ANALYSIS OF PATTERNS IN ALGAL COMMUNITY STRUCTURE IN

THE NORTH ALOUETTE RIVER WATERSHED, BRITISH COLUMBIA

by

91

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ABSTRACT

Patterns in algal community structure and physiochemical characteristics
of streams and one impounded subalpine lake in the mountainous North
Alouette River watershed, British Columbia, were described for one year
from June 1977 to June 1978. In this period, 266 algal taxa were recognized,
of which 59 were previously unrecorded in the province. The streams were
characterized by an epilithic flora consisting predominantly of unbranched
Chlorophyta and secondarily by both branched and unbranched Cyanophyta.
Bacillariophyta (diatoms) were species rich (over 100 taxa), but were at all
times relatively unimportant in the streams, although frequently dominant
in the epipelon of Jacob's Lake. Species of Rhodophyta were locally
abundant only in shaded habitats. Many epilithic and epiphytic species
were "host" specific in their substrate preferences.

Stream water in the North Alouette was slightly acid (pH 6-7) and
nutrient poor, the relative order of anions being SO_4^{2-} > SiO_2 > Cl^- > NO_3^-
> PO_4^{3-} and cations Ca^{2+} ≃ Na^+ > Mg^{2+} > K^+ > NH_4^+. $Fe^{2+/3+}$, Mn^{2+}, and Al^{3+}
were not detected in the dissolved fraction. Other variables indicated
this to be a rapidly flowing (often > $1m\ sec^{-1}$), cool (2-18°C seasonally),
poorly buffered ($HCO_3^- = .06-.40\ meq\ 1^{-1}$), and highly heterogeneous environ-
ment. Stations along the stream gradient differed in conditions of slope,
current velocity, degree of shading, and substrate size, but not in
temperature, pH, and possibly nutrient chemistry.

A principle coordinates analysis (P-Co-A) of seasonal succession at
one station (Station 1) revealed a cyclic pattern characterized by sequences
of gradual and abrupt changes in species composition. Temporal extinction
of dominant species did not occur, as has been shown for phytoplankton

populations in lakes. Current velocity, depth, temperature, Cl^-, and SO_4^{2-} were significantly correlated ($P<0.05$) with most of the seasonal variability in the algal community. A smaller amount of the seasonal change was correlated with the flux of dissolved cations. P-Co-A also exposed similarities between six stations within the watershed which were not consistent seasonally, and gave no evidence of distinct zones. Distribution of algal species within Station 1 in May shown by cluster analysis, occurred roughly in two groups, corresponding to near-shore and midstream habitats.

The general heterogeneity of algal distribution and the occasional disturbance by flooding gave rise to periodic peaks in diversity, although many common species never became abundant. Hence, no clear-cut relation was realized between the physiochemical environment and species diversity. Hypotheses are generated, suggesting that (1) distribution of red algae was shade limited; (2) diatom dominance was limited by nutrient chemistry; (3) the even pattern of seasonal succession was interrupted by periodic events, such as nutrient pulses and floods; and (4) a large degree of species coexistence was provided by these periodic disturbances.

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I. INTRODUCTION

Studies of algal communties in flowing waters have followed two

general approaches, one concerning metabolic or functional mechanisms, and

a second examining structural aspects. The descriptions of pattern in

community structure have been useful in recognizing how different ecosystems

generally are organized (May, 1976) and have specifically provided insight

into the complexities of stream communities (Patrick, 1975). Such works

for algal communities in streams have dealt with seasonality (e.g., Blum,

1957; Moore, 1977a, b), patterns of distribution (e.g., Kawecka, 1971;

Squires et al. 1973), and species diversity (Patrick, 1967, 1970; Archibald,

1972). The very few works on algal communities of streams in British

Columbia (Stockner and Shortreed, 1976, 1978) have dealt largely with

functional relations (nutrients and production), whereas studies using the

second approach, community structure, are unknown for the province.

Spatial and temporal structure in terrestrial plant communities have

often been studies through the use of multivariate statistical techniques

(Dale, 1975) and these techniques have been applied to problems in lake

phytoplankton (Levandowsky, 1972; Allen and Koonce, 1973; Bartell et al.,

1978), and both estuarine (McIntire, 1973) and stream (Hufford and Collins,

1976, Fabri, 1977; Leclercq, 1977) diatoms. No studies are known, however,

which assess the entire (diatom and non-diatom) community of algal species

in streams, using such methods.

The objectives of this study are to provide preliminary information on

the taxonomy and community ecology of the algae in a British Columbia stream

ecosystem, from a typical coastal mountain watershed. Community structure

(Whittaker, 1970) is described here in terms of growth habits of the species

the spatial distribution and diversity of communities in different reaches of the watershed, the spatial and seasonal variation within one community, and the relation between these patterns and the physiochemical environment. Multivariate methods and other ecological criteria are used to produce meaningful patterns from complex variations in the biotic and abiotic environment. These data are used to produce hypotheses as to how the structure of one algal community might differ from planktonic and other stream systems.

II. THE ENVIRONMENT

A. LOCATION

The North Alouette River is located in southwestern British Columbia
(Fig. 1A) along the southern slopes of the Coast Mountains, approximately
50 km east of Vancouver. It is a broad mountain stream situated in a
coastal coniferous forest, typified by many fast stretches over rugged
terrain. The stream's origin (49° 22'N; 122° 30'W) lies at an altitude
of ca. 1500 m near the peak of Mt. Blanshard and from there runs in a
southwesterly direction. At its completion (49° 16'N; 122° 43'W) it is
near sea level, where it joins the south fork of the Alouette River. These
flow into the Pitt River at a point 6 km upstream from a junction with the
Fraser River. The catchment area of the combined north and south forks of
the Alouette River has been estimated at 208 km^{2} (Benedict et al., 1973).

