TOTAL CARBON CONCENTRATIONS ($\mu g\ g^{-1}$)

IN SETTLED SEDIMENT FOR THREE PARTICLE SIZES

*Exposure Period	Station	Mesh size used to separate particle size (particle retention size in brackets)								
		< 80 (< 180 microns)			20-80 (180-850 microns)			> 20 (850-2000 microns)		
		No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ
April 12 - August 5	1	5	28000	2000	5	15000	1000	5	17000	2000
August 5 - September 11	1	5	33000	7000	5	18000	2000	4	12000	3000
April 12 - August 5	3	5	24000	700	5	23000	2000	3	23000	4000
August 5 - September 11	3	6	23000	2000	6	24000	5000	5	13000	5000

*Exposure Period refers to the length of time the pickle jars were placed in the stream bed.

TABLE 17

TOTAL NITROGEN CONCENTRATIONS ($\mu g\ g^{-1}$)
IN SETTLED SEDIMENT FOR THREE PARTICLE SIZES

* Exposure Period	Station	Mesh size used to separate particle size (particle retention size in brackets)								
		< 80 (< 180 microns)			20-80 (180-850 microns)			> 20 (850-2000 microns)		
		No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ
April 12 - August 5	1	5	1400	300	5	1000	300	5	1100	500
August 5 - September 11	1	5	1500	300	5	900	300	4	700	200
April 12 - August 5	3	5	1600	300	5	1800	500	3	1200	600
August 5 - September 11	3	6	1400	400	6	2000	500	5	1500	600

*Exposure period refers to the length of time the pickle jars were placed in the stream bed.

2. Water

Dissolved nitrogen in the Flathead River occurs mainly as nitrite plus nitrate. In the Flathead River, the biologically important nutrient, nitrite plus nitrate is present in concentrations of usually < .050 mg l^{-1} (Fig. 9). The nitrite plus nitrate values in the Flathead River are usually lower than the levels found in the Kootenay System (Whitfield, MS 1979; Thorp, MS 1980). The concentration of the nutrient ammonia which is also readily usable by algae is generally < .025 mg l^{-1}. The concentrations of dissolved organic nitrogen compounds such as urea, uric acid, and xanthine were calculated by subtracting the ammonia and the nitrite plus nitrate concentrations from the total dissolved nitrogen concentrations (Fig. 10). The levels for dissolved organic nitrogen were usually < .075 mg l^{-1}.

The dissolved phosphorus levels are all < .020 mg l^{-1} in the Flathead River (see Fig. 11). Total phosphorus levels were also measured (see Fig. 12) because a degree of uncertainty is associated with the forms of phosphorus available for plant growth (Stewart 1974). The levels are similar to those found in the Bull and Elk Rivers (Whitfield, MS 1979). Three of 376 samples taken for total phosphorus exceeded drinking water standards. These were associated with high suspended sediment levels and slush ice conditions at the time of sampling.

Nitrogen and phosphorus besides being present in the aqueous component of the river ecosystem can also be stored as surplus reserves in algae. Since the water nutrient data misses these other components, caution must be used when predicting nutrient related algal growth potentials. The low biomass values measured in the Flathead River (see section 1 Biomass p. 68) and the low nitrogen and phosphorus levels found stored in algal cells (see section 2 Chemical Composition p. 71) indicate the nitrogen and phosphorus levels in the water remained low and/or unavailable throughout the study period.

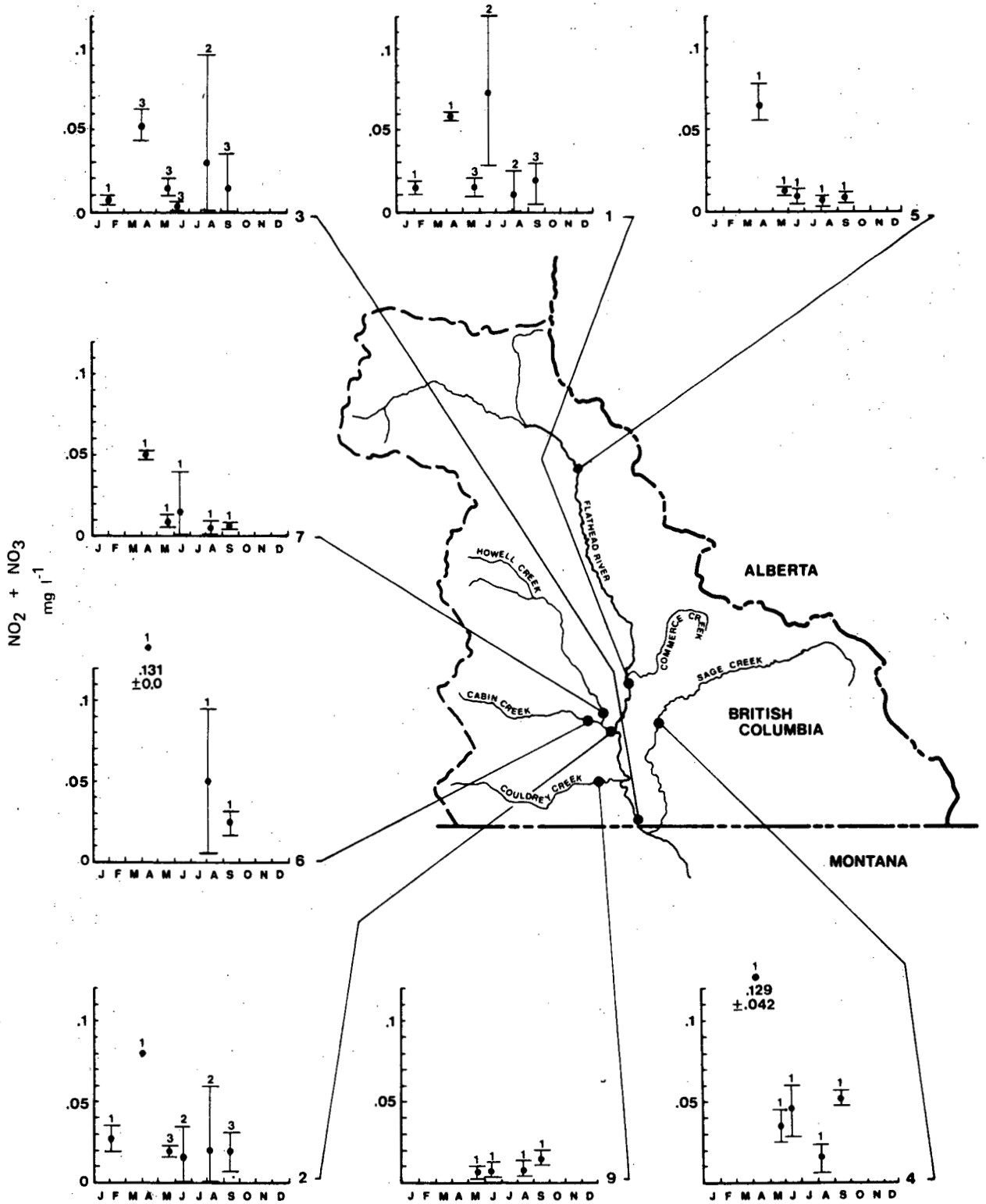

Fig. 9 Concentrations of nitrite (NO_2) + nitrate (NO_3) in the Flathead River Basin, Januauy-December, 1976.

The solid circle and the vertical bars indicate the mean ± one standard deviation. A solid circle without bars indicates the mean of six replicate samples with a zero standard deviation. The number above the bar indicates the number of consecutive days that the six replicate samples were taken.

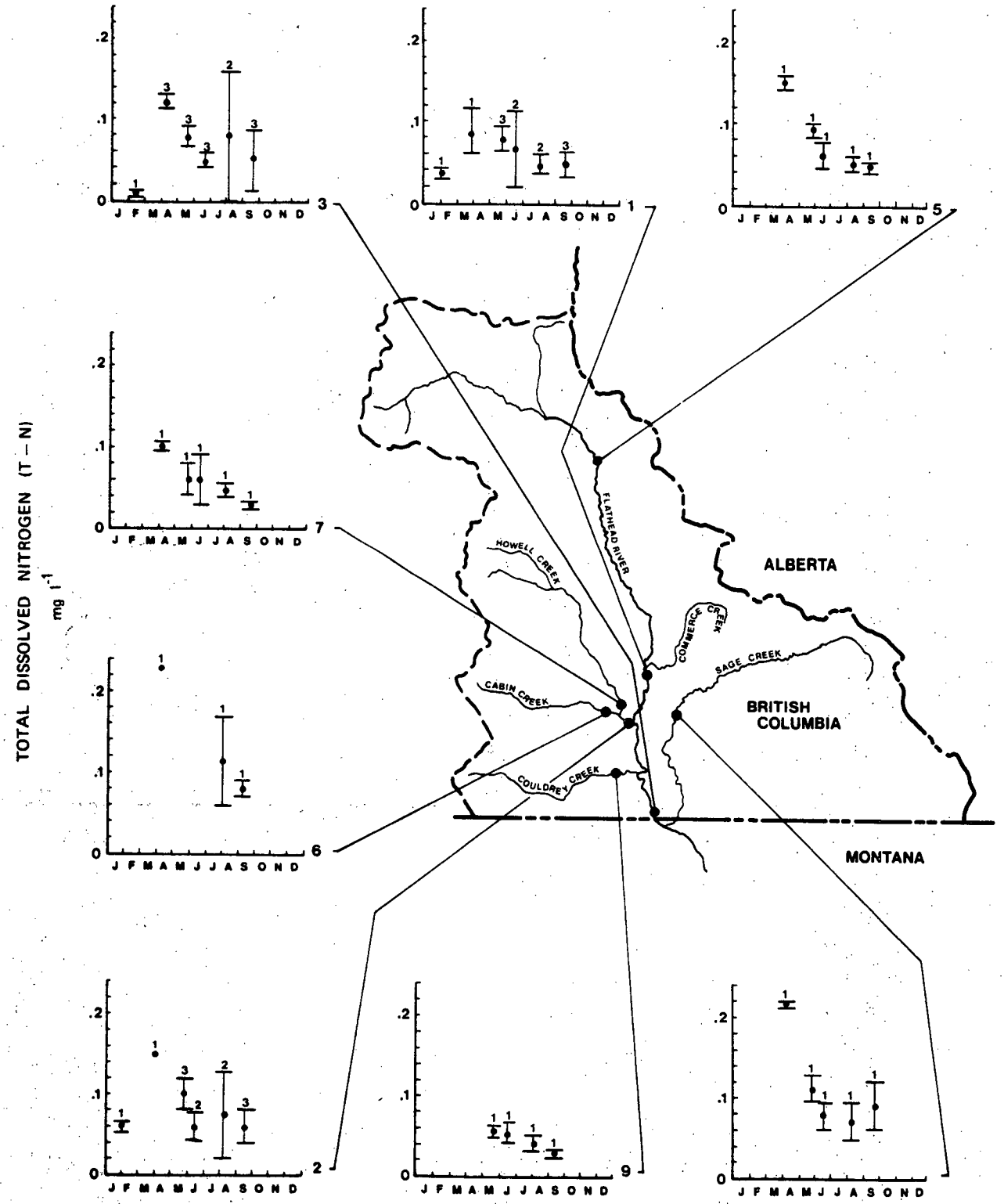

Fig. 10 Concentrations of Total Dissolved Nitrogen (T - N) in the Flathead River Basin, January - December, 1976.

The solid circle and the vertical bars indicate the mean ± standard deviation. A solid circle without bars indicates the mean of replicate samples with a zero standard deviation. The number above the bar indicates the number of consecutive days that replicate samples were taken.

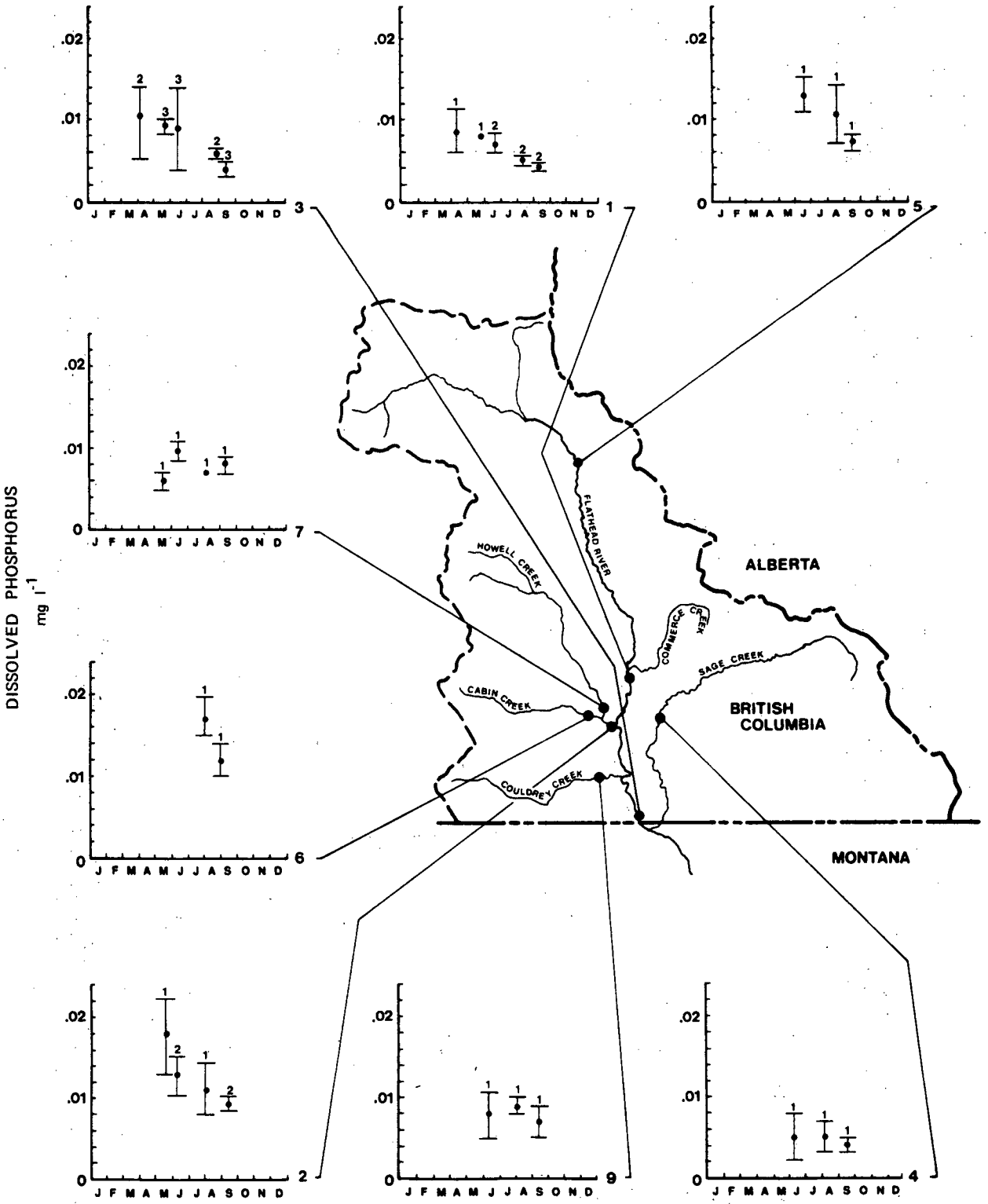

Fig. 11 Concentrations of dissolved phosphorus (Diss. P) in the Flathead River Basin, January - December, 1976.

The solid circle and the vertical bars indicate the mean ± one standard deviation. A solid circle without bars indicates the mean of replicate sample with a zero standard deviation. The number above the bar indicates the number of consecutive days that replicate samples were taken.

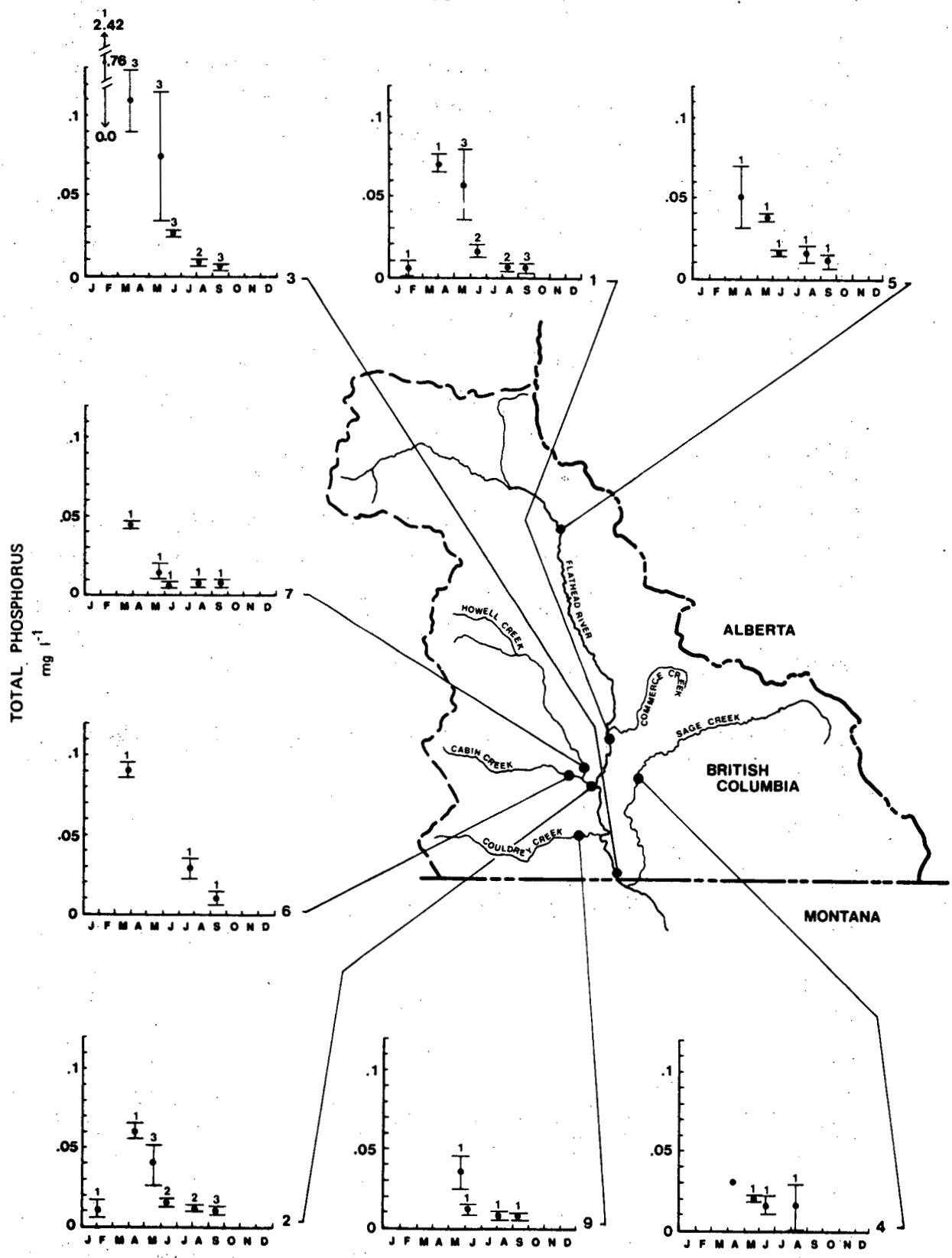

Fig. 12 Concentrations of total phosphorus (T - P) in the Flathead River Basin, January - December, 1976.

The solid circle and the vertical bars indicate the mean ± one standard deviation. A solid circle without bars indicates the mean of six replicate samples with a zero standard deviation. The number above the bar indicates the number of consecutive days that the six replicate samples were taken.

Table 18 identifies occasions when means derived from sets of six simultaneous replicate nutrient samples collected on a number of consecutive days were significantly different. Table 19 identified significant differences in mean concentration over five sampling trips. These data exhibit the occurrence of significant short term temporal variations in nutrient concentrations which make interpolation of concentrations between sampling times a questionable exercise. For this reason it is considered preferable to identify loadings (see section 3 Transboundary loading calculations p. 56) with instantaneous concentration rather than to attempt to calculate uncertain monthly or annual loading values.

3. Transboundary loading calculations

Ecologically important daily loading figures for total phosphorus, nitrite plus nitrate, and sediment (non-filterable residue) were calculated. Water Survey of Canada supplied discharge data from the International Boundary Station. The calculations for total phosphorus and nitrite plus nitrate daily loads are based on concentration means at the time of sampling and their associated errors (Table 20). The error associated with flow measurements is unknown and was not included in the loading calculation.

$$\bar{L} = 2.45\ (\bar{c} \times Q)$$

$\bar{c}$ = mean concentration value determined from six replicates mg l^{-1}

Q = daily flow $ft^3\ sec^{-1}$

$\bar{L}$ = mean load kg day^{-1}

2.45 = conversion constant $mg^{-1}\ l\ ft^{-3}\ sec\ kg\ day^{-1}$

$$SDL = \frac{\sigma}{\bar{c}} \times Q$$

σ = standard deviation of the six replicate concentration values.

$\bar{c}$ = mean concentration value determined from six replicates

SDL = standard deviation of the Load

TABLE 18

SIGNIFICANT DIFFERENCES ($p < .05$) IN MEAN CONCENTRATIONS OF NUTRIENTS OVER TWO AND THREE DAY SAMPLING PERIODS

Date by Month	Station	Total Phosphorus	Nitrite Plus Nitrate	Ammonia	Total Dissolved Nitrogen
April	3	NS	NS	NS	NS
May	1	S(3)	S(3)	NS	NS
	2	S(3)	S(3)	S(3)	S(3)
	3	S(3)	NS	NS	NS
June	3	NS	S(3)	S(3)	NS
August	1	NS	NS	NS	NS
	2	NS	NS	NS	NS
	3	NS	NS	NS	NS
September	1	NS	NS	S(2)	NS
	2	NS	NS	NS	NS
	3	NS	NS	S(3)	NS

Numbers in parenthesis indicate number of consecutive days where the means of sets of six replicate samples were compared.

S - significant
NS - nonsignificant

TABLE 19

SIGNIFICANT DIFFERENCES ($p < .05$) IN MEAN CONCENTRATION OVER FIVE SAMPLING TRIPS

Station	Total Phosphorus	Nitrite Plus Nitrate	Ammonia	Total Dissolved Nitrogen
3	S(5)	S(5)	NS(5)	S(5)

S - significant
NS - nonsignificant

TABLE 20

FLATHEAD RIVER AT THE INTERNATIONAL BOUNDARY

ESTIMATED DAILY TRANSBOUNDARY LOADING FIGURES

Date	Total Phosphorus Load		Nitrite plus Nitrate Load		Suspended Solids Load
	Mean Load Kg day^{-1} $\bar{L}$	Standard Deviation* Kg day^{-1} (SDL)	Mean Load Kg day^{-1} $\bar{L}$	Standard Deviation* Kg day^{-1} (SDL)	Tonnes day^{-1} L
August 20 1975	5.7	0.0	21.8	29.8	
December 18 1975	15.3	1.9	91.6	26.7	1.5
February 5 1976	279.3	613.3	2.9	.7	1.8
April 10 1976	349.1	110.7	174.5	10.1	315.5
April 12 1976	524.4	41.4	316.8	31.1	477.8
April 13 1976	702.7	93.5	368.9	0.0	702.7
May 27 1976	292.8	24.3	138.3	97.6	276.5
May 28 1976	1411.0	65.0	152.0	10.9	1628.0
May 29 1976	579.0	62.0	144.8	41.4	607.9
June 14 1976	149.5	6.0	12.0	0.0	62.2
June 15 1976	127.4	11.1	11.1	0.0	66.4
June 16 1976	130.7	22.8	39.8	34.1	13.6
August 4 1976	12.1	3.0	3.0	1.5	1.5
August 5 1976	14.5	1.6	28.9	32.1	3.2
September 11 1976	8.0	1.1	10.3	4.6	0.9
September 12 1976	9.2	3.4	6.9	4.6	1.1
September 13 1976	6.7	2.2	29.1	48.1	1.4

*The error associated with flow measurements has not been included in the calculation.

The large error associated with the load calculation for total phosphorus on February 5, 1976 can be explained by the presence of slush ice. Sediment particles are often attached to slush ice and when the water is sampled, these particles along with some of the ice may be collected resulting in erratic concentration values. The range for six total phosphorus replicates taken on February 5, 1976 was .008 mg l^{-1} to 4.155 mg l^{-1} with a mean value of .760 mg l^{-1}. The errors associated with nitrite plus nitrate calculations, however, cannot be explained.

C. Acidity

Acid water conditions occur when oxidized products of pyritic materials are present in the water in sufficient quantities to affect the pH. The oxidation of pyritic materials associated with coal can be described by the following reactions (Ahmad 1974):

$$FeS_2(s) + \frac{7}{2} O_2 + H_2O = 2SO_4^{-2} + Fe^{+2} + 2H^+ \quad (1)$$

$$Fe^{+2} + \frac{1}{4} O_2 + H^+ = Fe^{+3} + \frac{1}{2} H_2O \quad (2)$$

$$Fe^{+3} + 3H_2O = Fe(OH)_3 + 3H^+ \quad (3)$$

The overall relationship is described below:

$$FeS_2(s) + \frac{15}{4} O_2 + \frac{7}{2} H_2O = 2H_2SO_4 + Fe(OH)_3 \quad (4)$$

The sulphur content of eight core samples which were taken from eight different coal seams from the Flathead coal deposits is between 0.46 per-cent and 0.69 per cent (Rio Algom, unpublished data). The sulphur content associated with coal deposits in the Flathead Valley is low compared with the content of sulphur associated with deposits in the eastern United States where acid production from coal mines is a problem. The sulphur content of coal deposits can vary from 0.55 percent to 4.25 percent (Tennessee) Valley Authority, 1968). The oxidation rate which is a function of the oxygen concentration, temperature, degree of surface saturation by water, and pH of the solution in contact with the pyrite is important in $SO_4^=$

formation.

The Elk River which does not appear to have experienced decreases in pH as a result of the coal-mining activity in the Fording-Sparwood-Fernie area is located in an adjacent drainage basin. The coal from the Elk River basin and the Flathead River basin is part of the Kootenay formation (B.C. Dept. of Mines and Petroleum Resources, 1976). The Elk River has average levels of alkalinity of 100 mg l^{-1} and an average pH of 8.0 above the coal-mining activity (Rocchini, 1976). These levels are similar to the levels found in the Canadian section of the Flathead system (see Figures 13 & 14).

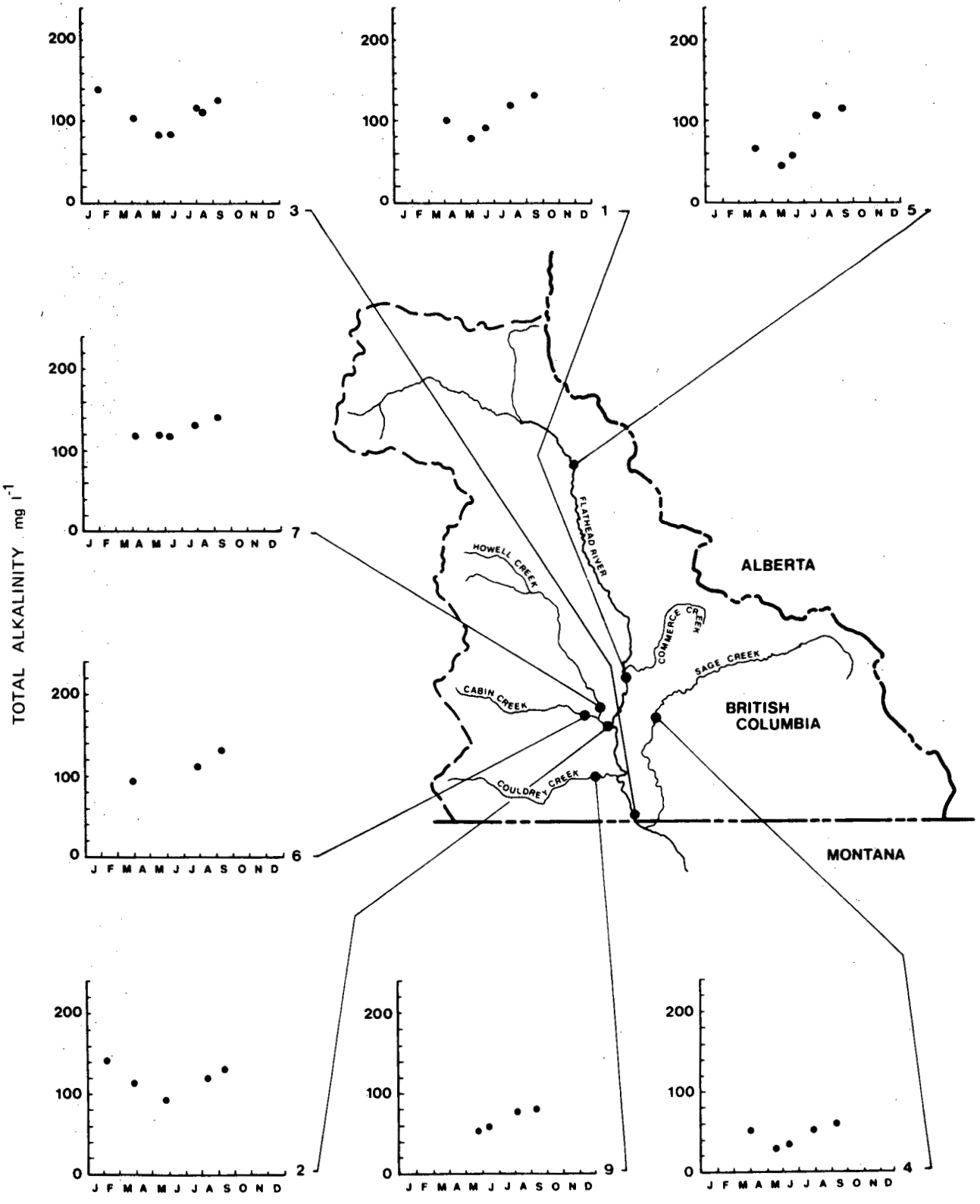

Fig. 13 Total alkalinity measurements in the Flathead River Basin, January - December, 1976.

Each dot represents a single measurement.

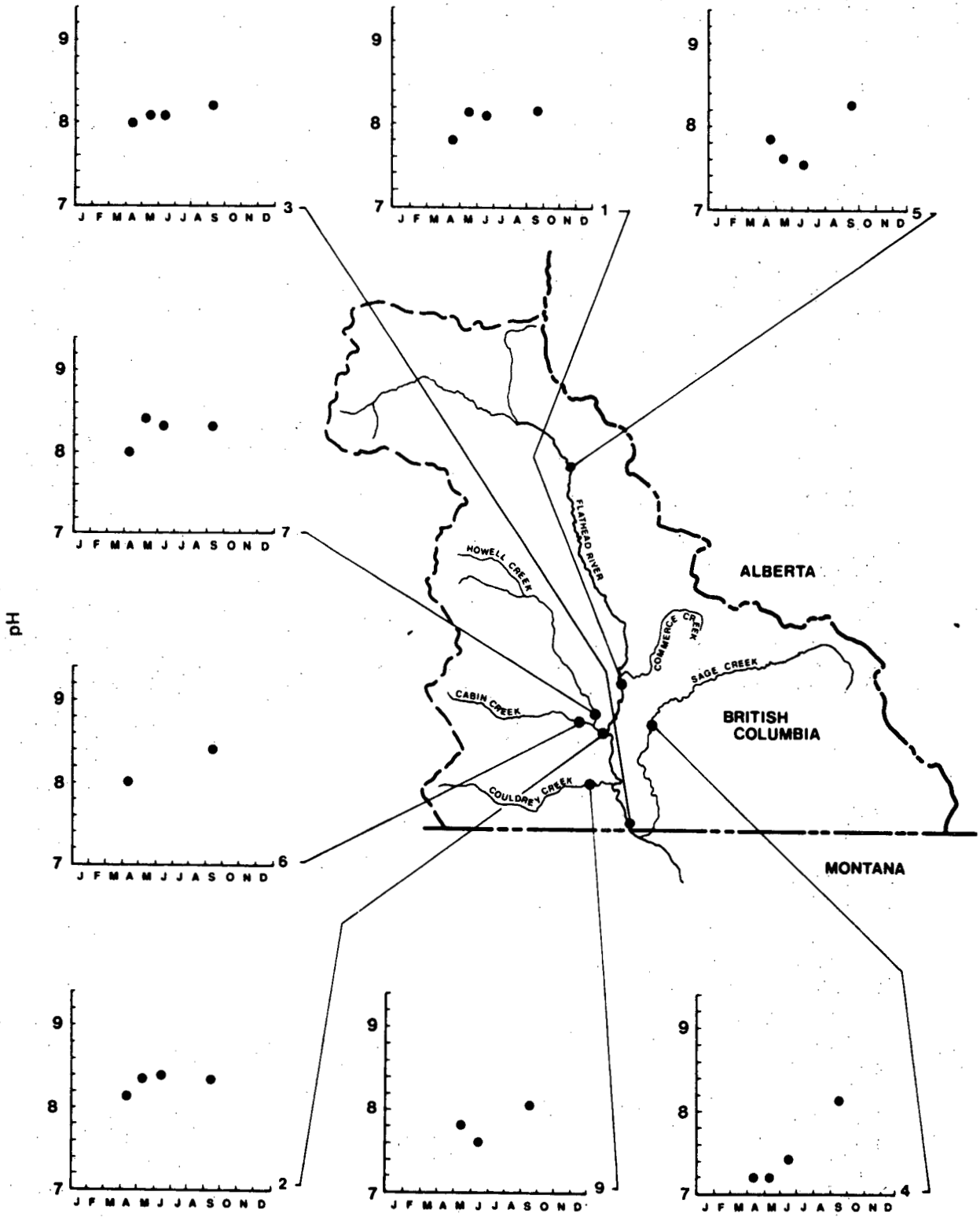

Fig. 14 pH measurements *in situ* in the Flathead River Basin, January - December, 1976.

Each dot represents a single measurement

D. Suspended Sediment

The concentration of suspended sediment in the Flathead River fluctuates with the flow regime. High concentations of suspended sediment are associated with the freshet period. On the Flathead River this period occurs in the spring, (April 13, 1976, a level of 120 mg l^{-1} and May 28, 1976, a level of 150 mg l^{-1} at station 3). Low concentrations of suspended sediment were noted during the low flow period, (i.e. August 5, 1976, a level of 2 mg l^{-1} and September 12, 1976, a level of 1 mg l^{-1} at station 3). Logging, road construction, and exploratory mining were in progress during the study period.

Suspended sediment can affect the light penetration, the temperature and the survival of aquatic organisms. For example, Dolly Varden deposit eggs in the gravel of the Flathead River and its tributaries from early August to October when suspended sediment concentrations are low. The eggs incubate over the winter months and hatch in the spring. Increases in suspended sediment concentrations during the incubation period could lead to increased sediment deposition, and the smothering effect is known to cause egg mortality in salmonids, (McNeil & Ahnell 1964; Lanager MS 1975).

E. Carbon (Total Organic Carbon and Total Inorganic Carbon) and Phenolics in Water

The concentrations during the study period for total inorganic carbon ranged from a maximum of 35 mg l^{-1} (for September 11, 1976) to a minimum of 18 mg l^{-1} (for June 14, 1976). Total organic carbon ranged from a maximum of 95 mg l^{-1} (for May 28, 1976) with a minimum value of <1.0 mg l^{-1} (for September 11, 1976) at Station 3. The significance of total organic carbon and total inorganic carbon levels in the water can only be given limited interpretation unless the chemical compounds present are identified. Of the organic compounds present only phenolics were analysed. They remained below the detection limit of 1 g l^{-1} throughout the study period.

F. Ions (Ca, Mg, K, Na, Cl, F, Si, SO_4)

The ions measured were all below the water quality criteria recommended for drinking water standards throughout the basin over the study period (EPA 1972, Canadian Dept. National Health and Welfare, 1968).

A summary of the data is presented in Table 21.

TABLE 21

SUMMARY TABLE FOR IONS ($mg\ l^{-1}$)

Station	Calcium Hardness			Magnesium Dissolved			Potassium Dissolved			Sodium Dissolved			Chloride Dissolved			Fluoride Dissolved			Silica Reactive			Sulphate Dissolved		
	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ	No. of Samples	$\bar{X}$	σ
1	11	32.3	6.8	11	6.7	1.5	11	.3	.0	11	.6	.1	11	.3	.1	11	.08	.01	11	4.5	.3	11	3.5	.7
2	12	36.8	5.4	12	7.7	1.8	12	.4	.1	12	.7	.1	12	.3	.1	11	.10	.01	12	4.8	.3	12	5.2	1.2
3	16	33.3	6.5	16	7.1	1.4	16	.3	.1	16	.7	.1	16	.3	.1	15	.09	.01	16	4.7	.4	16	4.3	1.2
4	5	14.6	3.2	5	3.5	1.1	5	.5	.0	5	1.1	.3	5	.3	.1	5	.05	.01	5	4.9	.5	5	6.2	2.6
5	5	23.1	7.7	5	4.9	2.0	5	.3	.0	5	.6	.1	5	.3	.0	5	.08	.02	5	4.1	.2	5	3.5	1.0
6	3	35.5	5.8	3	7.7	1.4	3	.5	.0	3	1.1	.3	3	.4	.1	3	.09	.01	3	4.9	.3	3	6.6	1.5
7	5	38.8	2.7	5	7.7	.7	5	.3	.1	5	.6	.0	5.	.3	.1	5	.10	.01	5	4.8	.2	3	4.6	.5
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	4	20.4	3.5	4	4.8	1.4	4	.3	.0	4	.8	.1	4	.2	.0	4	.06	.01	4	5.4	.1	4	3.1	.9

IX ALGAL DATA

The detailed algal data not found in this interpretative report can be obtained in the Flathead River Basin data report (Sheehan *et al.* in preparation).

A. Periphytic Algae

1. Biomass

a) Chlorophyll *a* determined Biomass:

Chlorophyll *a* estimates of algal biomass differed greatly depending on the sampling methodology used (see methods section). Chlorophyll *a* (mass per unit area) estimates based upon subsamples from rocks (Stockner Armstrong sampler) were always higher than estimates obtained from sampling entire rocks and results must be interpreted with care (Figure 15, 16). Most probably those regions on the rocks with densest algal growth were unknowingly selected when using the Stockner Armstrong sampler. Chlorophyll *a* levels obtained from entire rocks were usually less than 1.0 mg m^{-2} (Figure 15). These values are extremely low and closely comparable to values found in ultra oligotrophic systems such as Carnation Creek on Vancouver Island where chlorophyll *a* values in non-estuary regions averaged 1.9 mg m^{-2} (Stockner and Shortreed 1975). On site observations indicated that algal growth in the Flathead Basin was quite patchy both between rocks and on individual rocks. Occasional high chlorophyll *a* levels from entire rocks (once at stations 5 and 2) were not duplicated in replicate samples and appear to represent rocks that had unusually high algal growth. These values were less than 20 mg m^{-2} and still indicative of oligotrophic waters (values in oligotrophic, Lake Superior range from 14.9 - 73.5 mg m^{-2}; Stokes *et al.* 1970).

Chlorophyll *a* values obtained from subsamples off rocks exhibited some variability within the Flathead River Basin. Chlorophyll *a*

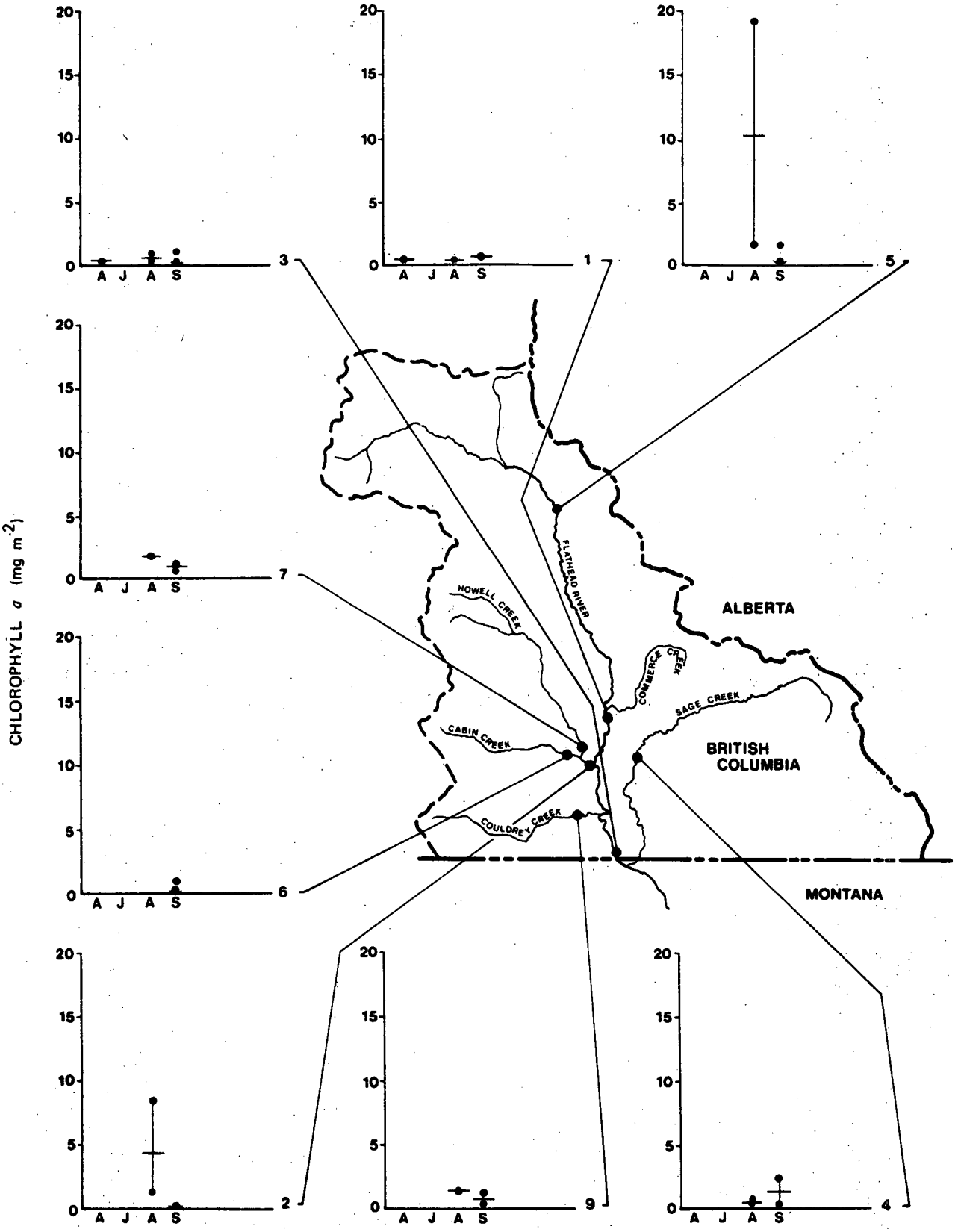

Fig. 15 Regional and seasonal variations in the amount of chlorophyll *a* attached to rock substrates (entire rock sampled) at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Solid circles represent chlorophyll values from single samples, circles with downward pointed arrows represent below detection limit values; horizontal lines represent mean values.

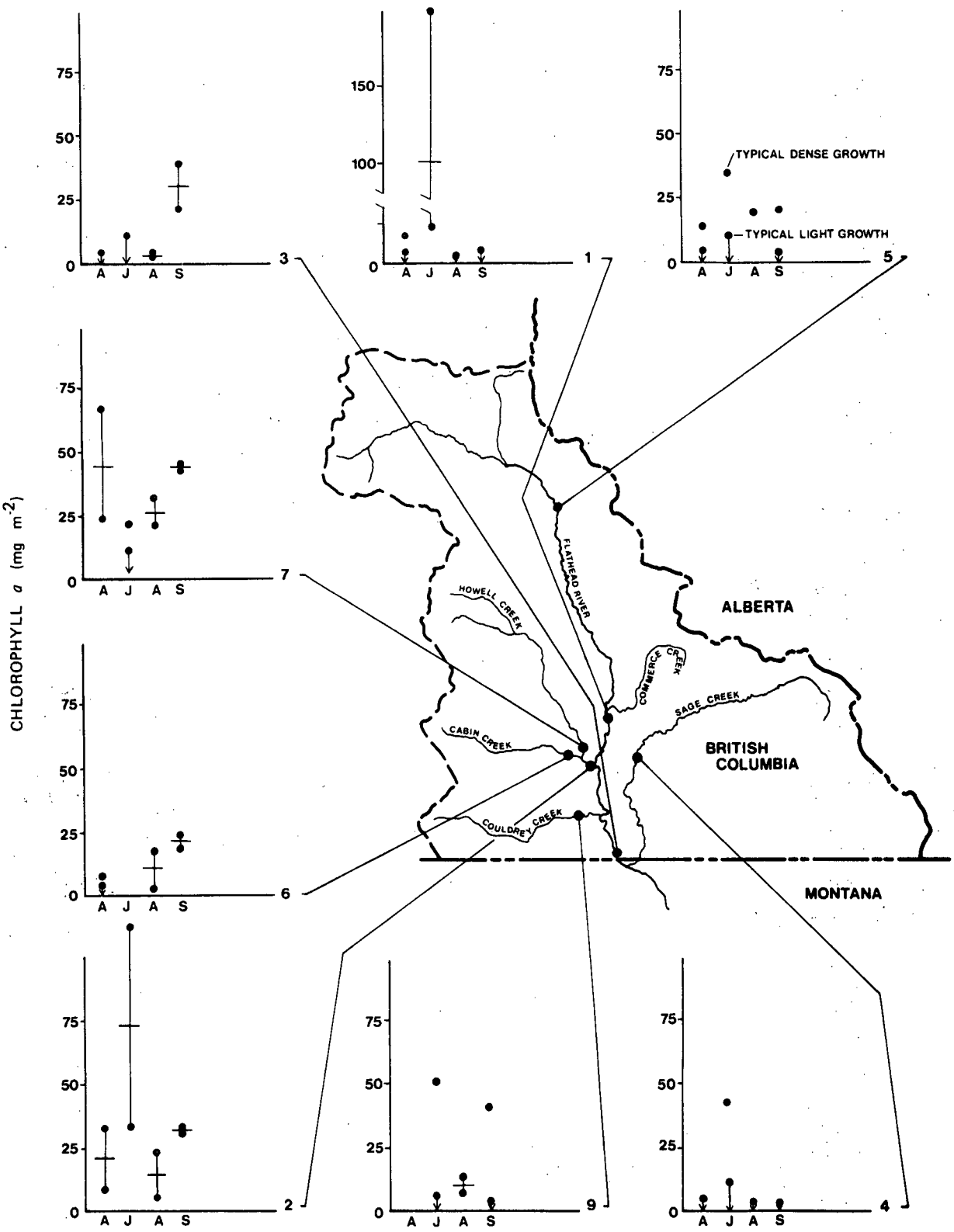

Fig. 16 Regional and seasonal variations in the amount of chlorophyll *a* attached to rock substrates ("SA scraped rocks") at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Solid circles represent chlorophyll values from single samples, circles with downward pointed arrows represent below detection limit values; horizontal lines represent mean values.

levels were generally highest in Howell Creek at stations 2 and 7. Dissolved phosphorus levels, during non-freshet periods, were often slightly higher at these stations than elsewhere, and probably permitted denser algal populations to develop on selected areas of the rocks in Cabin and Howell Creeks. Chlorophyll *a* levels were only occasionally high on the mainstem Flathead River and at station 9 located on Couldrey Creek.

b) Organic Biomass

Organic biomass (ash free dry weight) estimates of community biomass also indicated that the Stockner Armstrong subsampling method selected for areas of densest biomass on single rocks (Figures 17, 18). Biomass measured by this method tended to be higher than comparable chlorophyll *a* estimates of biomass. Any contamination in the samples such as organic sediment, leaf litter, or invertebrates would of course, result in an exaggerated estimate of algal organic biomass but would not affect chlorophyll *a* estimates. Generally organic biomass values were below 3.0 mg cm^{-2} , indicative of unenriched, low nutrient water (Pitcairn and Hawkes 1973; Northcote *et al.* 1975) but certainly above values found in ultra oligotrophic waters (Stockner and Shortreed 1975). Trends in organic biomass did parallel chlorophyll *a* trends with the highest biomasses being found at stations 2 and 7 in the Cabin-Howell Creek region. Also, station 5 on the mainstem Flathead River, had dense algal growths during August.

2. Chemical Composition

a) Nitrogen and Phosphorus:

During September algal samples were taken and the nutrient composition of the cells analysed. Nitrogen content varied from 17 - 41 µg N mg^{-1} dry weight algae (Table 22), with a mean value of 29 µg N mg^{-1} algae. Highest nitrogen levels occurred in the Cabin-Howell Creek region and were usually measured in *Nostoc verrucosum*, a blue-green alga that can fix nitrogen gas (a complete list of the algal

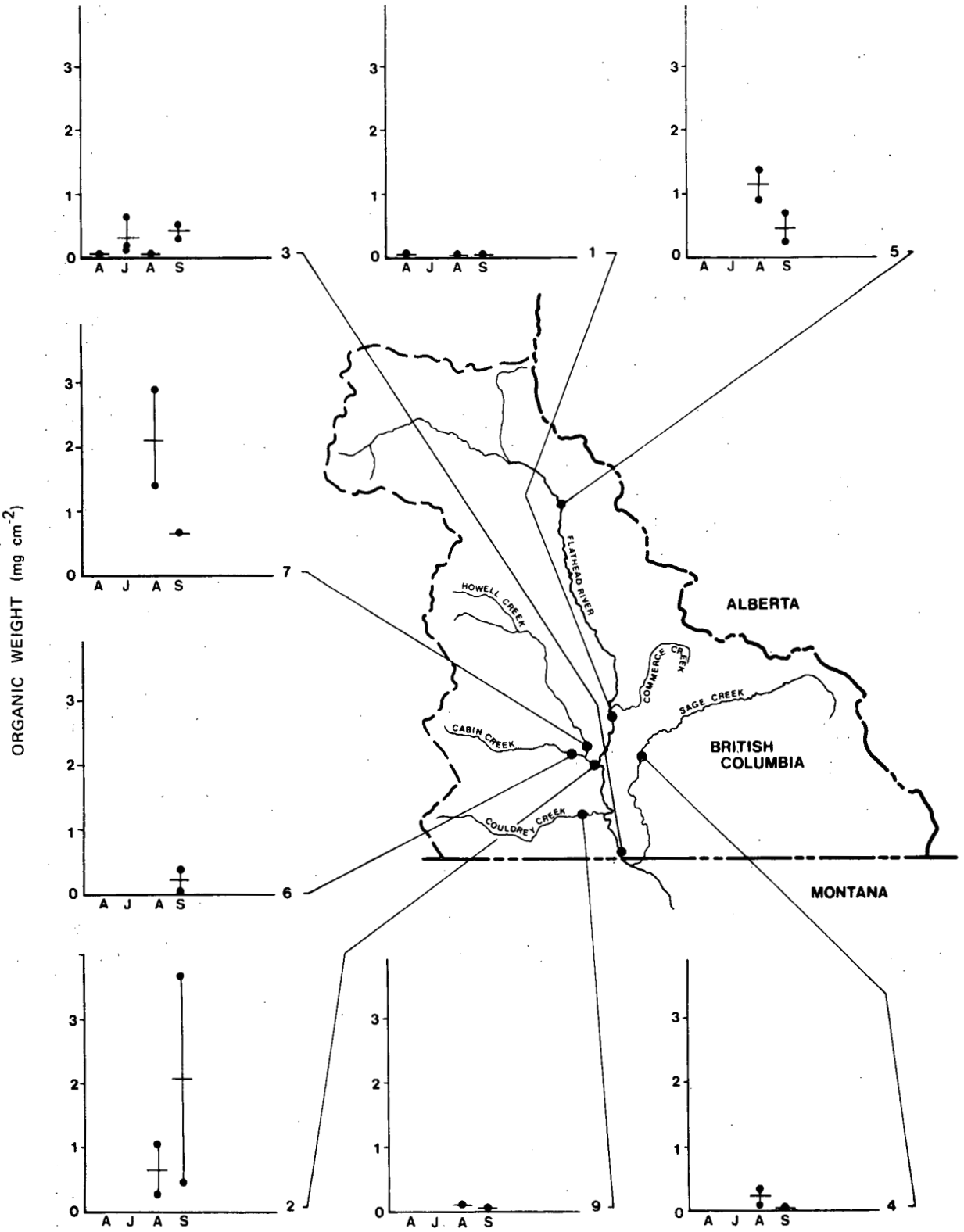

Fig. 17 Regional and seasonal variations in the amount of organic weight attached to rock substrates (entire rock sampled) at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Solid circles represent organic weight values from single samples; horizontal lines represent mean values.

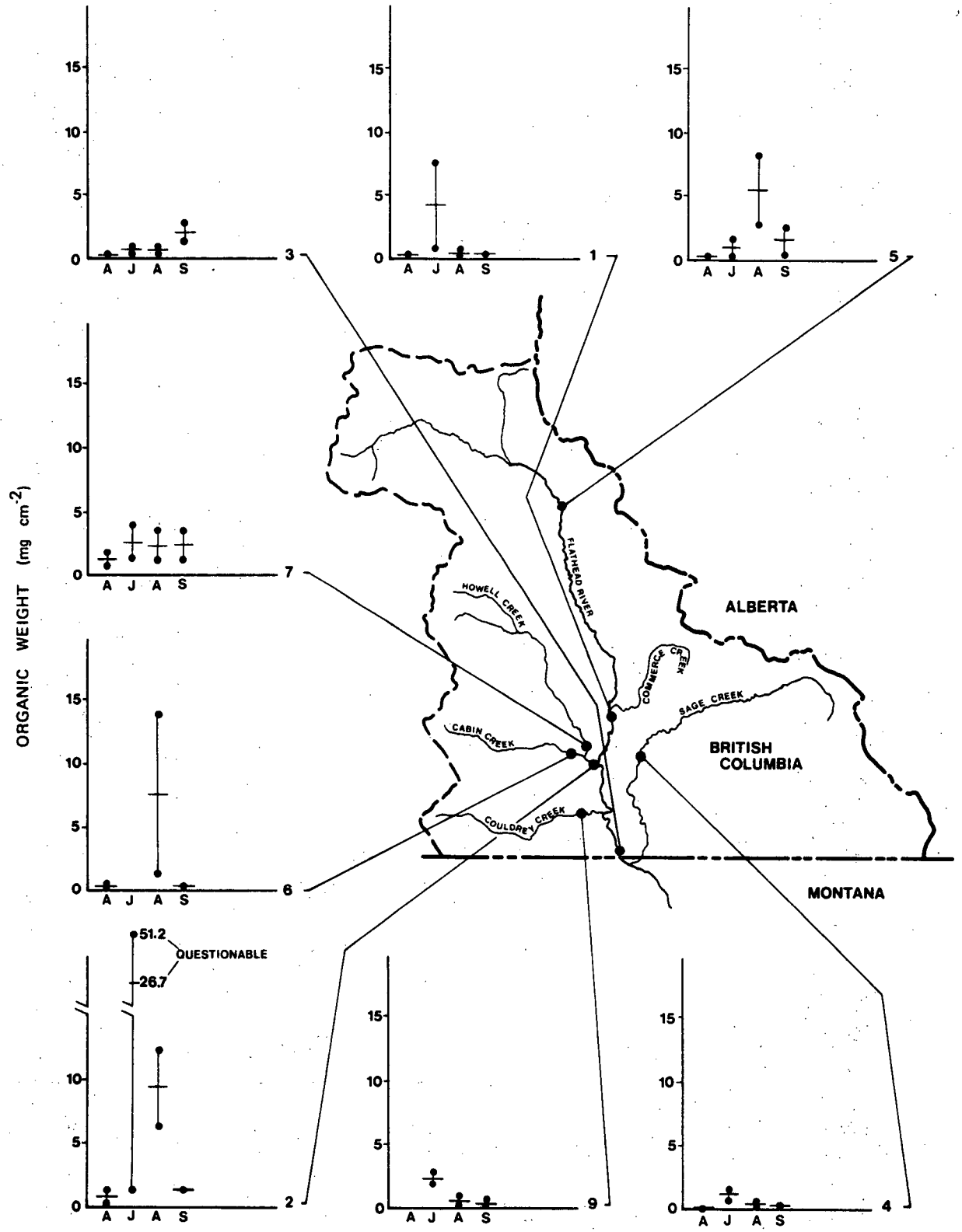

Fig. 18 Regional and seasonal variations in the amount of organic weight attached to rock substrates ("SA scraped rocks") at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Solid circles represent organic weight values from single samples; horizontal lines represent mean values.

TABLE 22 TOTAL NITROGEN AND TOTAL PHOSPHORUS CONTENT OF PERIPHYTIC ALGAL SAMPLES COLLECTED IN THE FLATHEAD RIVER BASIN DURING SEPTEMBER, 1976

Station	Sample No.	Dominant Phyla or Class	Dominant alga(e) and Percent Abundance		Total N[1.]	Total P[2.]	N:P ratio
1	C-500	Bacillariophyceae Chlorophyta	*Cocconeis pediculus* *Closterium sp.*	99% 1%	29	1.6	18
2	C-501	Cyanophyta Chlorophyta	*Nostoc verrucosum* *Stigeoclonium*	99% 1%	41	1.5	28
2	C-502	Chlorophyta	*Stigeoclonium sp.* *Closterium sp.*	100% trace	26	1.1	23
3	C-503	Chlorophyta Bacillariophyceae	*Mougeotia sp.* *Cocconeis pediculus*	65% 35%	29	0.4	66
3	C-504	Chlorophyta	*Ulothrix zonata*	100%	20	0.8	24
5	C-505	Chlorophyta	*Ulothrix zonata*	100%	27	1.1	25
6	C-506	Chlorophyta Bacillariophyceae	*Monostroma sp.* *Cocconeis pediculus*	98% 2%	42	3.8	11
7	C-507	Cyanophyta	*Nostoc verrucosum*	100%	34	1.4	24
7	C-508	Chlorophyta	*Ulothrix zonata*	100%	17	1.6	11
9	C-509	Chlorophyta	*Monostroma sp.*	100%	32	1.9	17

1. µg N mg^{-1} dry wt. algae
2. µg P mg^{-1} dry wt. algae

species involved in these analyses is presented in Table 22). Phosphorus content averaged 1.5 μg P mg^{-1} dry weight algae (Table 22). Both nitrogen and phosphorus content fall within the range reported in the literature (Healey 1973). However, both nitrogen and phosphorus content are low compared to most other reports (typical literature N content is 55 μg N mg^{-1} for algae, typical literature P content is 11 μg P mg^{-1} for algae). This suggests that algae in the Flathead Basin are limited in growth by low nutrient levels.

The ratio of nitrogen to phosphorus (N:P ratio) also provides valuable information on factors affecting algal growth. The literature indicates that average cellular N:P ratios are approximately 5:1 (Healey 1973), although this ratio can change dramatically depending upon the physiological state of the plants (Kistritz 1979). Most values in the Flathead Basin were over 20:1 indicating that populations are low in phosphorus and perhaps phosphorus limited.

b) Excess Stored Phosphorus:

Algae store excess phosphorus in their vegetative cells for use when exogenous phosphorus is limiting (Fitzgerald and Nelson 1966; Stewart and Alexander 1971). All values in the Flathead Basin were below a level of 1.0 μg mg^{-1} dry weight algae (Table 23), considered indicative of phosphorus limited populations (Fitzgerald 1969).

3. Algal Phyla Abundance and Succession

The attached algal flora consisted of blue-green algae (Cyanophyta), green algae (chlorophyta), diatoms (Chrysophyta - Bacillariophyceae), as well as algae belonging to the Chrysophyta classes - Chrysophyceae and Xanthophyceae.

There was a marked succession in the abundance of the major algal groups that formed the Flathead Basin flora. Diatoms, for instance,

TABLE 23 EXCESS STORED PHOSPHORUS CONTENT OF PERIPHYTIC ALGAL SAMPLES COLLECTED IN THE FLATHEAD RIVER BASIN DURING SEPTEMBER, 1976

Station	Sample No.	Dominant Phyla or Class	Dominant Alga(e) and Percent Abundance		Excess Stored Phosphorus (µg P mg^{-1} dry wt. algae)
1	C-500	Bacillariophyceae Chlorophyta	*Cocconeis pediculus* *Closterium sp.*	99% 1%	0.46
2	C-501	Cyanophyta Chlorophyta	*Nostoc verrucosum* *Stigeoclonium sp.*	99% 1%	0.84
2	C-502	Chlorophyta	**Stigeoclonium sp.* *Closterium sp.*	100%	0.56
3	C-503	Chlorophyta Bacillariophyceae	*Mougeotia sp.* *Cocconeis pediculus*	65% 35%	0.27
3	C-504	Chlorophyta	*Ulothrix zonata*	100%	0.19
5	C-505	Chlorophyta	*Ulothrix zonata*	100%	0.16
6	C-506	Chlorophyta Bacillariophyceae	*Monostroma sp.* *Cocconeis pediculus*	98% 2%	0.97
7	C-507	Cyanophyta	*Nostoc verrucosum*	100%	0.48
7	C-508	Chlorophyta	*Ulothrix zonata*	100%	0.41
9	C-509	Chlorophyta	*Monostroma sp.*	100%	0.41

**Stigeoclonium* is the dominant species.

were generally dominant in April, the Chrysophycean alga *Hydrurus foetidus* was important in June while green algae were volumetrically important in August and September (Figures 19, 20). Blue-green algae were sometimes abundant in April or in August and September. If samples are collected in future years the inherent periodicity of the algal groups should be considered when interpreting the results. It should be noted that samples collected either by subsampling rocks or by scraping entire rocks generally showed comparable results (Figures 19, 20).

Besides the seasonal pattern there were also distinct spatial variation in the distributions of the algal phylas. In the Cabin-Howell Creek area (stations 6, 2 and 7) blue-green algae were much more abundant than elsewhere in the Basin. This was primarily due to the abundance of the large colonial blue-green alga *Nostoc verrucosum*. The denser algal biomasses in the Cabin-Howell Creek region (Figures 15 - 18) are also associated with this large blue-green alga. Couldrey Creek also had periods of *Nostoc verrucosum* dominance. Blue-green dominance in Sage Creek were not associated with *Nostoc* but occurred instead at a time when community biomasses and abundancies of other algal phylas were particularly low.

4. Species Composition

a) Green Algae

Ten species of green algae were identified in the periphytic algae of the Flathead Basin (Table 24). In addition, one other green alga, *Haematococcus* sp. was in the water-filled rock pools alongside the upper reaches of Cabin Creek. Although several green algal species were often present in individual samples, only *Ulothrix zonata*, *Stigeoclonium* sp., or *Monostroma* sp. were volumetrically important.

Both *Ulothrix zonata* and *Stigeoclonium* sp. were widespread in their distribution in the Flathead Basin. The distribution and abundance of *U. zonata* the most common of the two algae is illustrated in

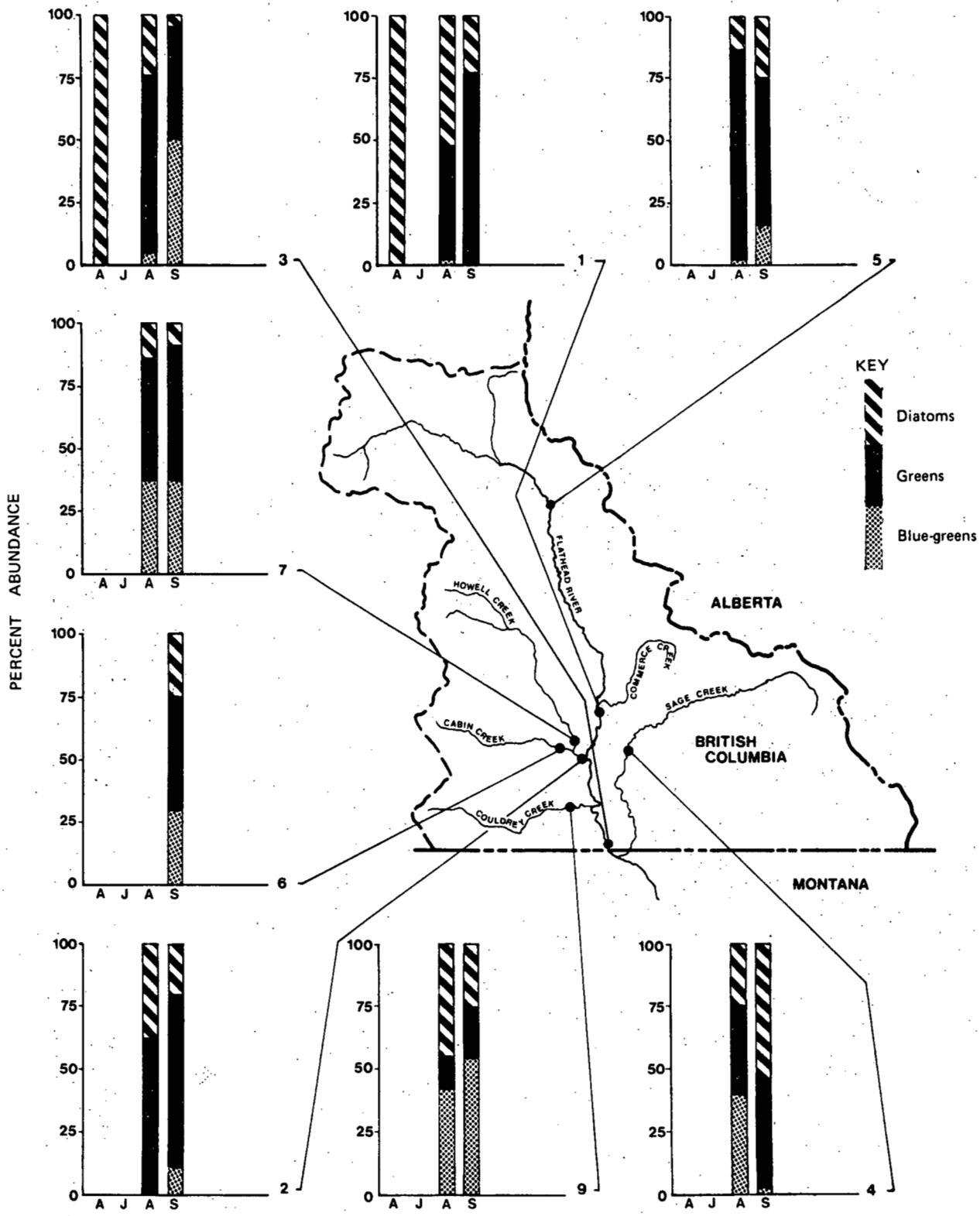

Fig. 19 Regional and seasonal variations in the average percentage abundance (by volume) of diatoms, green algae, and blue-green algae attached to rock substrates (entire rock sampled) at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Vertical bars represent mean percentage abundancies of two samples from different rocks.

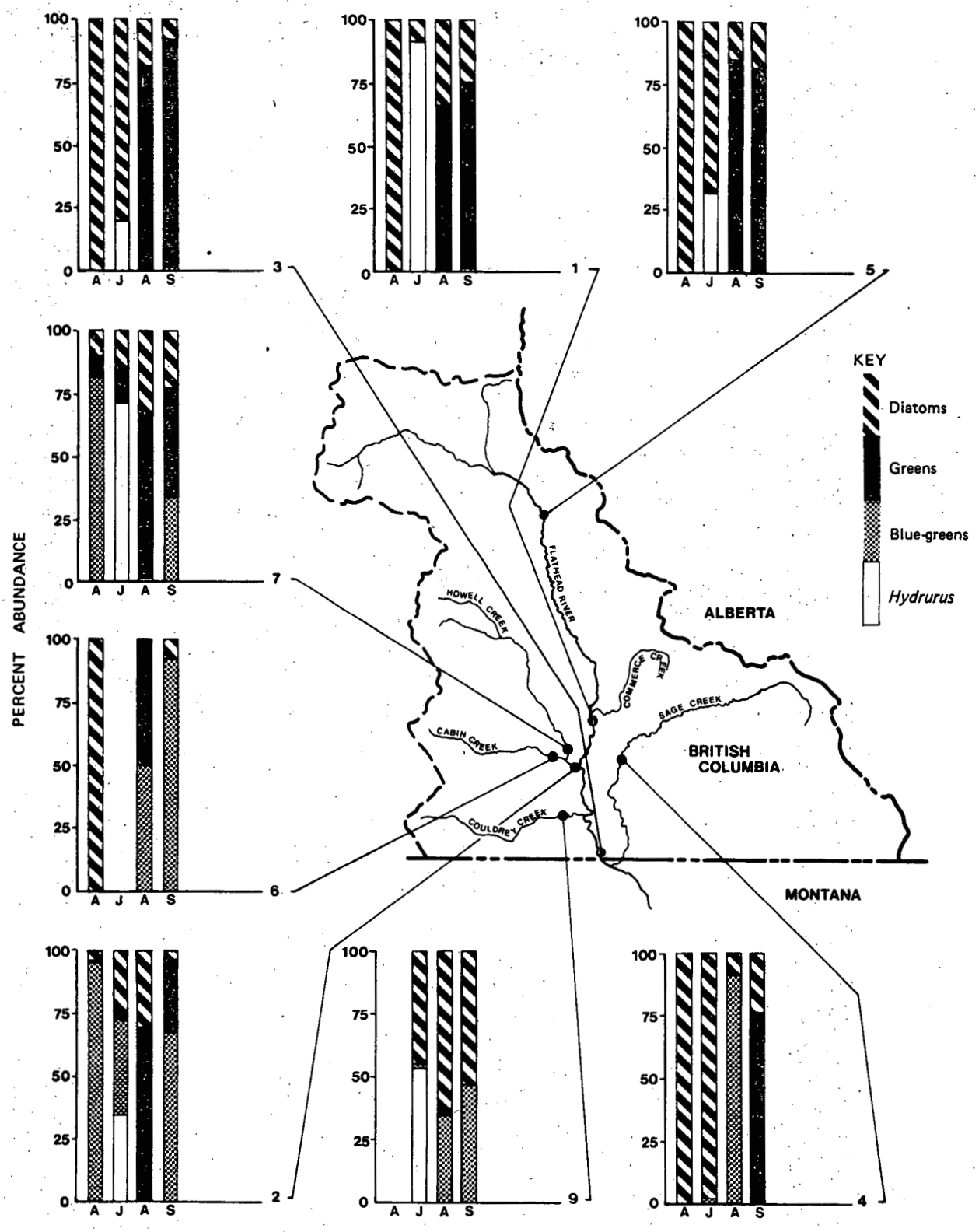

Fig. 20 Regional and seasonal variations in the average percentage abundance (by volume) of diatoms, green algae, blue-green algae and Chrysophyceae (*Hydrurus*) attached to rock substrates at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Vertical bars represent mean percentage abundances of two samples from different "SA scraped" rocks.

TABLE 24 A list of the Cyanophyta, Chlorophyta, Chrysophyceae and Xanthophyceae species occurring in the periphyton of the Flathead River Basin, 1976.

Species	Occurrence		
	Entire rocks	SA rocks	Plexiglass
Cyanophyta			
Lyngbya spp.	x	x	x
Microcystis sp.	x		
Nostoc verrucosum Vaucher	x	x	
Oscillatoria spp.	x	x	x
Raphidiopsis - like	x		x
Rivularia sp.	x		
Tolypothrix sp.	x	x	
Unidentified species			x
Unidentified Chrococcales species	x		
Chlorophyta			
Closterium sp.	x	x	x
Haematococcas sp. (in rock pools)			
Microspora			x
Monostroma sp.		x	
Mougeotia			x
Spirogyra sp.			x
Stigeoclonium sp.	x	x	x
Tetraspora sp.			x
Ulothrix sp.		x	x
Ulothrix zonata (Ubber & Mohr) Kutz.	x	x	x
Unidentified filament			x
Chrysophyta - Chrysophyceae			
Hydrurus foetidus (Vill.) Trev.		x	x
Chrysophyta - Xanthophyceae			
Tribonema sp.			x

Figure 21. This species is frequently found in cold streams (Prescott 1962) and in the Flathead Basin was present at all sample stations.

Monostroma sp. was restricted in distribution to Cabin and Howell Creeks (stations 6 and 2) and to Couldrey Creek (station 9). The freshwater species of *Monostroma* are found in alpine and subalpine streams around the world (Parker *et al.* 1973). In the Flathead system it was most common at station 6 in the upper reaches of Cabin Creek, a high altitude location where the creek consisted of a series of cataracts. At this sampling location *Monostroma* sp. was often the only alga in large sections of the river. (Near the edge of the creek *Monostroma* sp. occurred with *Nostoc verrucosum* and some species of diatoms.) In the United States, Parker *et al.* (1973) report the occurrence of *Monostroma quaternarium* (Kutz.) Desmaz. in streams draining into the Middle Fork of the Flathead River. In this U.S. section of the Flathead Basin *Monostroma quaternarium* grows best in cold running semi-shaded streams (such as Cabin Creek, station 6), although it will tolerate a wider range of light intensity. *Monostroma* also has an apparent preference for iron-rich (and perhaps sulphide-rich) locations (Parker *et al.* 1973).

b) Blue-Green Algae

Nine species of blue-green algae were identified from the periphytic flora of the Flathead Basin (Table 24). Most species were widespread in distribution but rare in numbers. However, *Nostoc verrucosum* was most abundant at the Cabin-Howell Creek locations (stations 6, 7 and 2) where the flora was sometimes composed entirely of this species of *Nostoc* (Figure 22). *Nostoc verrucosum* was also abundant in Couldrey Creek. It was generally not encountered in the mainstem Flathead River except for occasional populations growing at stations 3 and 5. It was never found at station 4 in Sage Creek. *Nostoc verrucosum* grows on rocks and stones in several rivers (Huber-Pestalozzi,

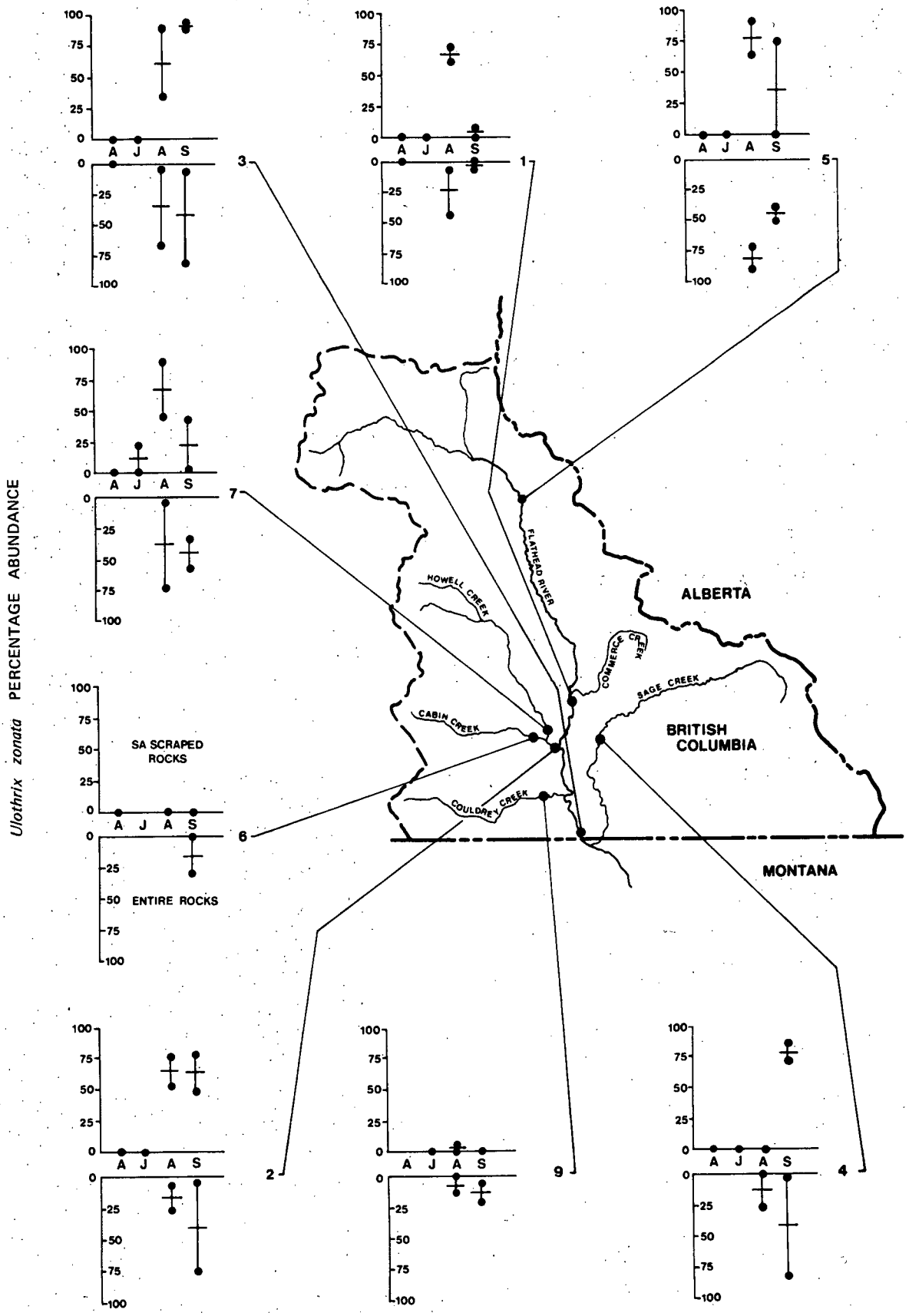

Fig. 21 Regional and seasonal variations in the percentage abundance of *Ulothrix zonata* attached to rock substrates at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Top half of graphs represent "SA scraped" samples while bottom half represents "entire rock" samples. Solid circles represent abundances from single samples; horizontal lines represent mean values.

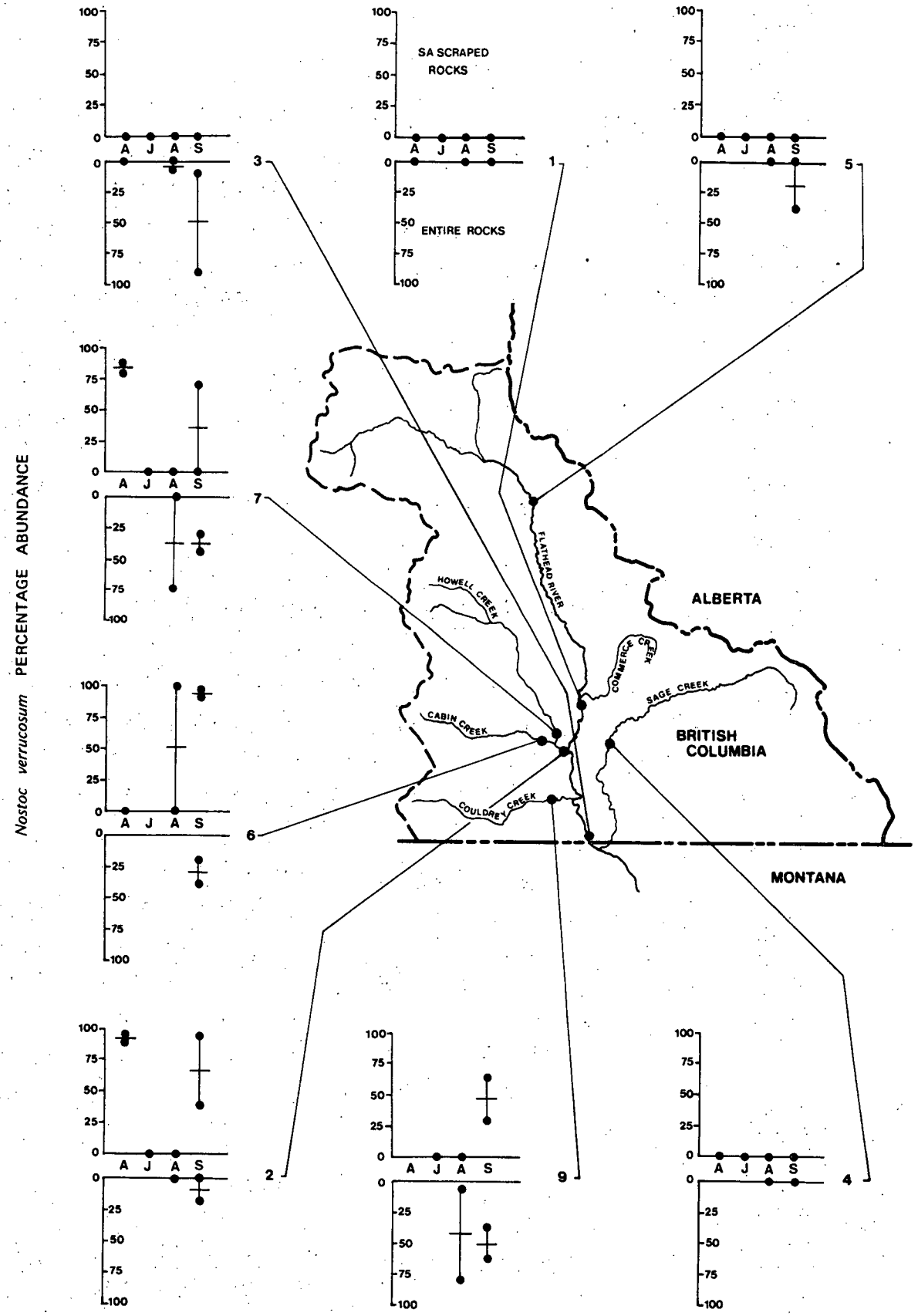

Fig. 22 Regional and seasonal variations in the percentage abundance of *Nostoc verrucosum* attached to rock substrates at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Top half of graphs represent "SA scraped" samples while bottom half represents "entire rock" samples. Solid circles represent abundances from single samples; horizontal lines represent mean values.

1938) and has a number of adaptations which allow it to flourish in low nutrient, oligotrophic waters. Like other *Nostoc* species *N. verrucosum* has the ability to fix atmospheric nitrogen. Also, *N. verrucosum* can accumulate phosphate from the environment much faster than other species of *Nostoc* and the ratio of phosphorus in *N. verrucosum* to phosphorus in water is highest in water containing the least amount of phosphorus (Whitton 1967). Whitton (1967) suggests that the presence of *N. verrucosum* in British waters with low phosphorus values (2 - 3µg l^{-1}) is related to the alga's ability to accumulate phosphorus.

c) Non-Diatom Chrysophytes

Only two non-diatom chrysophytes were identified, *Tribonema* sp. (Xanthophyceae) was found once growing on a plexiglass plate. The other species, *Hydrurus foetidus* (Chrysophyceae), was very common in June but not present at any other time. During June *H. foetidus* was generally the most abundant alga in the Flathead Basin; Sage Creek (station 4) being the only site without *H. feotidus* (Figure 23). *Hydrurus foetidus* is also reported growing in subalpine streams draining into the U.S. portion of the Flathead River (Parker *et al.* 1973). Although *H. foetidus* prefers high light intensities (Parker *et al.* 1973) the major factor regulating *H. foetidus* is water temperature. It is found in cold, usually mountainous, streams throughout the world (Stein 1975; Bourrelly 1974; Levadnaya and Kuz'mina 1974; and Squires *et al.* 1973). Parker *et al.* (1973) also report that *H. foetidus* prefers pH 6.4 - 8.0 and waters which flow over igneous or non-calcareous rock.

d) Diatoms

Diatoms were present in almost every sample and were therefore examined in detail. The diatom species were identified to the species or variety level and cell counts performed. The following sections present results in terms of diatom cell numbers, numbers of

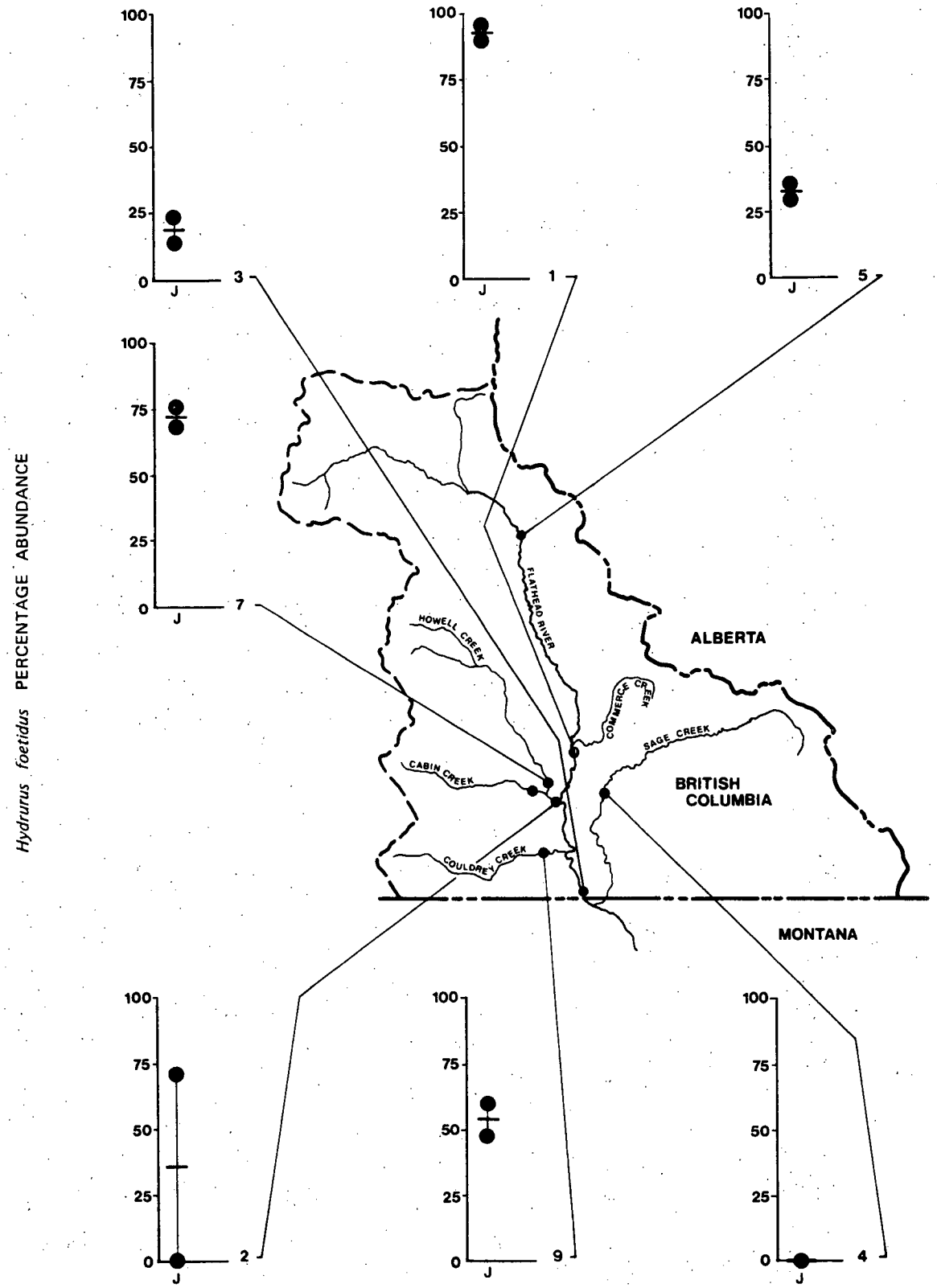

Fig. 23 Regional variations in the percentage abundance of *Hydrurus foetidus* attached to rock ("SA scraped") substrates at an approximate depth of 0.5m in the Flathead River Basin, during June, 1976. Solid circles represent abundances from single samples; horizontal lines represent mean values.

species, Shannon-Wiener diversity indicies, species composition and distributions.

i) diatom cell numbers

As noted for chlorophyll *a* and organic weights there were more diatoms (up to 15 x 10^6 diatoms per cm^2) in collections obtained by subsampling rocks (Figure 24) than in collections where the entire rock (Figure 25) was sampled (maximum of 1.5 x 10^6 diatoms per cm^2). It appears that the subsampling method overestimates biomass as determined by diatom cell numbers. Results from entire rocks are similar to diatom cell counts obtained from natural substrates in other oligotrophic waters although wide-ranging literature reports make it hard to be conclusive about the trophic status of the Flathead Basin. The numbers reported here are, for instance, less than those reported by Douglas (1958) from a nutrient-poor English stream but comparable to values in the nutrient rich but turbid Fraser River (Northcote *et al.* 1975). Physical factors such as turbidity also regulate diatom numbers making it difficult to relate algal biomass directly to nutrient status of rivers.

ii) diatom diversity

The number of diatom species identified per sample ranged from 2 to 25 species. Number of diatom species were also comparable in either subsampled or entirely sampled rocks (Figures 26 and 27). The number of species (and cell numbers) seen were least in April at the start of freshet when the river was cold and turbid. Greatest diversity was observed in August and September. There appeared to be little regional variation in diversity except for the reduced number of species at the Sage Creek station. Results are not easily comparable to other studies since the numbers of species identified is related to the effort spent in enumerating individual samples (see method section).

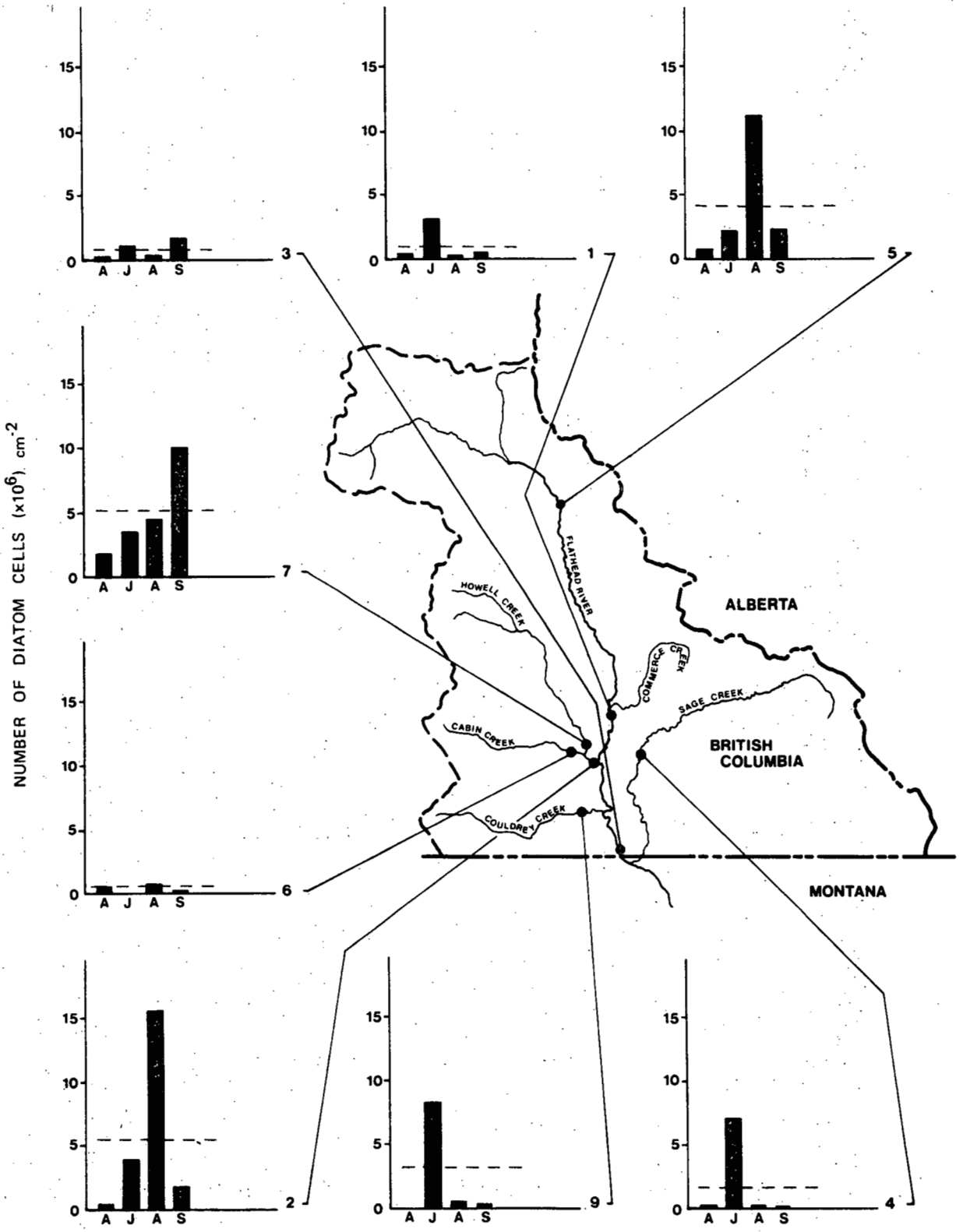

Fig. 24 Regional and seasonal variations in the average number of diatom cells (x 10^6) attached to rock substrates taken from an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Vertical bars represent mean numbers of two samples from different "SA scraped" rocks; horizontal dashed lines represent the grand mean during the entire sampling period.

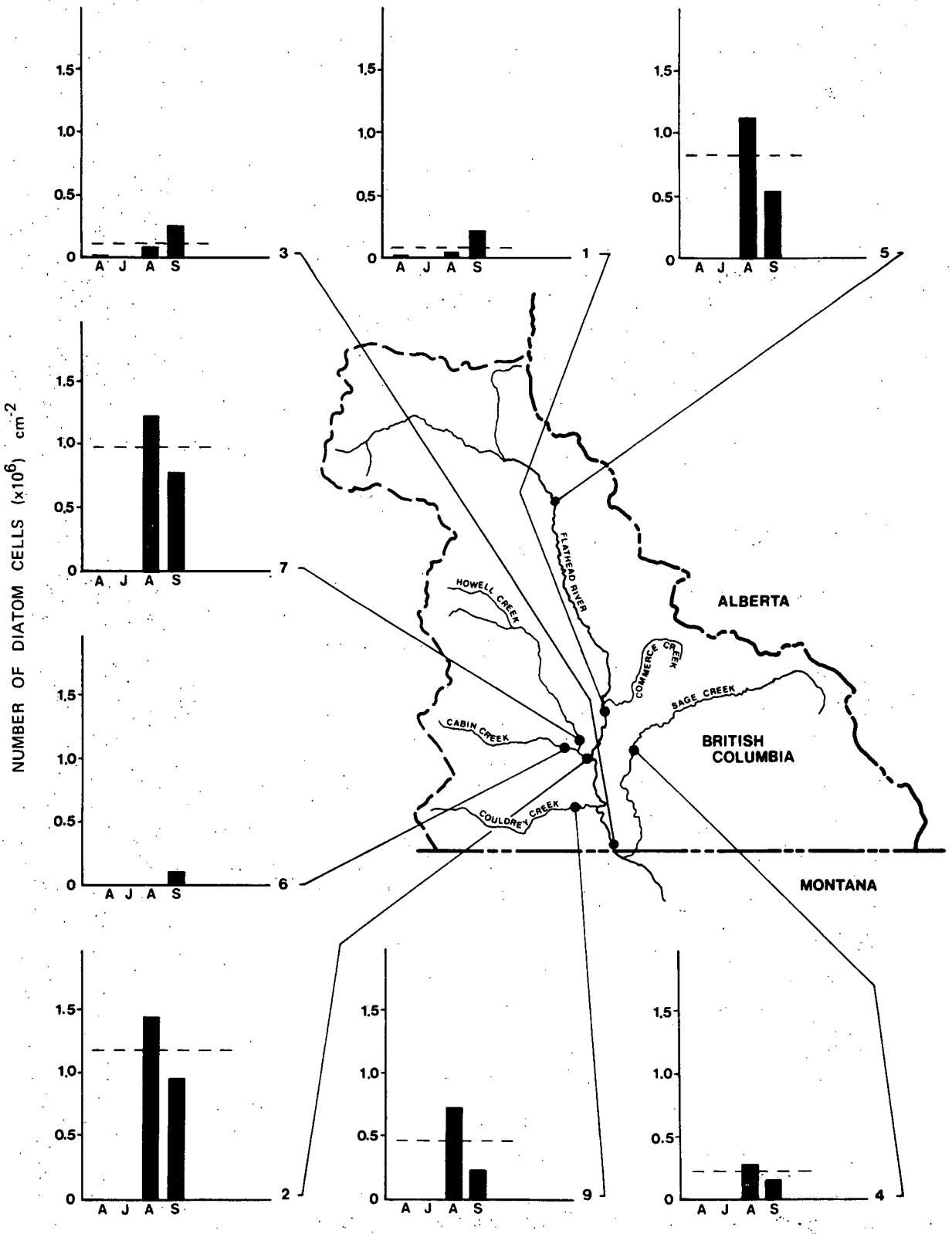

Fig. 25 Regional and seasonal variations in the average number of diatom cells (x10^6) attached to rock substrates (entire rock sampled) taken from an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Vertical bars represent mean numbers of two samples from different rocks; horizontal dashed lines represent the grand mean during the entire sampling period.

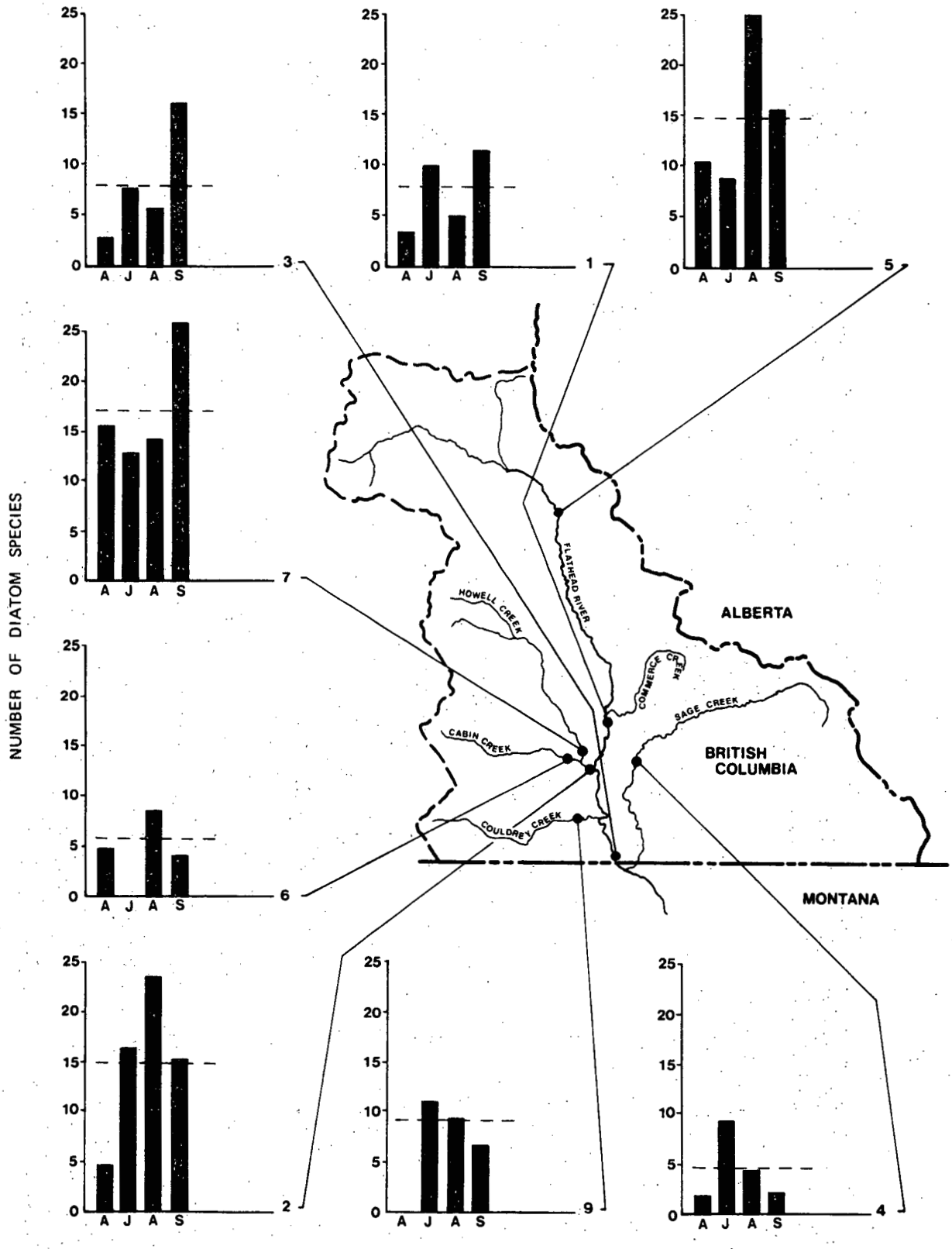

Fig. 26 Regional and seasonal variations in the average number of diatom species attached to rock substrates at approximately 0.5m in the Flathead River Basin, April - September, 1976. Vertical bars represent mean number of species of two samples from different "SA scraped" rocks; horizontal dashed lines represent the grand mean during the entire sampling period.

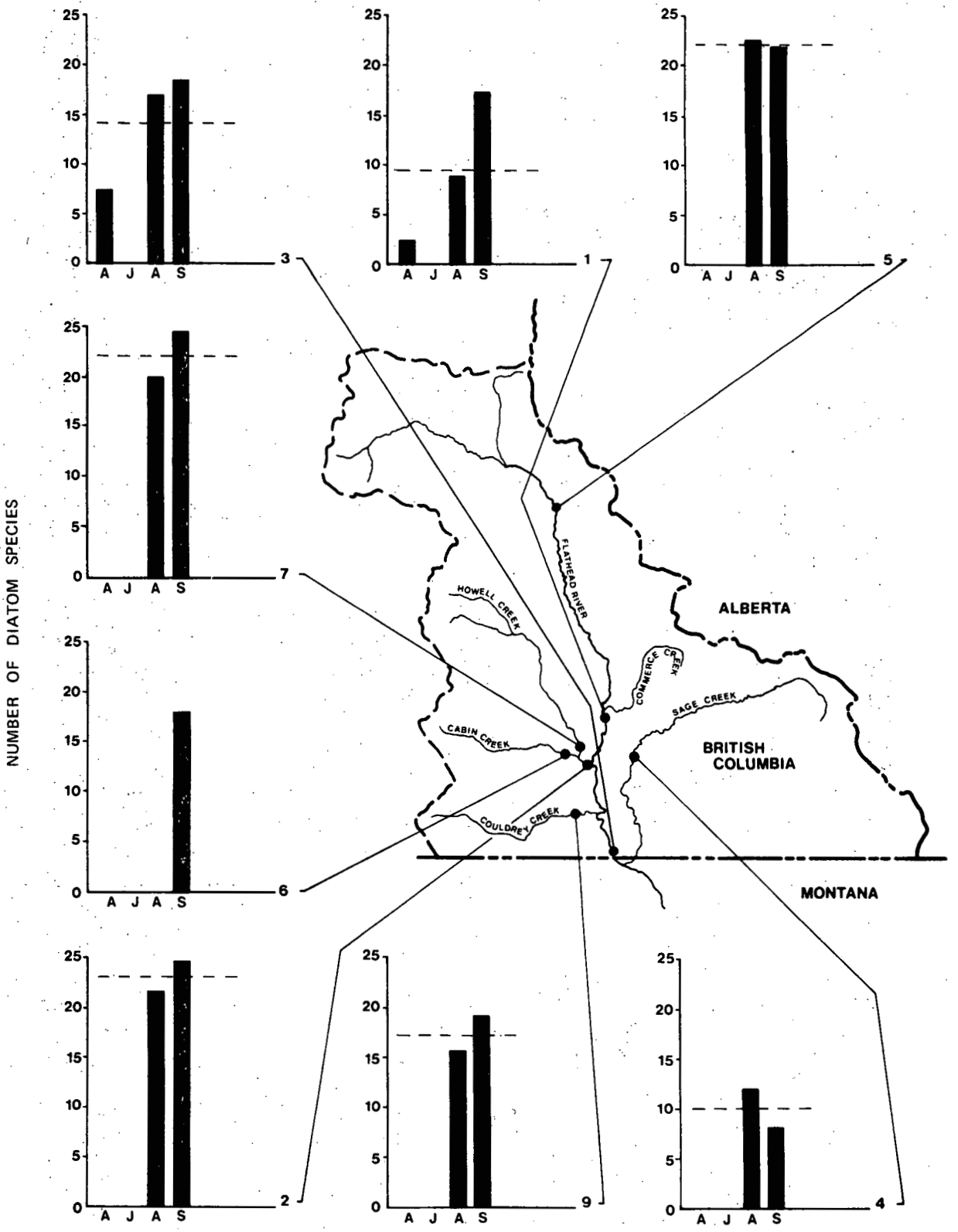

Fig. 27 Regional and seasonal variations in the average number of diatom species attached to the rock substrates (entire rock sampled) taken from an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Vertical bars represent mean number of species of two samples from different rocks; horizontal dashed lines represent the grand mean during the entire sampling period.

A measure of diatom species diversity which depends on both the number of taxa and abundance of individuals within each taxa was also calculated. This index, called the Shannon-Wiener function (see section VII page 31 for the mathematical formula) produces results that are easily compared with other studies. The sampling effort has less influence on the results because increases in the number of rare species are offset by the greater abundance of individuals in the common species. The diversity values range from below 1 for low diversity often in polluted waters (Weber 1973) to values as high as 3 or 4 in unpolluted waters.

In the Flathead Basin diversities were often near 1.0 in April, at the begining of freshet, but increased to values between 2 - 4 later in the year (Figures 28 and 29). The only exception was Sage Creek which had diversities generally between 1 - 2 on rock subsamples (with slightly higher diversities from entire rocks) throught the year. The lower diversities found for Sage Creek cannot be explained. Generally, results were comparable between the two sampling methods, both sets of data reflecting the unpolluted status of the river.

iii) diatom composition

In the attached flora of the Flathead Basin there were 86 diatom species identified (Table 25). But only 28 species were dominant - made up more than 10 percent of any single sample's numeric abundance (solid circles Table 25). More diatom species (and dominant species) were observed from rock subsamples than from entire rock samples (72 versus 67) but this is probably because of the larger number of samples collected by the subsampling method. Diatoms collected on the artificial substrates are also listed in Table 25; it is interesting to note that those species also occurred on natural substrates. Furthermore, the most

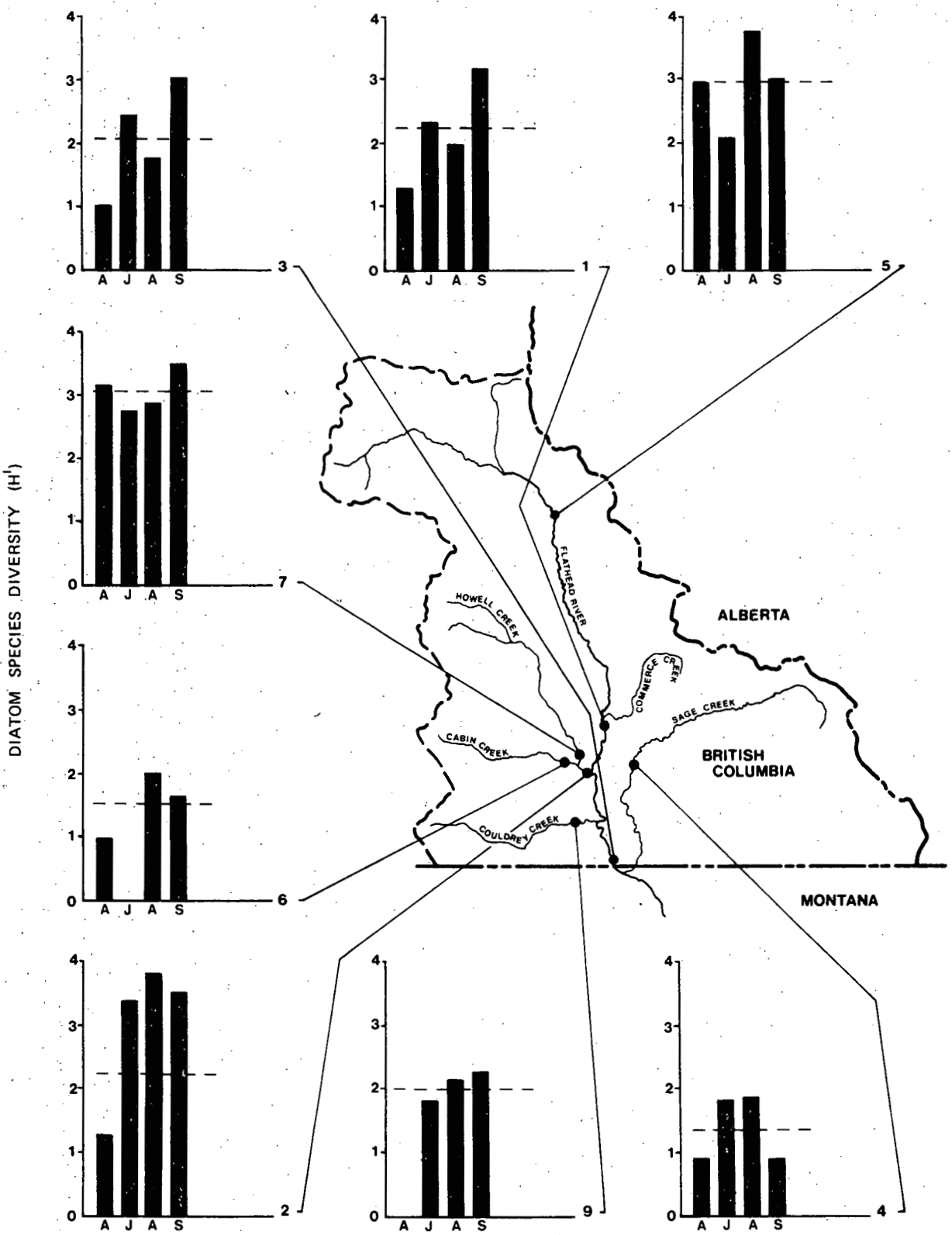

Fig. 28 Regional and seasonal variations in average diatom diversity (Shannon - Wiener function, H') of samples taken from an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Vertical bars represent mean diversities of two samples from different "SA scraped" rocks; horizontal dashed lines represent the grand mean diversity during the entire sampling period.

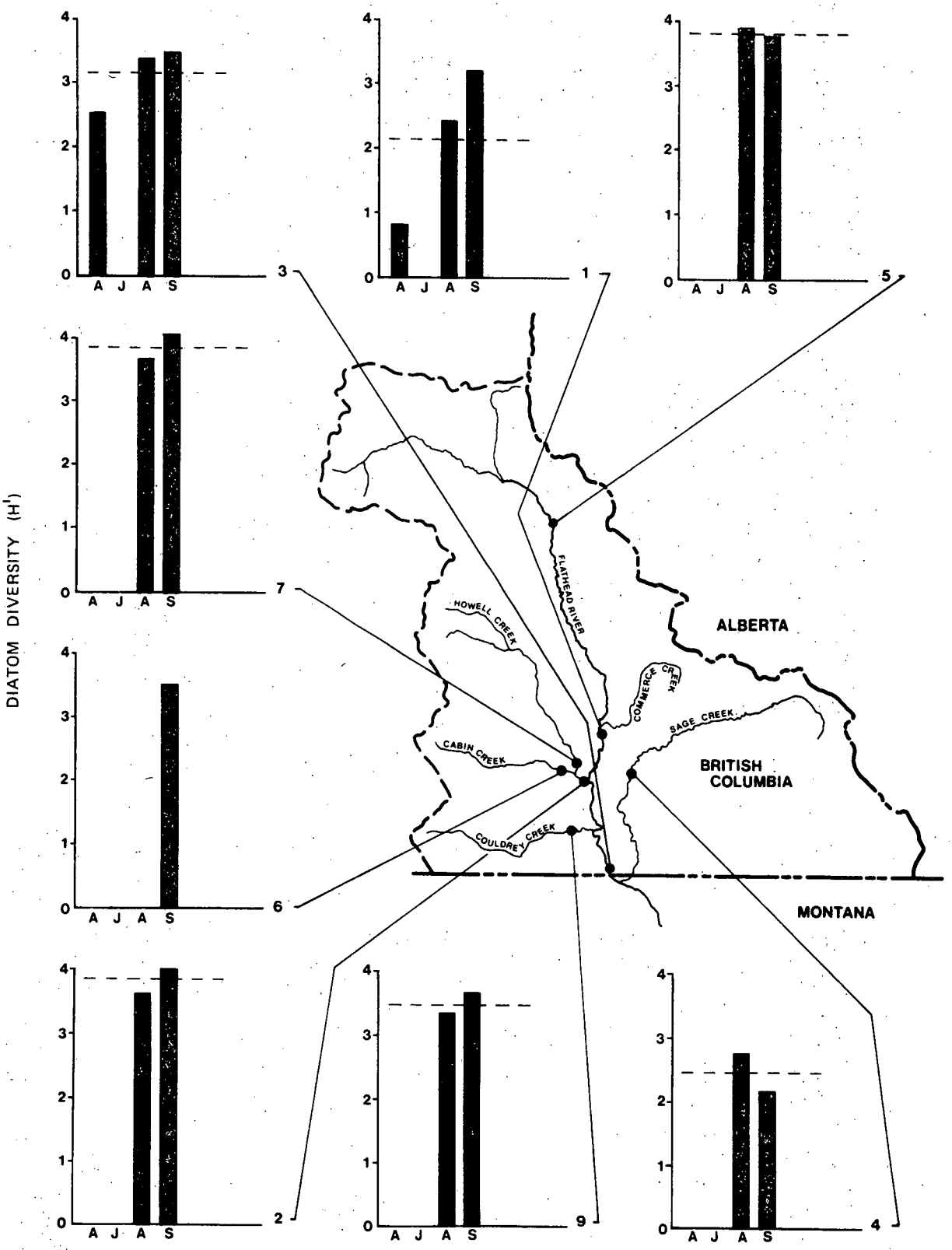

Fig. 29 Regional and seasonal variations in average diatom diversity (Shannon - Wiener function, H^1) of samples (entire rock sampled) taken from an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Vertical bars represent mean diversities of two samples from different rocks. Horizontal dashed lines represent the grand mean diversity during the entire sampling period.

Table 25 A list of the attached diatom species and their numeric occurrence on natural or artificial substrates at approximately 0.5m in the Flathead River Basin, 1976. For occurrence; open circles (o) denote a species always made up less than 10% of a sample's abundance, solid circles (●) denote that a species made up greater than 10% of at least one sample's abundance.

	Bacillariophyceae Species	Occurrence: Natural Substrates — Rock Subsamples	Natural Substrates — Whole Rocks	Artificial Substrates — Plexiglass Plates
	Coscinodiscales:			
1.	*Cyclotella* sp. A	o	o	
	Fragilariales:			
2.	*Asterionella formosa* Hass.	o		
3.	*Diatoma hiemale* (Lyngb.) Heib.	o	o	o
4.	*Diatoma hiemale* var. *mesodon* (Ehr.) Grun.	o		
5.	*Diatoma vulgare* Bory	o	●	o
6.	*Fragilaria capucina* Desm.	●	o	
7.	*Fragilaria construens* (Ehr.) Grun.		o	
8.	*Fragilaria construens* var. *binodis* (Ehr.) Grun.	o	o	
9.	*Fragilaria construens* var. *venter* (Ehr.) Grun.	o	o	o
10.	*Fragilaria leptostauron* (Ehr.) Hust.	o	o	o
11.	*Fragilaria producta* (Lagst.) Grun.		o	
12.	*Fragilaria vaucheriae* (Kutz.) Peters.	●	o	o
13.	*Hannaea arcus* (Ehr.) Patr.	●	●	●
14.	*Hannaea arcus* var. *amphioxys* (Rabh.) Patr.	●	●	
15.	*Meridion circulare* (Grev.) Ag.	●	o	o
16.	*Synedra ulna* (Nitz.) Ehr.	●	●	●
17.	*Synedra ulna* var. *impressa* Ehr.		o	
18.	*Synedra ulna* var. *oxyrhynchus* (Forti) Hust.	o	o	o
	Achnanthales:			
19.	*Achnanthes flexella* (Kutz.) Brun	o		
20.	*Achnanthes lanceolata* (Breb.) Grun.	●	●	o
21.	*Achnanthes lemmermanni* Hust.		o	
22.	*Achnanthes minutissima* Kutz.	●	●	●
23.	*Achnanthes* sp. A	o	o	o
24.	*Achnanthes* sp. B	o	o	o
25.	*Achnanthes* sp. C	o	o	
26.	*Cocconeis pediculus* Hantz.	●	●	o
27.	*Cocconeis placentula* Ehr.	●	●	●
28.	*Rhoicosphenia curvata* (Kutz.) Grun.	o	o	
	Naviculales:			
29.	*Amphipleura pellucida* (Kutz.) Kutz.	o	o	
30.	*Amphora ovalis* Kutz.	o	o	
31.	*Cymbella affinis* Kutz.	o	o	
32.	*Cymbella caespitosa* (Kutz.) Brun	●	●	●
33.	*Cymbella cistula* Hempr.	o		o
34.	*Cymbella cymbiformis* Ag.		o	
35.	*Cymbella gracilis* (Rabh.) Cl.	o		
36.	*Cymbella prostrata* (Berk.) Cl.		o	
37.	*Cymbella sinuata* Greg.	●		
38.	*Cymbella* sp. A	o		
39.	*Cymbella turgida* Greg.	o		o
40.	*Cymbella ventricosa* Kutz.	●	●	●
41.	*Diploneis ovalis* (Hilse) Cl.	o		
42.	*Frustulia rhomboides* (Ehr.) DeT.	o	o	
43.	*Frustulia rhomboides* var. *viridula* (Breb.) Cl.		o	
44.	*Gomphonema geminatum* (Lyngb.) Ag.	o	●	o
45.	*Gomphonema hebridenses* (Greg.) Her.		o	
46.	*Gomphonema herculeanum* Ehr.	o	o	o
47.	*Gomphonema intricatum* Kutz.		o	
48.	*Gomphonema lanceolatum* Ehr.	●	o	o
49.	*Gomphonema olivaceum* (Lyngb.) Kutz.	●	●	●
50.	*Gomphonema parvulum* (Kutz.) Kutz.	●	●	●
51.	*Gomphonema parvulum* var. *genuinum* May.	o	o	o
52.	*Gomphonema* sp. A	o		

Table 25 (Continued)

Bacillariophyceae Species	Occurrence: Natural Substrates — Rock Subsamples	Natural Substrates — Whole Rocks	Artificial Substrates — Plexiglass	Artificial Substrates — Plates
Naviculales: (Cont'd)				
53. *Gyrosigma spencerii* (Queck.) Griff & Heafr.	o	o		
54. *Navicula bicephala* Hust.	o	o		o
55. *Navicula cryptocephala* Kutz.	●	o		
56. *Navicula cuspidata* (Kutz.) Kutz.	o			
57. *Navicula festiva* Krasske	o			
58. *Navicula gottlandica* Grun.		o		
59. *Navicula minima* Grun.	o	o		
60. *Navicula muralis* Grun.	o	o		o
61. *Navicula pupula* Kutz.		o		o
62. *Navicula radiosa* Kutz.	o	o		o
63. *Navicula reinhardii* (Grun.) Grun.	o	o		o
64. *Navicula salinarum* var. *intermedia* (Grun.) Cl.	●	●		o
65. *Navicula* sp. A	o	o		o
66. *Navicula* sp. B	o	o		o
67. *Navicula* sp. C	o			
68. *Navicula tripunctata* (O.F. Mull.) Bory	o	●		
69. *Neidium binode* (Ehr.) Hust.		o		
70. *Neidium dubium* (Ehr.) Cl.		o		
71. *Stauroneis anceps* Ehr.	o			
72. *Stauroneis phoenicenteron* (Nitz.) Ehr.		o		
Surirellinees:				
73. *Cymatopleura solea* (Breb.) W. Sm.	o			
74. *Epithemia sorex* Kutz.	o	o		
75. *Epithemia turgida* (Ehr.) Kutz.	●	o		
76. *Nitzschia acicularis* W. Sm.	o			o
77. *Nitzschia amphibia* Grun.	o			
78. *Nitzschia angustata* (W. Sm.) Grun.	o			
79. *Nitzschia dissipata* (Kutz.) Grun.	●	●		●
80. *Nitzschia frustulum* (Kutz.) Grun.	o	●		o
81. *Nitzschia linearis* W. Sm.	o	●		o
82. *Nitzschia palea* (Kutz.) W. Sm.	●	●		●
83. *Rhopalodia gibba* (Ehr.) O.F. Mull.	o			
84. *Surirella angustata* Kutz.	●	o		o
85. *Surirella biseriata* Breb.	o	o		
86. *Surirella ovata* Kutz.	o	o		

abundant species on the artificial substrates were also dominant on natural substrates, indicating that the plexiglass plates were non-selective for diatom growth. The relatively few diatoms (39 species) encountered on the artificial substrates is probably due to the fewer number of samples collected.

Most diatom species belonged to the orders: Achnanthales, Naviculales, Surirellinees or Fragilariales. Although these orders have some species that are planktonic, almost all species observed in the Flathead Basin are representative of the truely attached forms. Species belonging to the planktonic order Coscinodiscales were virtually absent from the attached assemblages of the Flathead Basin. The most diverse diatom order was the Naviculaes. There were more species of *Navicula* (15) than any other genus, but only three of the Navicula species were numerically important.

iv) diatom distributions

The distribution and percentage abundance of the dominant diatom species is illustrated in Figures 30 and 31. Individual species abundances are not similar between the two sampling methods although species from the same genera usually predominate for both sampling techniques. In the Flathead Basin species belonging to the genera *Achnanthes, Cocconeis, Cymbella, Gomphonema, Hannaea* and *Nitzschia* are widespread in distribution. Other diatoms (Table 25) such as *Synedra,* and *Navicula* are only occasionally abundant and usually patchy in distribution.

Achnanthes minutissima and *Achnanthes lanceolata* are the two most abundant and widespread *Achnanthes* species in the Flathead Basin. Patrick and Reimer (1966) indicate that both these species can tolerate a wide range of ecological conditions but it is significant to note that *A. lanceolata* is reported as being sparce where organic enrichment occurs and that *A. minutissima* does not occur where oxygen levels are low or where toxic conditions such as

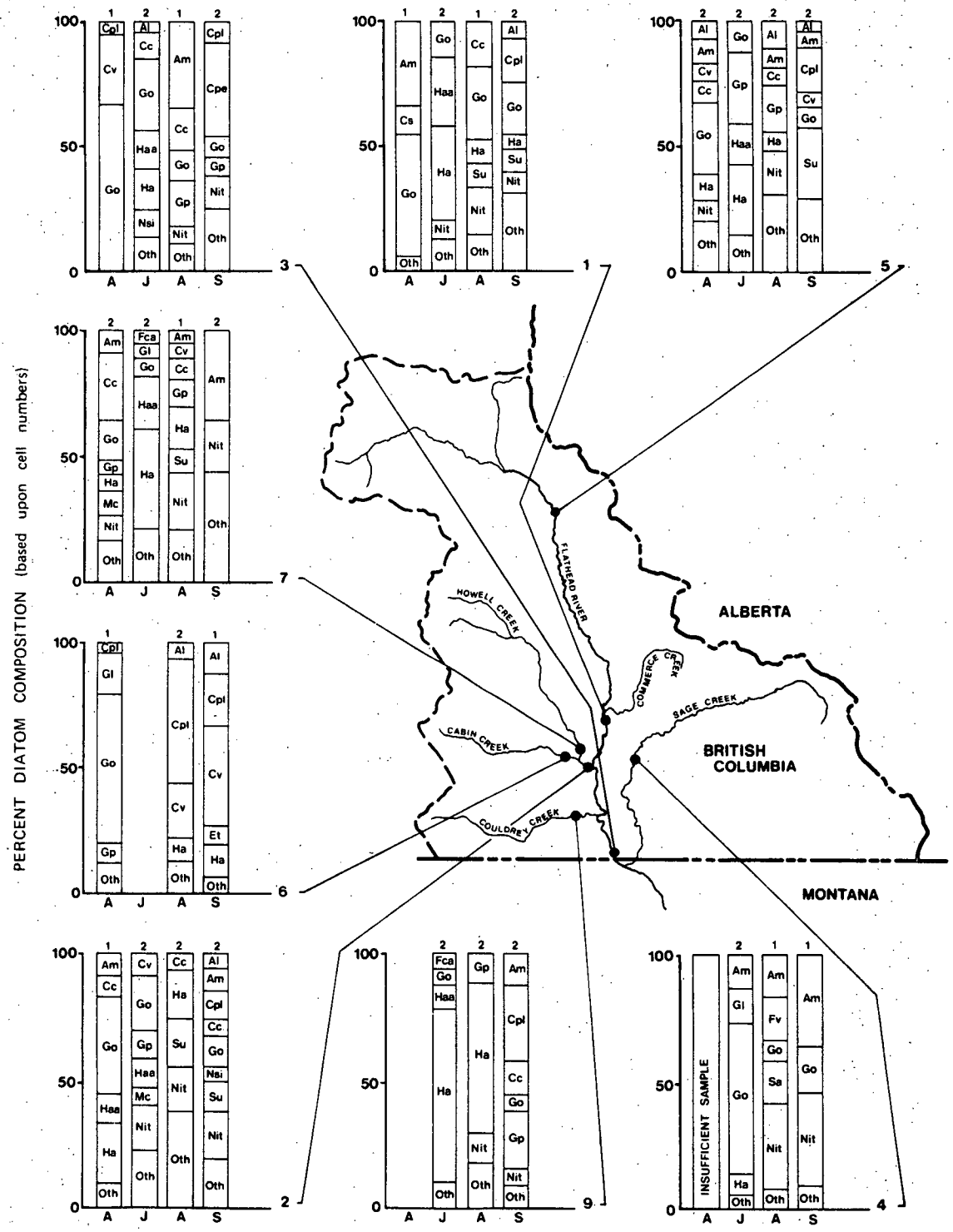

Fig. 30 Regional and seasonal variations in the percent numeric composition of common diatom species (≥5 percent of the total number) attached to rock substrates (SA scraped rocks) at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Numbers above monthly data refer to the number of replicate samples taken.

The diatom species are: Al, *Achnanthes lanceolata*; Am, *Achnanthes minutissima*; Cc, *Cymbella caespitosa*; Cpe, *Cocconeis pediculus*; Cpl, *Cocconeis placentula*; Cs, *Cymbella sinuata*; Cv, *Cymbella ventricosa*; Et, *Epithemia turgida*; Fca, *Fragilaria capucina*; Fv, *Fragilaria vaucheriae*; Gl, *Gomphenoma lanceolatum*; Go, *Gomphonema olivaceum*; Gp, *Gomphonema parvulum*; Ha, *Hannaea arcus*; Haa, *Hannaea arcus* var. *amphioxys*; Mc, *Meridion circulare*; Nit, All *Nitzschia* species; Nsi, *Navicula salinarium* var. *intermedia*; Oth, All other species; Sa, *Surirella angustata*; Su, *Synedra ulna*.

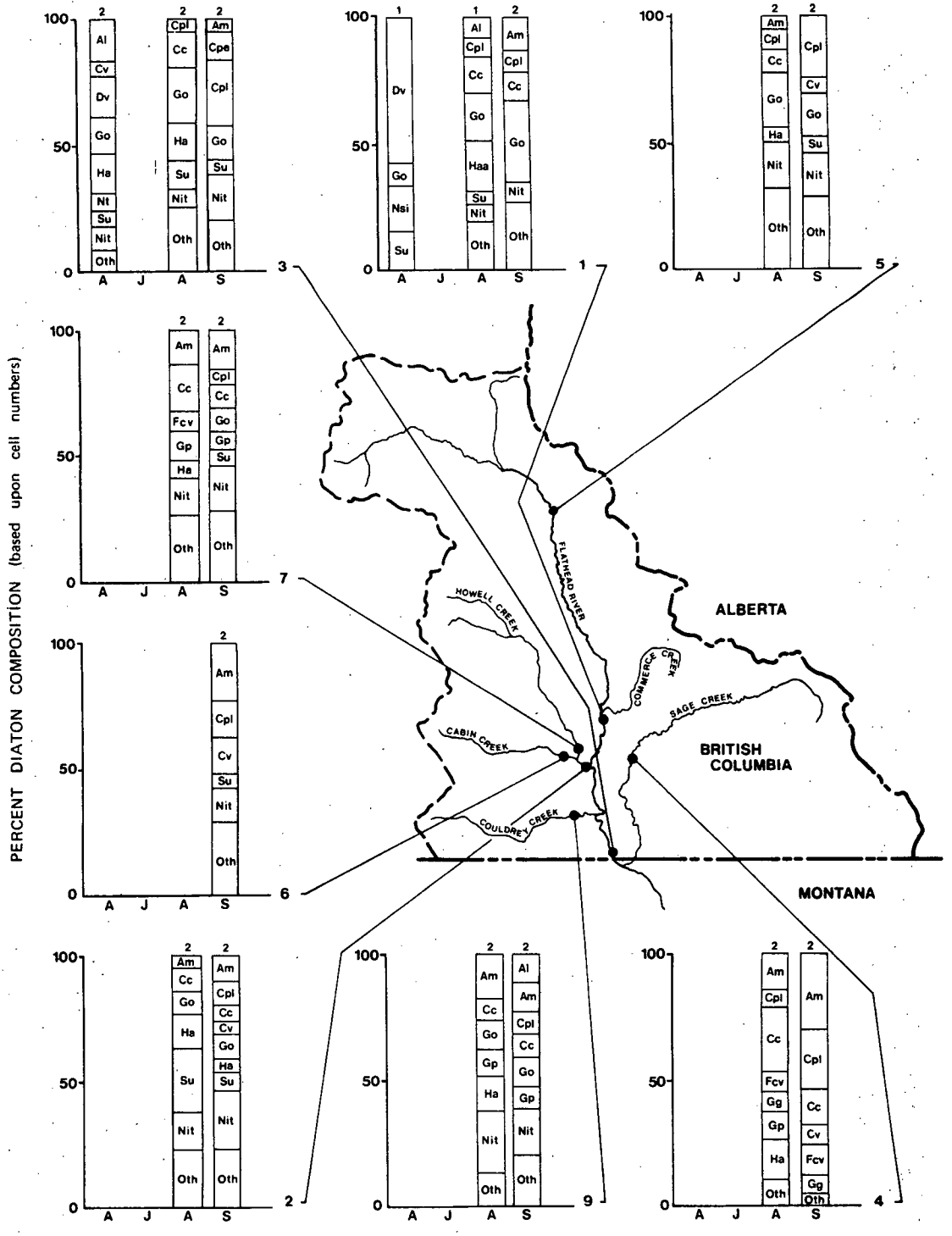

Fig. 31 Regional and seasonal variations in the percent numeric composition of common diatom species (≥5 percent of the total number) attached to rock substrates (entire rock sampled) at an approximate depth of 0.5m in the Flathead River Basin, April - September, 1976. Numbers above monthly data refer to the number of replicate samples taken.

The diatom species are: Al, *Achnanthes lanceolata*; Am, *Achnanthes minutissima*; Cc, *Cymbella caespitosa*; Cpe, *Cocconeis pediculus*; Cpl, *Cocconeis placentula*; Cv, *Cymbella ventricosa*; Dv, *Diatoma vulgare*; Fcv, *Fragilaria construens* var. *venter*; Gg, *Gomphonema geminatum*; Go, *Gomphonema olivaceum*; Gp, *Gomphonema parvulum*; Ha, *Hannaea arcus*; Haa, *Hannaea arcus* var. *amphioxys*; Nit, All *Nitzschia* species; Nsi, *Navicula salinarium* var. *intermedia*; Nt, *Navicula tripunctata*; Oth, All other species; Su, *Synedra ulna*.

high zinc levels occur (Ennis, MS 1977).

Cocconeis placentula, although widespread, was particularly common at station 6 on Cabin Creek where it was epiphytically growing on the leafy green alga, *Monostroma*. This is not unexpected since Patrick and Reimer (1966) describe *C. placentula* as being eurytopic and epiphytic. Other species such as *Cymbella ventricosa* which are also reported as being eurytopic (Patrick and Reimer 1966) are widespread in the Flathead River Basin.

Many diatoms found in the Flathead River Basin are typical cool water species. *Gomphonema olivaceum*, for instance, prefers cool hard water and also has a high calcium preference (Patrick and Reimer 1966).

The diatom that most characterizes the present day Flathead River Basin is *Hannaea arcus*. This species prefers low nutrient cool, flowing water in mountainous regions. It is reported as being common in an arctic river (Moore 1974), in the French Alps (Bourrelly 1974), and several other cool flowing rivers in mountainous regions (Patrick and Reimer 1966). *Hannaea arcus* is also dominant in the low nutrient ultra oligotrophic waters of Carnation Creek (Stockner and Shortreed 1976) and in other low nutrient streams (Moore 1974). In the Flathead River Basin *H. arcus* was abundant at all sampling sites, particularly during June and August, when *H. arcus* and its subspecies *H. arcus* var. *amphioxys* sometimes accounted for as much as 76 percent of the total diatom numbers (Figures 30 and 31).

Diatom species indicative of polluted waters were, if present, low in numbers and numerically unimportant. In the Flathead River Basin the largest group of these pollution indicators belong to the genus *Nitzschia* whose species are most abundant in waters suffering from organic enrichment. However, even the combined abundance of the seven *Nitzschia* species observed in this study

were only 5 - 10 percent (Figures 30 and 31). These *Nitzschia* levels in the Flathead Basin are far less than the dominance levels of at least 50 percent which are associated with high nitrogen levels from sewage plant outfalls (Schoeman 1972).

B. Planktonic Algae

1. Abundance

Phytoplankton density was low at all sampling sites, usually below 500 cells ml^{-1} (Figure 32). Even the maximum cell count of about 2600 cells ml^{-1} in the Flathead Basin is low compared to phytoplankton numbers in lakes, and in some rivers such as the upper Thames, England where counts can exceed 70,000 cells ml^{-1} during the spring peak (Lack 1971). These Flathead phytoplankton counts represent cells with chloroplasts; cell counts from dead cells without chloroplasts were not included.

Percentages of cells with chloroplasts ranged from below 5 percent to 43.9 percent (Figure 33) with a mean of approximately 15 percent. This extremely low number probably overestimates the number of cells that are viable since cells with chloroplasts can be dead.

2. Species Composition

Virtually all of the 68 phytoplankton species identified from the Flathead Basin were diatoms (Table 26) with only 6 "non-diatom' forms being recorded. Also, most of the planktonic forms (97 percent) are usually found in attached algal assemblages and most of these species were identified in the periphytic samples. This data combined with the low viable cell density and high percentage of dead cells observed in the plankton provides strong evidence that a true phytoplankton community does not exist. Instead, these planktonic algae probably represent portions of the periphyton which have been detached from rock substrates by physical factors or algae which have been sloughed off after death. This observation is not unusual and agrees with Hynes's (1972) contention that benthic algae at the headwaters of a river are the plankton source.

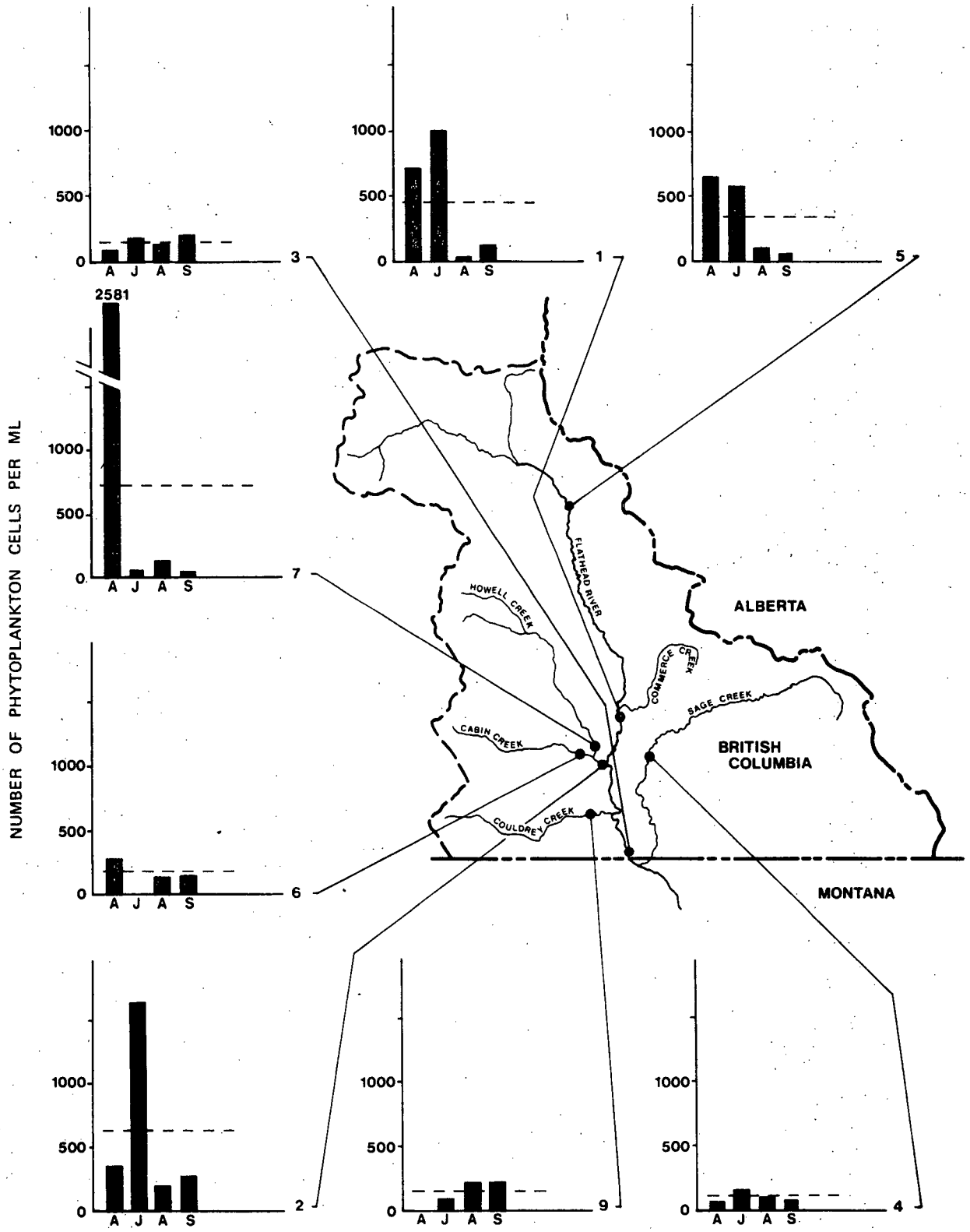

Fig. 32 Regional and seasonal variations in the number of phytoplankton cells with chloroplasts in the Flathead River Basin, April - September, 1976. Vertical bars represent numbers per ml in single samples, horizontal dashed lines represent mean numbers per ml during the entire sampling period.

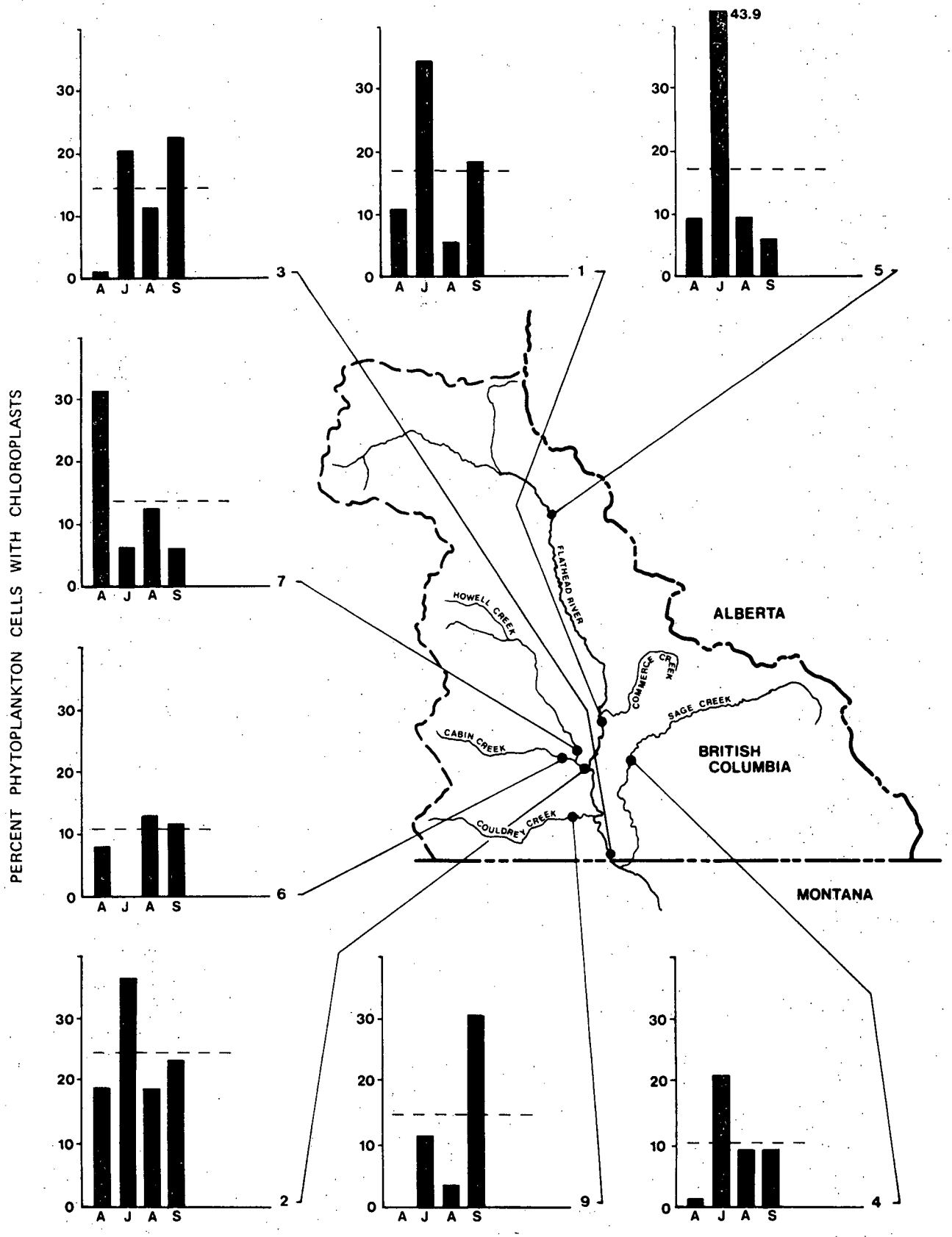

Fig. 33 Regional and seasonal variations in the percentage of phytoplankton cells with chloroplasts in the Flathead River Basin, April - September, 1976. Vertical bars represent percentage abundance in single samples, horizontal dashed lines represent the mean percentage abundance during the entire sampling period.

Table 26 A list of the planktonic algal species and their numeric occurrence in the Flathead River Basin, 1976. For occurrence; open circles (o) denote a species always contributing to less than 10 percent of a sample's abundance, solid circles (●) denote that a species made up greater than 10 percent of at least one sample's abundance. Species that are usually periphytic, or common in the Flathead's periphyton, are indicated with a plus (+) sign.

	Species	Occurrence: Cells with Chloroplasts	Occurrence: Cells without Chloroplasts	Usually Periphytic
	Diatoms:			
1.	*Achnanthes lanceolata* (Bréb.) Grun.		o	+
2.	*Achnanthes minutissima* kütz	●	●	+
3.	*Achnanthes* sp. A		o	+
4.	*Achnanthes* sp. B		o	+
5.	*Amphipleura pellucida* (kütz.) kütz.		o	+
6.	*Amphora ovalis* kütz.		o	+
7.	*Cocconeis pediculus* Hantz.	●	o	+
8.	*Cocconeis placentula* Ehr.	●	●	+
9.	*Cymatopleura solea* (Bréb.) W. Sm.	o		+
10.	*Cymbella caespitosa* (kütz.) Brun	●	●	+
11.	*Cymbella sinuata* Greg.		o	+
12.	*Cymbella turgida* Greg.	●	o	+
13.	*Cymbella ventricosa* kütz.	●	o	+
14.	*Diatoma hiemale* (Lyngb.) Heib.	●	o	+
15.	*Diatoma tenue* Ag.		o	+ (planktonic also)
16.	*Diatoma vulgare* Bory	●	o	+
17.	*Epithemia sorex* kütz.		o	+
18.	*Epithemia turgida* (Ehr.) kütz.	●	o	+
19.	*Eunotia pectinalis* (O.F. Müll.) Rabh.		o	+
20.	*Fragilaria capucina* Desm.		o	+
21.	*Fragilaria construens* (Ehr.) Grun.		o	+
22.	*Fragilaria construens* var. *binodis* (Ehr.) Grun.		o	+
23.	*Fragilaria construens* var. *venter* (Ehr.) Grun.	●	o	+
24.	*Fragilaria leptostauron* (Ehr.) Hust.	o	o	+
25.	*Fragilaria vaucheriae* (kütz.) Peters.	●	o	+
26.	*Frustulia rhomboides* (Ehr.) DeT.	●	o	+
27.	*Gomphonema geminatum* (Lyngb.) Ag.		o	+
28.	*Gomphonema herculeana* Ehr.	●	o	+
29.	*Gomphonema lanceolatum* Ehr.		o	+
30.	*Gomphonema olivaceum* (Lyngb.) kütz.	●	●	+
31.	*Gomphonema parvulum* (kütz.) kütz.	●	●	+
32.	*Gomphonema parvulum* var.*genuinum* May.		o	+
33.	*Gyrosigma kutzingii* (Grun.) Cl.		o	+
34.	*Hannaea arcus* (Ehr.) Patr.	●	●	+
35.	*Hannaea arcus* var. *amphioxys* (Rabh.) Patr.	o	o	+
36.	*Melosira varians* Ag.		o	+
37.	*Meridion circulare* (Grev.) Ag.	●	●	+
38.	*Navicula bergii* A. Cl.		o	+
39.	*Navicula bicephala* Hust.	o	o	+
40.	*Navicula cryptocephala* kütz.	o	o	+
41.	*Navicula muralis* Grun.		o	+
42.	*Navicula pupula* kütz.	●	o	+
43.	*Navicula radiosa* kütz.	●	o	+
44.	*Navicula salinarum* var. *intermedia* (Grun.) Cl.	●	o	+
45.	*Navicula tripunctata* (Grun.) Cl.	o	o	+
46.	*Navicula* sp. A		o	+
47.	*Navicula* sp. B		o	+
48.	*Navicula* sp. C		o	+
49.	*Navicula* sp. X		o	+
50.	*Neidium affine* (Ehr.) Pfitz.		o	+
51.	*Neidium incurvum* (Greg.) Östr.		o	+
52.	*Nitzschia acicularis* W. Sm.	●	o	+
53.	*Nitzschia dissipata* (kutz.) Grun.	●	o	+
54.	*Nitzschia frustulum* (kutz.) Grun.		o	+
55.	*Nitzschia linearis* W. Sm.	o	o	+

Table 26 (Continued)

	Species	Occurrence: Cells with Chloroplasts	Cells without Chloroplasts	Usually Periphytic
	Diatoms: (Cont'd)			
56.	*Nitzschia palea* (kütz.) W. Sm.	●	●	+
57.	*Pinnularia subrostrata* A. Cl.		o	+
58.	*Rhoicosphenia curvata* (kütz.) Grun.	●	o	+
59.	*Stephanodiscus astraea* var. *minutula* (kütz.) Grun.		o	
60.	*Surirella angustata* kütz.	●	o	+
61.	*Synedra ulna* (Nitz.) Ehr.	●	●	+
62.	*Synedra ulna* var. *oxyrunchus* (Fortii) Hust.	o	●	+
	Chlorophyta:			
63.	cf. *Chlamydomonas*	●		
64.	*Mougeotia* sp. A	o		+
	Cyanophyta			
65.	*Nostoc* sp.	o		+
66.	*Oscillatoria* sp.	●		+
	Chrysophyta			
67.	Order Chrysosaccale like	●		+
	Xanthophyta			
68.	Order Vaucheriales sp.	o		+

3. Species Distribution

The distribution and percentage abundance of the dominant phytoplankton species is illustrated in Figure 34. The most important phytoplankters such as *Hannaea arcus*, *Achnanthes* spp., *Cocconeis* spp., *Gomphonema* spp., and *Cymbella* spp. were present at most sampling sites. Most species observed prefer oligotrophic waters or are considered to be eurytopic in distribution, reflecting the low nutrient cool water status of the Flathead River and its tributaries.

4. Species Diversity

a) Number of Taxa

There were generally between 5 and 10 phytoplankton species identified per sample (Figure 35) with little consistent variation in species number between stations. These data also show that the phytoplankton assemblages are less diverse than the periphytic community, which is presumably the source of the phytoplankton.

b) Shannon-Wiener (H') Diversity

In the Flathead Basin Shannon-Wiener phytoplankton diversities varied from 0 - 3.2 (Figure 36). There was little regional variation and, in contrast to periphyton results, there was little seasonal variation. Although most diversities were near 2.0 there were occasional values of zero. It is most unlikely that these infrequent zero values are associated with pollution. Instead, it seems reasonable that these low diversities where only one viable species was seen and where cell numbers are extremely low (Figure 32) reflect some change in the release of cells by the diverse periphyton community.

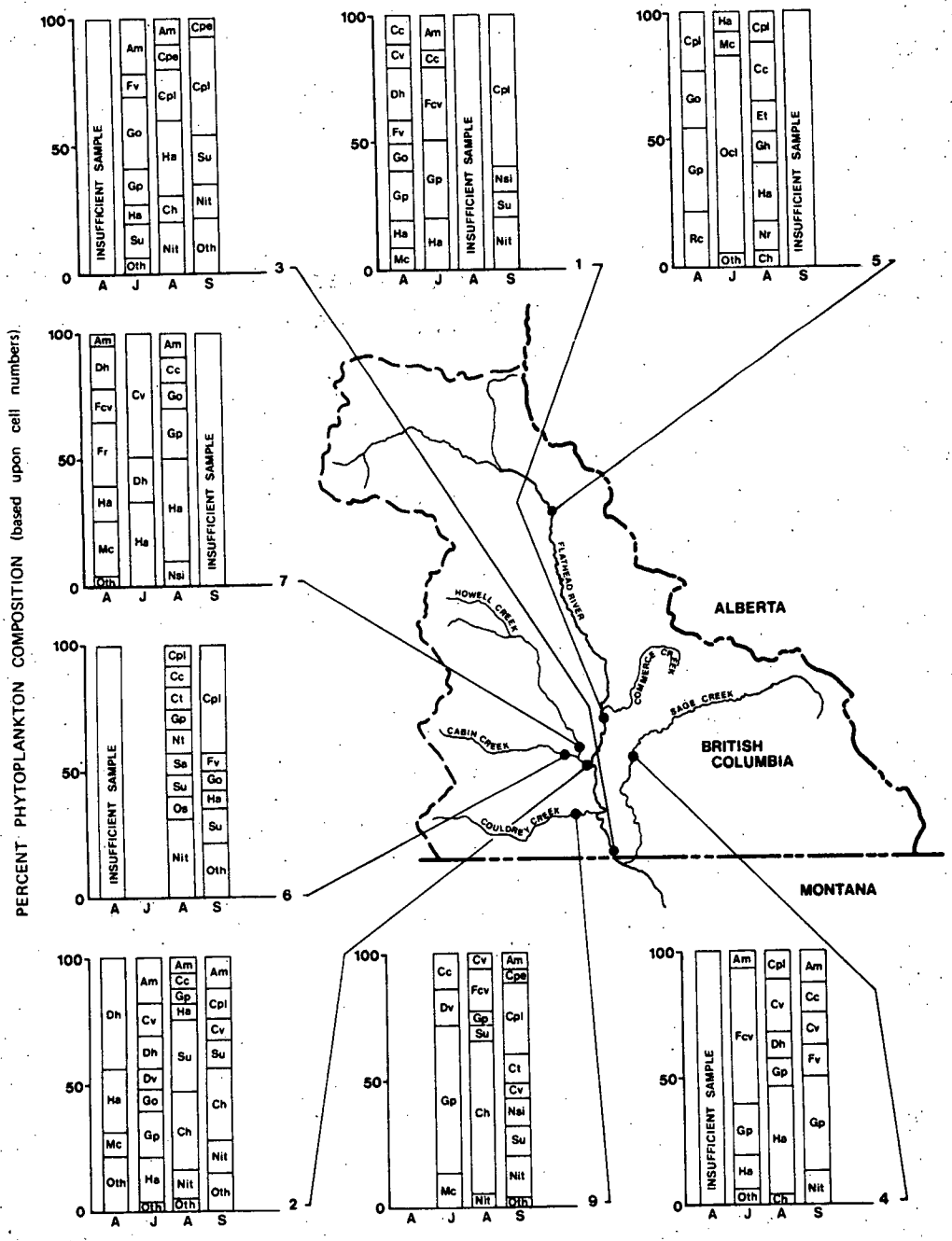

Fig. 34 Regional and seasonal variations in the percent numeric composition of common phytoplankton species (≥5 percent of the total number) in the Flathead River Basin, April - September, 1976.

The phytoplankton species are: Am, *Achnanthes minutissima*; Cc, *Cymbella caespitosa*; Cpe, *Cocconeis pediculus*; Cpl, *Cocconeis placentula*; Ct, *Cymbella turgida*; Cv, *Cymbella ventricosa*; Dh, *Diatoma hiemale*; Dv, *Diatoma vulgare*; Et, *Epithemia turgida*; Fcv, *Fragilaria construens* var. *venter*; Fr, *Frustulia rhomboides*; Fv, *Fragilaria vaucheriae*; Gh, *Gomphonema herculeana*; Go, *Gomphonema olivaceum*; Gp, *Gomphonema parvulum*; Ha, *Hannaea arcus*; Mc, *Meridion circulare*; Nit, All *Nitzschia* species; Nr. *Navicula radiosa*; Nsi, *Navicula salinarum* var. *intermedia*; Nt, *Navicula tripunctata*; Oth, All other species; Rc, *Rhoicosphenia curvata*; Sa, *Surirella angustata*; Su, *Synedra ulna*; Ch, cf. *Chlamydomonas*; Ocl; order Chrysosaccales like; Os, *Oscillatoria* sp.

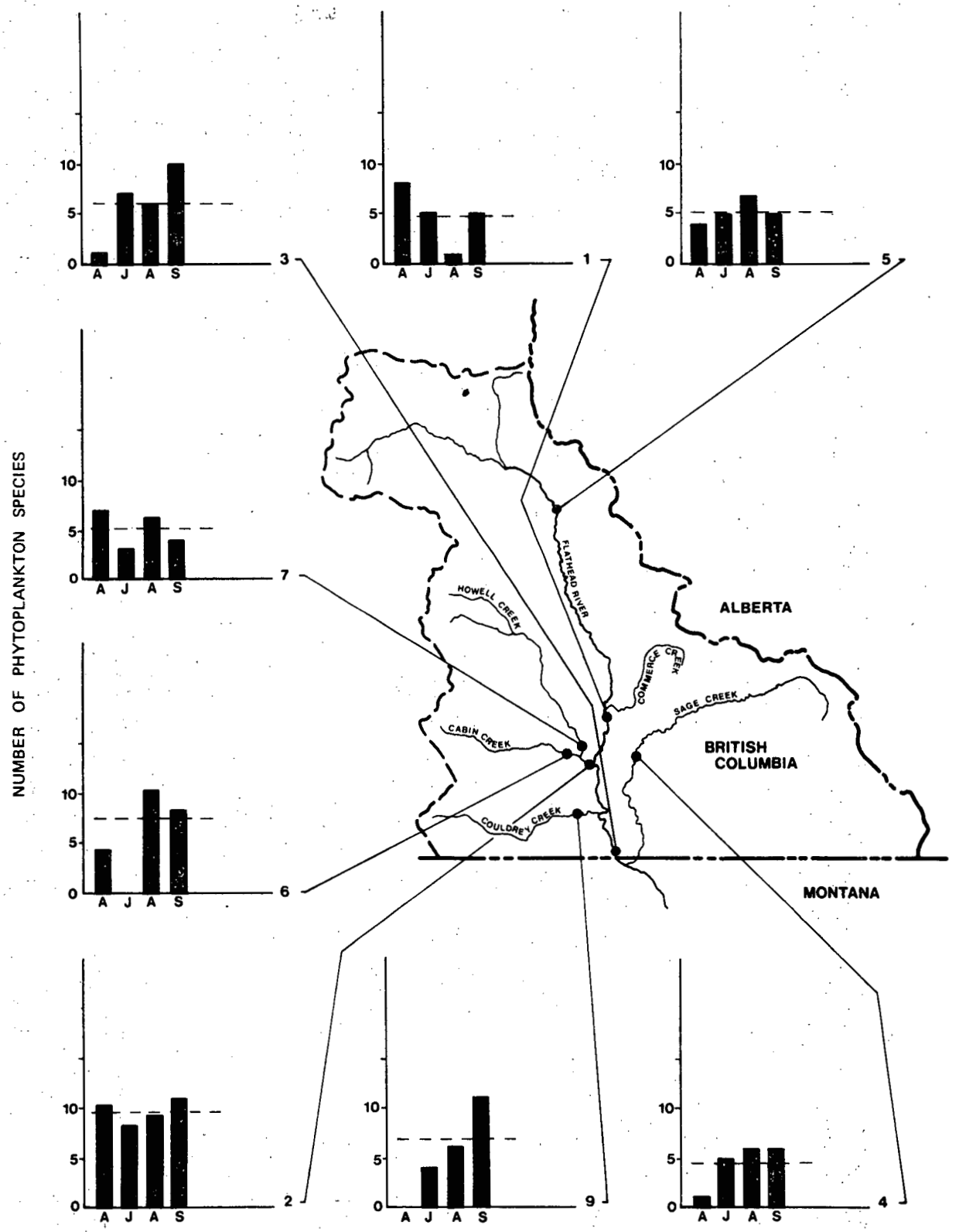

Fig. 35 Regional and seasonal variations in the number of surface water phytoplankton species in the Flathead River Basin, April - September, 1976. Only cells with chloroplasts included; vertical bars represent the number of species in single samples horizontal dashed lines represent the mean number of species during the entire sampling period.

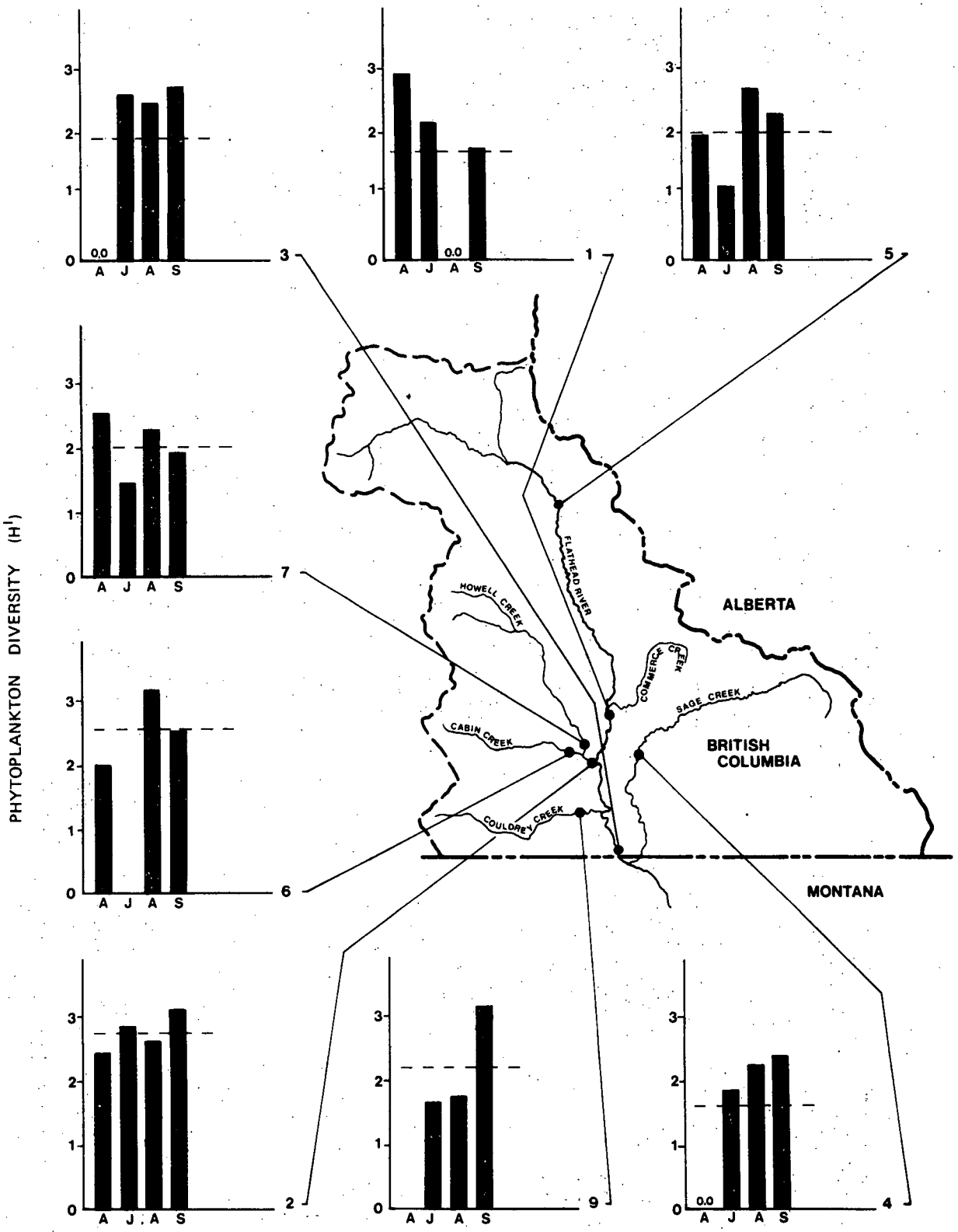

Fig. 36 Regional and seasonal variations in surface water phytoplankton diversity (Shannon - Wiener function, H') in the Flathead River Basin, April - September, 1976. Only cells with chloroplasts included; vertical bars represent single sample diversities, horizontal dashed lines represent the mean diversity during the entire sampling period.

X MACROINVERTEBRATE DATA

The detailed macroinvertebrate data not found in this interpretative report can be obtained in the Flathead River Basin data report (Sheehan *et al.* in preparation).

A. Benthos Composition

Macroinvertebrate samples from the Flathead Basin were comprised mainly of the class Insecta (Table 27). Most of the insect species belonged to the orders Diptera, Ephemeroptera, Plecoptera, and Tricoptera while the remaining few insect species belonged to the orders Coleptera or Collembola.

The non insect benthic fauna were categorized to the taxonomic levels of Ostracoda, Turbellaria, Nematoda or Pelecypoda.

B. Abundance

A graphic summary of the total number of organisms per square meter at each station for each of the four sample periods is presented in Figure 37. In the Flathead Basin the density ranged from approximately 200 individuals per square meter to 7500 individuals per square meter and except for the April sampling period, most stations supported more than 1000 organisms per square meter. Temporal changes in abundance were very similar at all stations; numbers generally increased following the spring break-up of ice cover and appear to reach a maximum in September. Differences in abundance between sample sites were slight although numbers in the Flathead decreased with distance downstream, possibly because of increased river flow and scouring effects. Highest densities were observed at Cabin and Howell Creeks (stations 6 and 2).

C. Population Distributions

The percentage distribution of Ephemeroptera, Diptera, Plecoptera, Tricoptera, and all other macroinvertebrates is summarized in Figure 38. Ephemeropterans almost totally dominated the macroinvertebrate community of the Flathead River

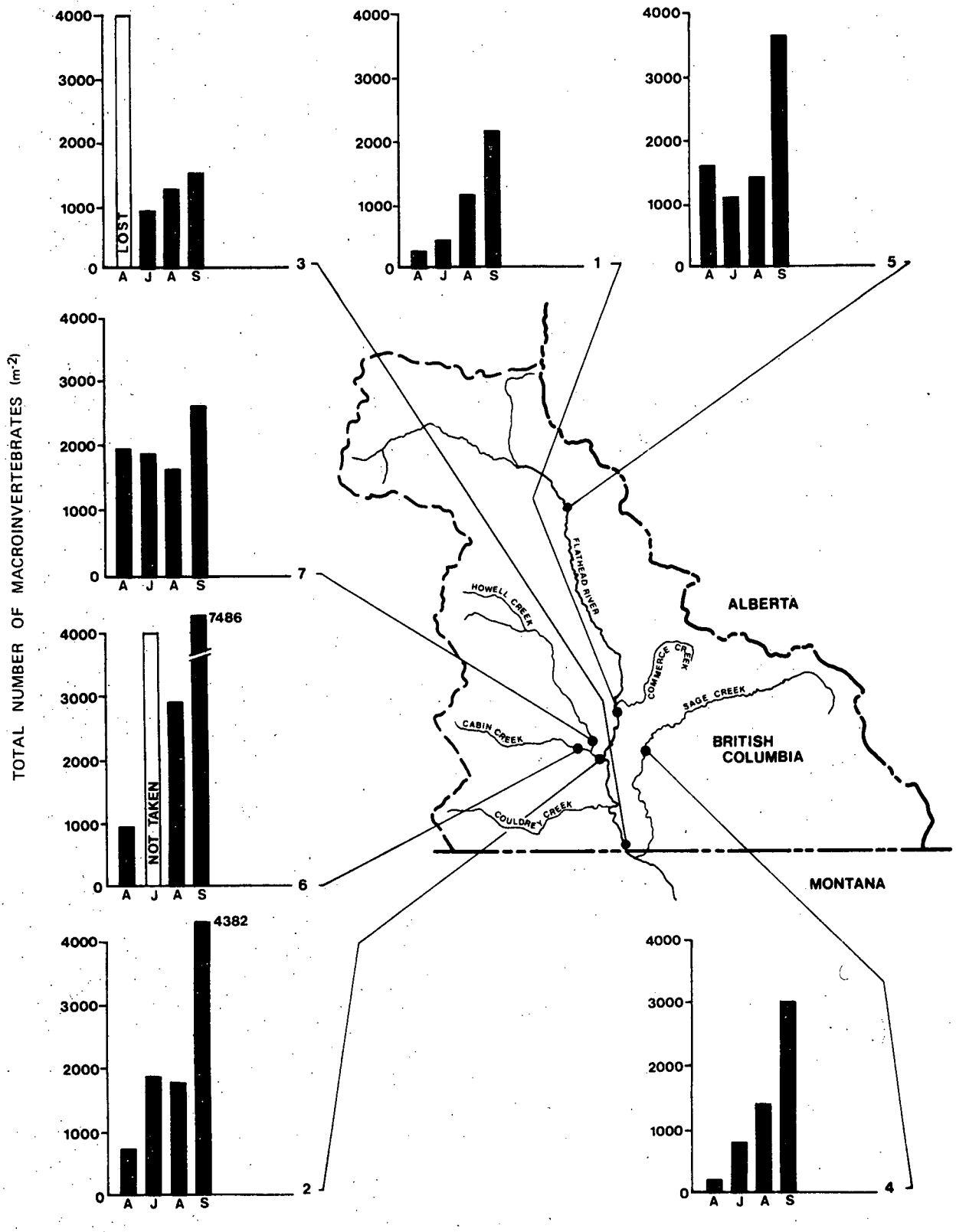

Fig. 37 Total number of macroinvertebrates per square meter for composite samples taken with a modified Hess Sampler in the Flathead River Basin, April - September, 1976.

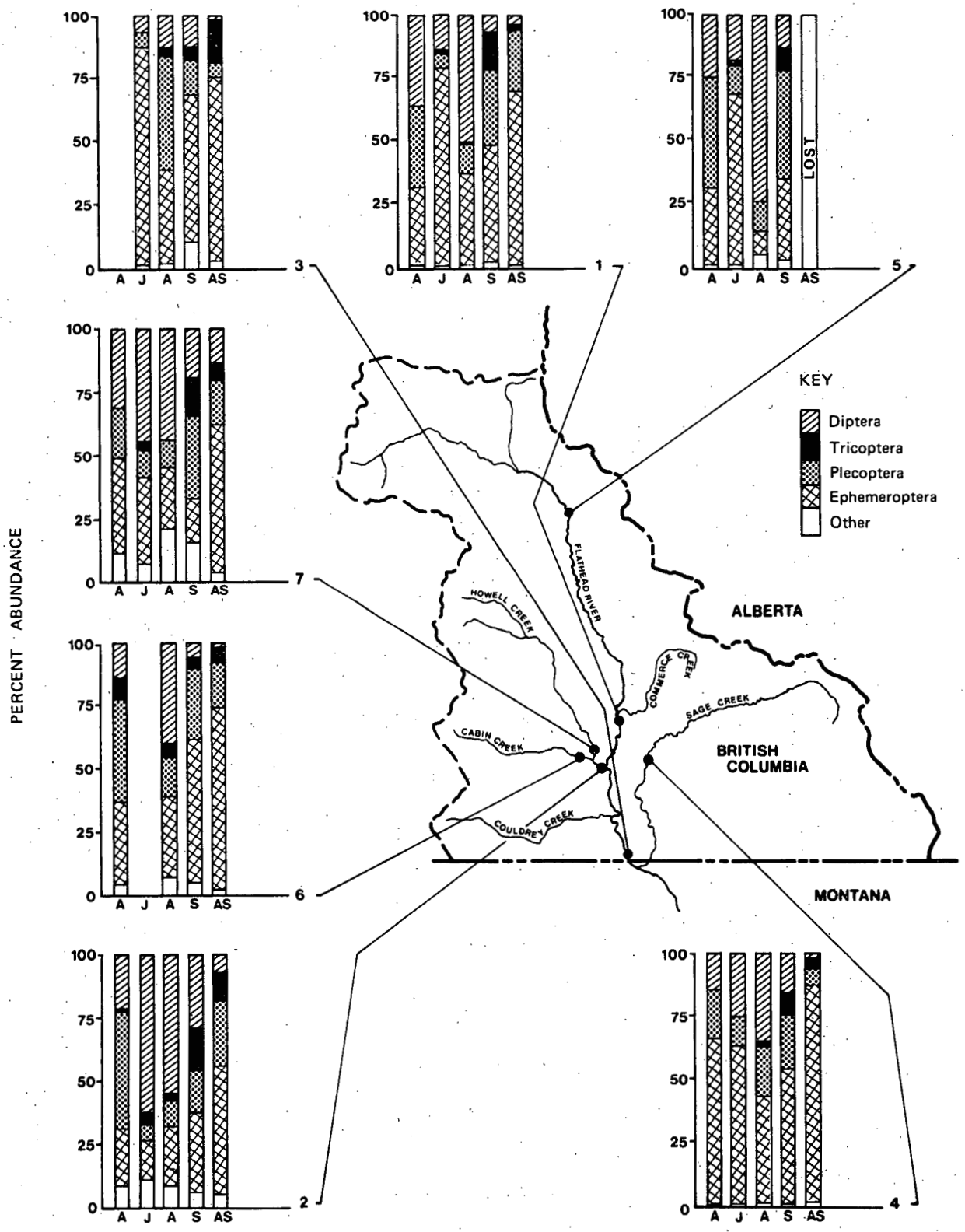

Fig. 38 Regional and seasonal variations in percentage abundance of Diptera, Tricoptera, Plecoptera, Ephemeroptera and other macroinvertebrates in the Flathead River Basin, April - September, 1976. Data is also presented for artificial substrates (AS, Hester-Dendy sampler) that were taken in September, 1976.

TABLE 27 A list of the benthic macroinvertebrates found in the Flathead River Basin, 1976. Numbers refer to categories used in the Shannon-Wiener diversity analysis. (Related taxa, genera and species, were combined into Family classifications for diversity analysis).

Group	Sub-group and Taxa	Diversity Category
Insecta	Coleptera unidentified	1
	Elmidae (larvea)	1
	Elmidae (adult)	1
	Collembola	2
	Diptera unidentified	3
	Cyclorrhapha	4
	Nematocera	5
	Ceratopogoniidae	6
	Psychodidae	7
	Tanyderidae	8
	Tendipididae	9
	Tipulidae	10
	Ephemeroptera unidentified	11
	Baetidae	12
	Ephemerellidae	13
	Ephemerella spp.	13
	E. of cuterpe	13
	E. coloradensis	13
	E. doddsii	13
	E. spinifera group	13
	E. serrata group	13
	Heptageniidae	14
	Rhithrogena	14
	Leptophlebiidae	15
	Siphlonuridae	16
	Plecoptera unidentified	17
	Holognatha	18
	Nemouridae	19
	Nemoura spp.	19
	N. subgroup *zapada*	19
	N. subgroup *zapada cinctipes*	19
	Capnilnae	20
	Capnia or *Eucapnopsis spp.*	20
	Taeniopteryginae	21
	Brachyptera	21
	Systellognatha	22
	Chloropeslidae	23
	Alloperla spp.	23
	Perlodidae	24
	Arcynopteryx subg *Megarcys spp.*	24
	Isogenus spp.	24
	Isoperla spp.	24
	Type red (unidentified)	24

Group	Sub-group and Taxa	Diversity Category
Insecta	Tricoptera unidentified	25
	Brachycentiidae	26
	Micrasema spp.	26
	Glossosomatidae	27
	Glossosoma spp.	27
	Agapetus spp.	27
	Hydropsychidae	28
	Hydropsyche spp.	28
	Parapsyche spp.	28
	Lepidostomatidae	29
	Limnephilidae	30
	Platycentropus spp.	30
	Oligophlebodes spp.	30
	Psychomyiidae	31
	Rhyacophilidae	32
	Rhyacophila spp.	32
Ostracoda		33
Acari		34
Oligochaeta		35
Turbellaria		36
Nematoda		37
Pelecypoda		38

at the International Boundary and of Sage Creek (stations 3 and 4). At all other sites Dipterans and Ephemeropterans together dominated (depending upon the season).

Plecopterans usually made up approximately 10 percent of the population throughout the study period. Tricopteran numbers were negligible during April but increased through the summer and occasionally made up to 15 percent of the numbers at some sampling sites during September.

The remaining fauna, comprised primarily of the non insect invertebrates, were low in numbers but increased during the last month of the study. Their combined totals seldom accounted for as much as 10 percent of any sample.

Artificial substrates (Hester-Dendy samplers) were found to be selective for Ephemeropterans (Figure 38). The between station similarities of data from Hester-Dendy samples are possibly related to these large numbers (50-86 percent) of Ephemeropterans. The differences between the faunal composition of natural versus artificial substrates is very likely related to the substrate preferences of these organisms. For instance, Northcote *et al.* (1976) noted in their lower Fraser River study area that invertebrate biomass and species types varied according to the substrate type present when Hester-Dendy samplers are used, invertebrates unlikely to reach the artificial substrate by drift, or with a lesser ability for attachment, or with a preference for sediment, would be underestimated.

D. Number of Taxa

The total number of taxa (taxa is defined as family or lowest identifiable level above family) at each station and for each sampling period are summarized in Figure 39. Generally, each sample site contained between 24 and 26 major taxa during the four sampling periods or at least increased to this level of representation by the September collections. Sample site 3 was the only site to contain less than 20 taxa during September; however there were 24 taxa found in the previous collection period at that site.

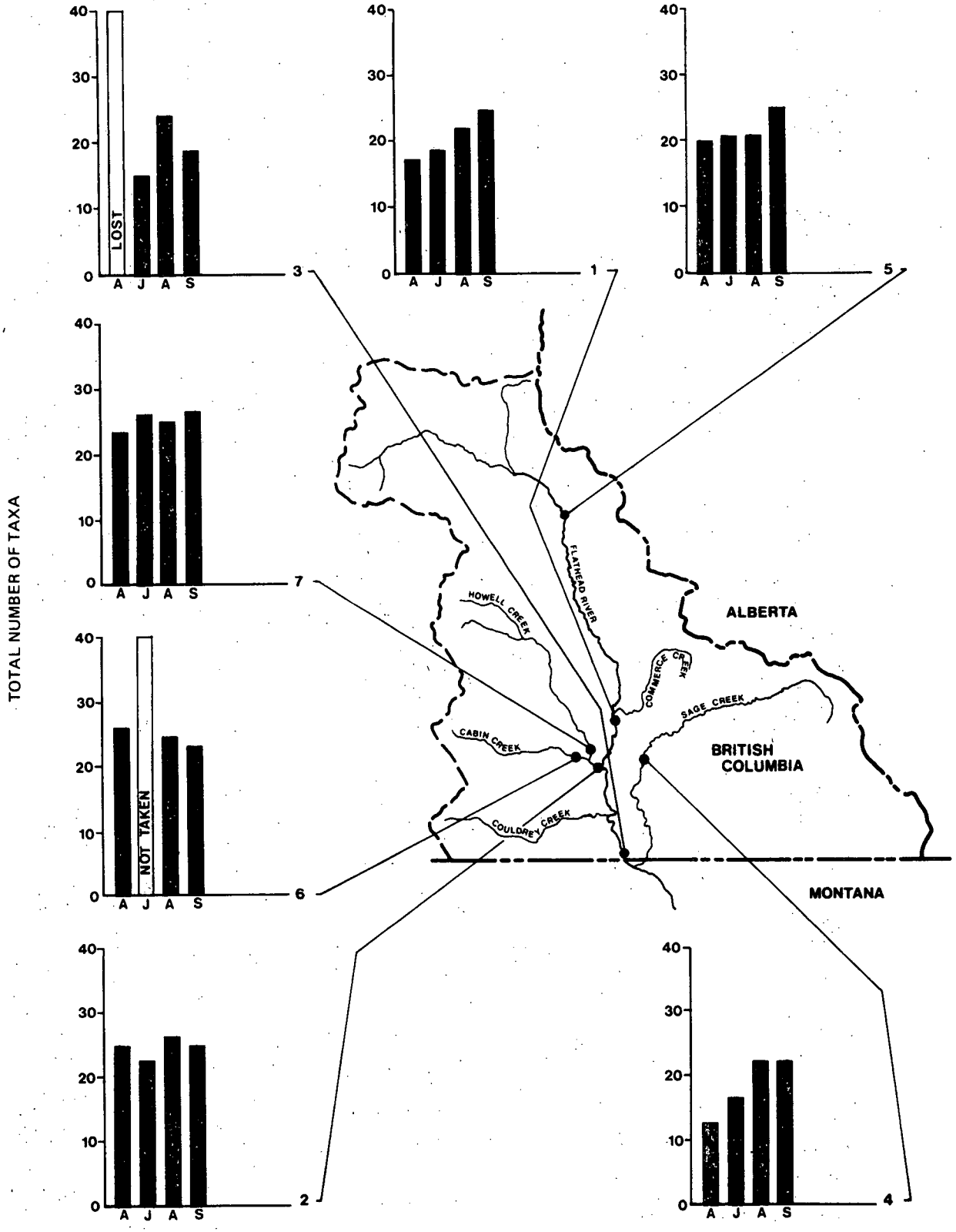

Fig. 39 Total number of macroinvertebrate taxa for samples taken with a modified Hess Sampler in the Flathead River Basin, April - September, 1976.

E. Diversity and Evenness

Diversity values have been calculated to facilitate the future assessment of the impact that proposed coal mining or any other disruption may have on the Flathead drainage basin. The diversity index (H') which summarizes information on the numbers and kinds of organisms present has been widely accepted as an indication of water quality (Wilhm and Dorris 1968; Cole 1973). Generally, diversity values greater than 3.0 are found in unpolluted productive waters while heavily polluted waters have values of less than 1.0. In our study it should be noted that because of taxonomic difficulties the diversity values were not calculated from data at the same taxonomic level. For instance, most insects were identified to the family level while there was no breakdown beyond the class level for specimens in such classes as Oligochaeta and Ascari. This is not a serious problem as there are very few individuals in these classes. (But should the Flathead River System macroinvertebrate community change with Oligochaeta species increasing in number, the diversity index would not reflect this as the Oligochaete breakdown is only to the class level).

The macroinvertebrate diversities presented in Figure 40 indicate that the Flathead system has an acceptable water quality. Diversity values were always above 1.0 and usually between 2.0 - 4.0. Diversity values were always lower in June following the freshet than in April. Diversity values then increased at all stations, except at station 6 (which was already high) and at station 5 (which was low in August), to reach a maximum of greater than 3.0 in the September collections.

Statistical analysis (ANOVA) of the diversity data revealed that a significant difference ($P < 0.001$) existed both among sample sites and among sample periods ($P < 0.001$). The variance components show that the greatest percentage ($\simeq$ 40 percent) of this difference was due to differences among sample periods. Hester-Dendy samplers were consistently lower ($P < 0.001$) in diversity than were natural substrates, because of the lower number of taxa utilizing the artificial substrates. The greatest variance in the artificial substrate data was attributable to the differences between sample sites (62 percent).

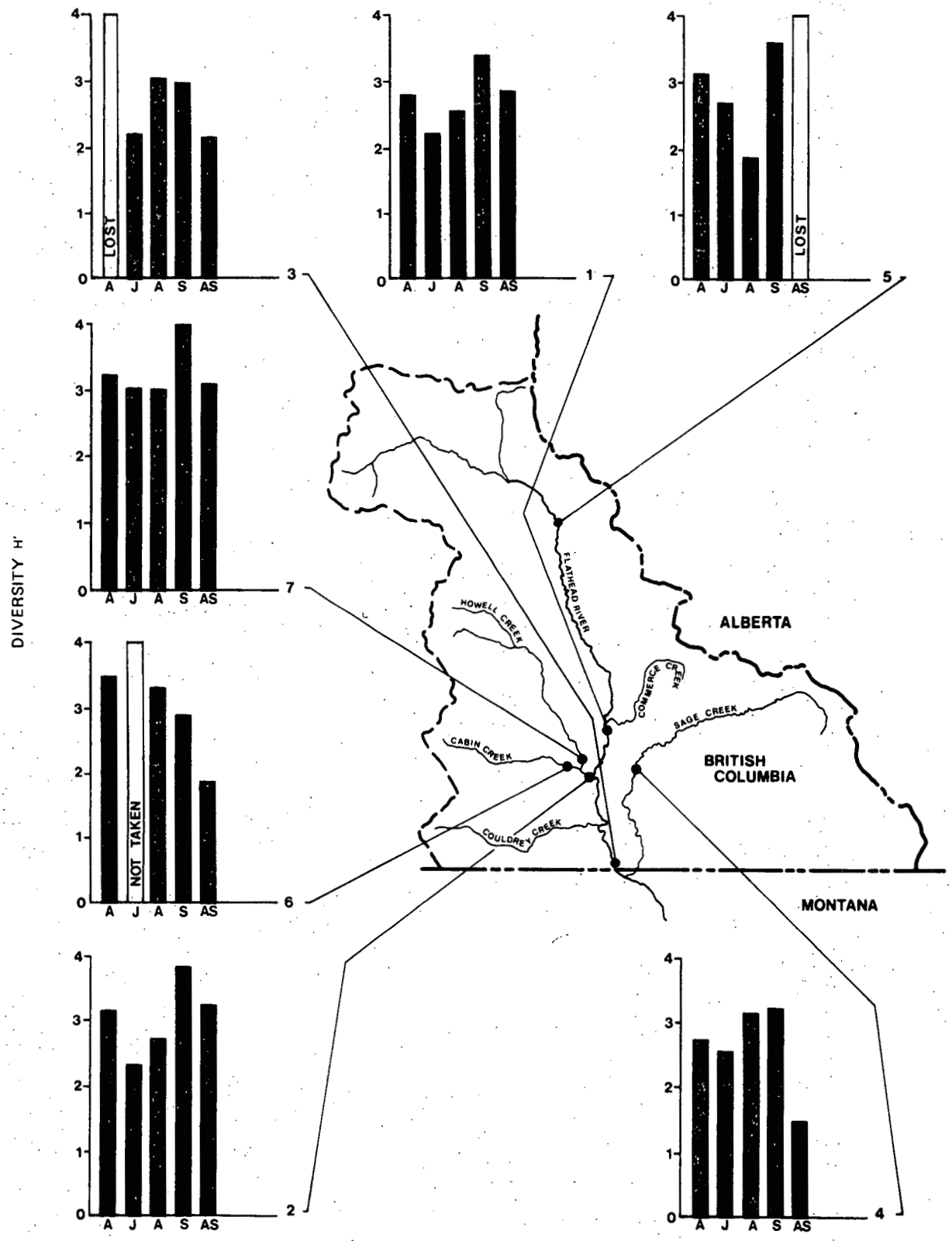

Fig. 40 Diversity values for the macroinvertebrate communities in the Flathead River Basin taken with the modified Hess Sampler April - September, 1976. Data is also presented from artificial substrates (AS, Hester - Dendy Sampler) that were retrieved in September, 1976.

J. Pielou's (1966, 1967) evenness value (J) ranges from 0 in the case where only one taxon is present to a maximum of 1 where each taxon has the same number of species. In natural healthy populations the evenness of diversity ranges from 0.5 to 0.8. Evenness values throughout all four collections averaged 0.63 for composite samples and 0.725 for individual samples. Composite samples were derived by adding the contents of the five collected samples. These values are relatively high and confirm that the high H' diversity values primarily reflect a fairly even distribution of individuals in the taxa (about 20).

F. Pollution Sensitivity

Many benthic macroinvertebrate species are sensitive to pollution or environmental stress and react quickly to it, and because they serve as integrators of water quality, they are becoming an increasingly important tool in the assessment of aquatic environments. Invertebrates differing in terms of their water quality requirements, can be grouped according to their tolerance to particular levels of a pollutant. The groupings used in this report are a combination of standards set by MacKenthus (1969), Cairns and Dickson (1971), and Servizi (1978).

Sensitive organisms that characterize pristine water conditions include Ephemeroptera, Tricoptera, and Plecoptera. Conversely, those organisms such as Oligochaetes, which can be found even in the presence of large amounts of pollution, are termed "tolerant". Diptera, which can withstand moderate amounts of pollutants are found in all conditions and termed "facultative".

The percentage distribution of sensitive, facultative, and tolerant organisms are presented in Figure 41 to facilitate a quick comparison of the composites of all months, samples sites and sampling methods. In all cases, sensitive and facultative macroinvertebrates accounted for 90 percent or more of the population. In the majority of cases greater than 50 percent of this segment were of the sensitive category. There was an overall decrease in the percentage of sensitive macroinvertebrates from April to August and a return to pre-freshet levels by September. This trend was almost entirely attributable to

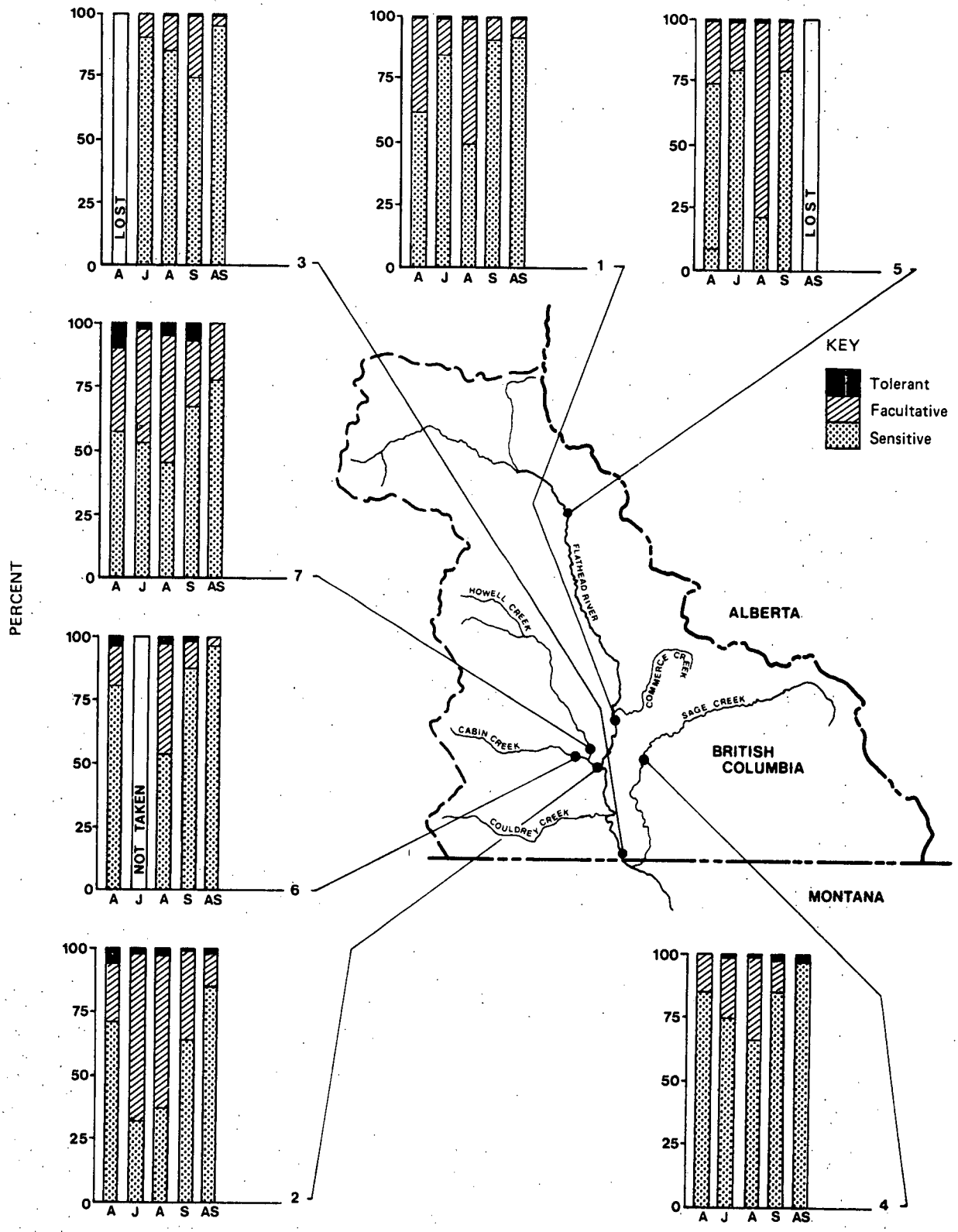

Fig. 41 The percentage values for the distribution of sensitive, facultative and tolerant macroinvertebrates in the Flathead River Basin. Samples were taken with the modified Hess Sampler, April - September, 1976. Data is also presented from artificial substrates (AS, Hester - Dendy Sampler) that were retrieved in September, 1976.

the increase in Diptera during these four months, followed by an increase of Tricoptera, Ephemeroptera, and Plecoptera from August to September.

XI CONCLUSIONS

A. Transboundary movement of nutrients, pollutants, and other materials

The concentrations of total phosphate and nitrite plus nitrate and total dissolved nitrogen in water crossing the border were low and no nuisance growth of plants and algae occurred in the downstream portion of the river studied. Measurements of sediments, nutrients and other materials are not typical of an undeveloped watershed since logging, exploration for coal, and the construction of roads were in progress during the study period. The proposed coal development at Cabin Creek would result in further disruption of vegetative cover and rock formations. These activities could lead to increased suspended sediment concentrations reaching the Flathead River which could affect some aquatic organisms.

B. Chemical parameters of importance in the water of the Flathead River Basin by comparing the concentration levels with Canadian drinking water standards

The levels of metals, nutrients, major ions, and organics were well below drinking water standards except for a small portion of the samples taken for manganese, phosphorus and barium. The high levels of phosphorus were either associated with freshet conditions or slush ice conditions (see nutrient section). The levels of barium which exceeded drinking water standards were measured during low flow when the ground water contribution to the total flow was likely high. Because of the low sulphur content of the Flathead coal deposits, there should be no significant reduction in pH levels from the proposed mining activities.

C. Metal content in algae, macroinvertebrates and fish tissue

Metals were measured in algae, macroinvertebrates, and fish tissue. Methodology problems prevent the use of the macroinvertebrate metal results. However, our data showed that pollution sensitive macroinvertebrates dominate the fauna, indicating that toxic pollutants, such as metals, are probably low in concentration. Algae in the Flathead Basin are also dominated by pollution intolerant species and their metal content was low. Although

there are no criteria or standards with which to compare the algal metal levels, actual Flathead River Basin metal concentrations were generally below those found in even the least polluted streams in the nearby Kootenay River Basin. Levels of metals in the slimy sculpin also indicate the lack of a water quality problem as the heavy metal levels are all well below the Canadian Food and Drug Directorate regulations for levels in fish used for human consumption.

D. Limiting nutrients for algal growth

Both water and algal nitrogen and phosphorus nutrient levels in the Flathead River Basin were low. Algal N:P ratios were near 20:1 and low surplus stored phosphorus values indicate that phosphorus, not nitrogen, is the limiting nutrient.

E. The species composition, population diversity, and abundance of algae and benthic invertebrates in the Flathead River Basin

Periphytic biomasses in the Flathead River Basin are representative of oligotrophic or even ultra oligotrophic systems. Diatoms often dominate the algal community although green algae, blue-greens and Chrysophycean algae are also important at certain sampling stations and dates. Diatoms, represented by 86 species, were studied in more detail than the other algal groups. Diatom diversities usually ranged from 2 - 4, indicative of unpolluted waters. Diatom cell numbers were low and typical of low nutrient waters. Algal species from all the groups including the blue-green *Nostoc verrucosum*, the Chrysophyte *Hydrurus foetidus* and the diatom *Hannaea arcus* have adaptations to live in the cool, low-nutrient, flowing waters of the Flathead River Basin.

It seems clear that the planktonic algae are actually derived from sloughed off periphytic algae. Planktonic algal numbers are low and there are always more dead than live cells. Furthermore, 97 percent of the planktonic forms are considered to be typical periphytic species. Most diversities were near 2 but sometimes less during periods of low cell numbers, probably reflecting changes in the release of cells from the periphytic community rather than a polluted condition.

Benthic macroinvertebrate densities ranged from 200-7500 organisms m^{-2} with the lowest number occurring in April and numbers generally increasing to a September maximum. The fauna was comprised primarily of individuals and taxa belonging to the Insecta orders; Diptera, Ephemeroptera, Plecoptera and Tricoptera. Most sample sites had between 24 - 26 taxa and Shannon-Wiener diversities were usually between 2.0 - 4.0, indicative of unpolluted waters. Macroinvertebrates were also categorized into pollution sensitive, facultative, and tolerant organisms and in all cases sensitive and facultative organisms accounted for 90 percent or more of the population. In the majority of cases greater than 50 percent of the population were defined as pollution sensitive organisms.

F. The Sensitivity of the Aquatic Biota below the International Boundary to changes in Water chemistry

Species of algae and macroinvertebrates were very similar at all our stations (covering a distance of approximately 44 km) on the Canadian section of the North Fork of the Flathead River. Attached algae and macroinvertebrate data from the U.S. section was not available for review but U.S. phytoplankton and chemical data reviewed during this study were found to be similar to our Canadian data somewhat confirming the similarities above and below the International Boundary. Since the aquatic biota downstream of the International Boundary are also likely adapted to low nutrient unpolluted waters, their sensitivity to possible changes in water chemistry would be similar.

XII SUGGESTED ADDITIONAL STUDIES PRECEDING COAL MINING DEVELOPMENT

The results and observations obtained during this one year study have identified supplementary or complementary information needed to more effectively meet the objective of chatacterizing the aquatic environment prior to development. The following list contains examples of the type of information identified:

- Additional phosphate, barium, and other heavy metal measurements during low flow periods in sediment, biota, groundwater and surface water.

  Only two sampling trips were conducted in sub-zero conditions during the low flow period in the 1975-76 winter but results indicated that certain parameters such as barium and phosphorus were high at this time.

- Supplementary data on attached algae collected during the winter before freshet including measures of productivity, species composition and metal uptake.

  A winter sampling program for algae was not undertaken in this study. There are indications that groundwater contributes significantly to the flow in the winter thus leading to changes in water chemistry and in turn possibly algal productivity and species composition.

- In situ and/or algal bioassay using sediments from the Cabin Creek area.

  Added information from bioassay studies would better predict the effects of coal mine development on the algal population.

- Measurements of present levels of polycyclic aromatics in groundwater, surface water and possibly biota.

  These additional measurements would further assist in assessing the impact of the proposed coal development.

XIII SUGGESTED MONITORING FOLLOWING THE INITIATION OF COAL MINE DEVELOPMENT

Although a proposal for a detailed program to monitor water quality during mining operations was not an objective of this study, some suggestions for monitoring based on information and knowledge acquired can be made. The measurements suggested should supplement the requirements set forth in the Guidelines for Coal Developments (B.C. Environmental and Land Use Committee, 1976).

- The concentrations of the metals Cu, Zn, Pb, Hg, and Ba and other chemical parameters should be monitored at the time biota are collected to assist in correlating biological and chemical data. Sampling before and after freshet, during mid summer and before freeze up will provide representative data.

- Particular attention should be paid to a algal abundance and species composition. The algal species *Hannaea arcus*, *Hydrurus foetidus*, and *Nostoc verrucosum*, are indicative of low nutrient waters, and are useful indicators of change in the aquatic environmental.

- Total numbers of Diptera, Tricoptera, Plecoptera, and Ephemeroptera (with indentification of Ephemeropterans to the family or generic level as was done in this study) should be monitored since they provide effective indicators. If Ephemeroptera abundance or taxonomic composition change then the other invertebrates should be identified to the family or generic level.

ACKNOWLEDGEMENTS

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GLOSSARY

ALGAE (ALGA - Singular; ALGAL - Adjective)	A vast array of plants of approximately 1,800 genera and 21,000 species which are highly diverse with respect to size, physiology, biochemistry and reproduction. All algal phyla lack a structured archegonium (where reproductive cells are produced) such as is found in all other plants.
ANOVA (Analysis of Variance):	The analysis of variance is a method for dividing the variation observed in experimental data into different parts, each part assignable to a known source, cause or factor.
BACILLARIOPHYCEAE:	See diatoms.
BENTHOS (BENTHIC - Adjective):	Flora or fauna found at the bottom of a river, lake or sea from the water's edge to the greatest depth.
BLUE-GREEN ALGAE:	A phylum (Cyanophyta) of primitive algae which are blue-green in colour and which have no obvious internal cellular structures such as chloroplasts.
CHLOROPHYLL:	General name for green fat-soluble photosynthetic pigments.
CHLOROPLAST:	A structure within a plant cell which contains the green pigment chlorophyll; where energy from sunlight is "trapped" in the chloroplast and used in manufacture of complex organic matter, especially sugar, from simple inorganic raw materials.
CHRYSOPHYCEAE:	A class of algae within the phylum Chrysophyta. Cells are usually golden in appearance and have several distinctive features including apical flagellae (1 or 2) and usually a chrysolaminarin storage product.
CHRYSOPHYTA:	An algal phylum whose cells appear yellow-green or yellow-brown in colour. Bacillariophyceae (diatoms), Chrysophyceae and Xanthophyceae are all classes within the phylum.
CLASS:	Taxonomic category which is a major subdivision of a phylum and which includes one or more orders which have certain phylogenetic characters in common. (See taxonomic category.)

CHLOROPHYTA:	See green algae.
CYANOPHYTA:	See blue-green algae.
DIATOMS:	A class (Bacillariophyceae) of algae within the phylum Chrysophyta. Diatoms are characterized by having cell walls of silica and a typical golden-brown colour.
DIVERSITY:	A term used to express the amount of "structure" or "richness" in a community; represented by the number of different species it has, and often also by the number of individuals within each species. Communities of high diversity are characterized by large numbers of species with no single species overwhelmingly abundant; those of low diversity contain few species some of which have a great many individuals. High diversity is characteristic of relatively undisturbed, unpolluted waters. Low diversity is often associated with disturbed, stressed or polluted waters, but not invariably so.
DRIFT:	Term applied to macroinvertebrates which leave their benthic habitat and "drift" in the river current.
EPILITHIC:	Growing on rocks.
EPIPHYTIC:	Growing on plants.
EURYTOPIC:	Having an ability to live in a wide range of ecological conditions, i.e. being able to live in oligotrophic, mesotrophic or eutrophic waters.
EUTROPHIC:	An aquatic habitat richly supplied with nutrient materials and hence very productive; eutrophication refers to the enrichment of an aquatic habitat either gradually by natural processes or rapidly and often excessively by effects of man.
FACULTATIVE:	A term used in this report to characterize macroinvertebrates which can live in either polluted or unpolluted waters.
FAMILY:	Taxonomic category including one or more genera which have certain phylogenetic characters in common. (See taxonomic category.)
FAUNA:	Collectively, the animal life of any particular area.

FLORA:	Collectively, the plant life (in this report algal life) of any particular area.
FRUSTULE:	One half of a diatom cell; the two frustules which make up a single diatom cell fit together like a pill box with overlapping edges.
GENERA (GENUS - Singular):	Taxonomic category including one or more species which have one or more fundamental characteristics in common. (See taxonomic category.)
GREEN ALGAE:	A phylum (Chlorophyta) of algae characterized by their green colour; this turns black when starch stains such as iodine are applied.
MACROINVERTEBRATES:	Invertebrates such as insects which can be easily recognized with the naked eye, microscopic invertebrates such as rotifers are not included.
OLIGOTROPHIC:	An aquatic habitat poorly supplied with nutrient materials and therefore very unproductive.
ORDER:	Taxonomic category including one or more families having certain features in common. (See taxonomic category.)
PERIPHYTON (PERIPHYTIC - Adjective):	Algae which grow attached to or on aquatic substrates such as rocks, logs, mud or submerged plants.
PHYLA (PHYLUM - Singular):	The large principle divisions of the plant or animal kingdom. (See taxonomic category.)
PHYTOPLANKTON:	Algae which drift freely in the water rather than being attached to any substrate.
PLANKTON (PLANKTONIC - Adjective):	Collectively, all those organisms (plants or animals) suspended in the water.
SENSITIVE:	A term used in this report to characterize macroinvertebrates which can live only in unpolluted waters.
SPECIES:	Group of organisms which actually (or potentially) interbreed and which are reproductively isolated from all other such groups; the fundamental category of taxonomic classification. (See taxonomic category.)

TAXA (TAXON - Singular): General term that can be applied to any taxonomic category.

TAXONOMIC CATEGORY: Scientific naming of organisms and their classification with reference to their precise position in the animal kingdom or plant kingdom. A hierarchy of categories is used as follows:

Kingdom
  Phylum
    Class
      Order
        Family
          Genus
            Species

TOLERANT: A term used in this report to characterize macroinvertebrates which can be found in highly polluted waters.

XANTHOPHYCEAE: A class of algae within the phylum Chrysophyta (Xanthophyceae is often considered to be a separate phylum). Cells are yellow-green in colour and have several distinctive features including two apical flagellae of unequal length and cellulose or pectin cell walls.

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