The upper reaches (8.7 km) of the stream are within Golden Ears
Provincial Park (see Fig. 1B) which then continues through the University
of British Columbia Research Forest (4.9 km). The lowest portion (10.0 km)
is within the municipality of Maple Ridge. Another segment of the watershed
is Jacob's Creek, a length of about 6 km, excluding all of its minor
tributaries. This secondary system in large part is within the Research
Forest and includes a number of small subalpine lakes. One of these,
Jacob's Lake (often as Marion Lake) is considered in this study. This and
the remainder of the collecting stations shown (Fig. 1B) will be discussed
later.
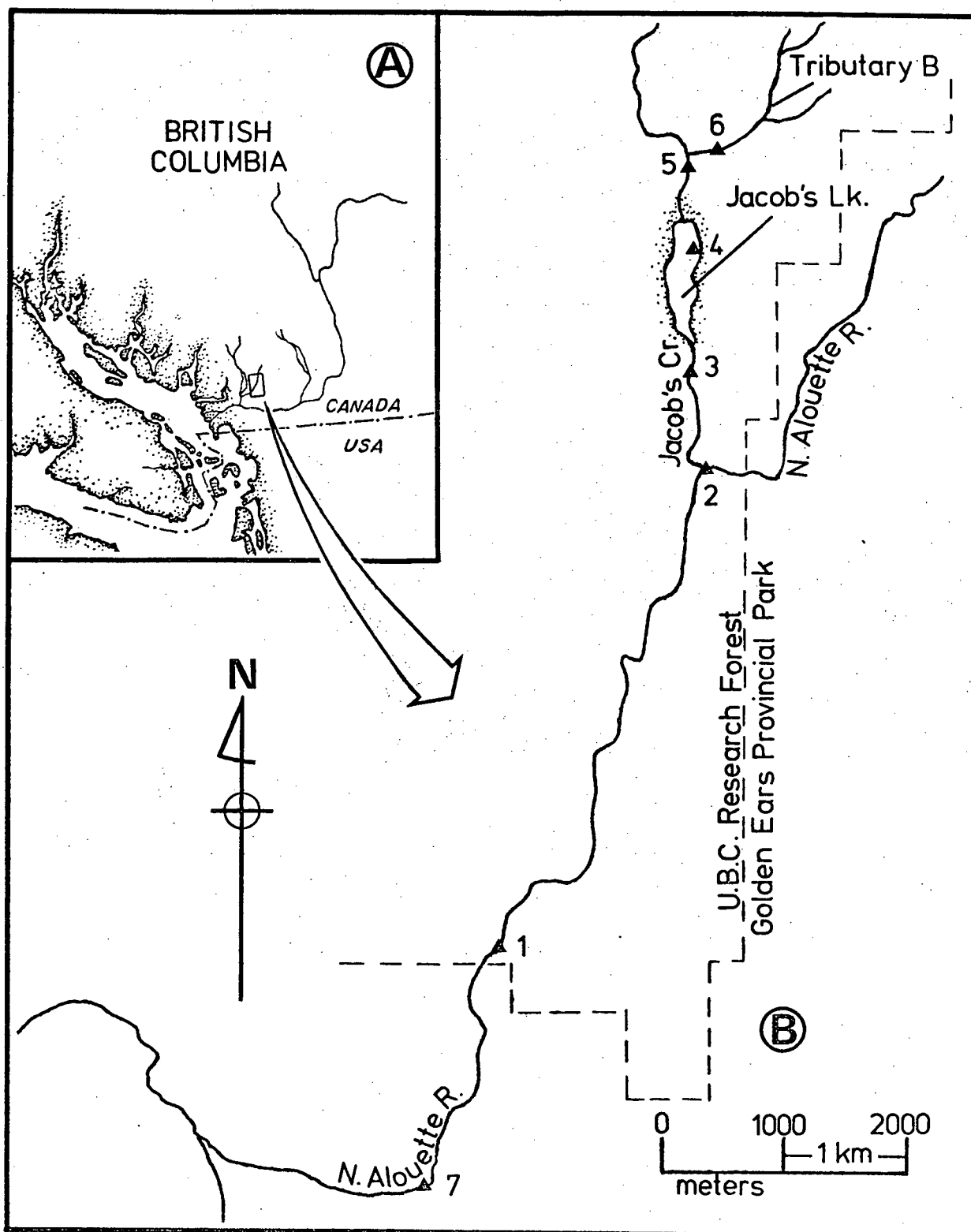
Figure 1. The southern portion of British Columbia, showing the
general location of the North Alouette River watershed (A), and
a detailed map of the positions of the sampling stations within
the watershed (B).

B. TOPOGRAPHY AND GEOLOGY

The mountainous slopes of the river basin run rather steeply, averaging $63.5^{\circ}/oo$, but varying widely from about $180^{\circ}/oo$ to $7^{\circ}/oo$. Along much of the segment studied, the stream lies within a narrow ($\sim.5$ km) V-shaped canyon. The streambed is rather wide, averaging about 15 m. Due to extreme flow, anchored substrate consists of boulders frequently greater than one meter in diameter. The tributary Jacob's Creek system is less severe, with an average slope of $23.8^{\circ}/oo$ and mean width of 9 m. The extreme physiography of the study area is considered typical of streams and small rivers in the Coast Mountains (McKee, 1972).

The geology and glacial history of the region have been summarized thoroughly by Roddick (1965) and Armstrong (1957, 1961) so that only a brief description is given here. During the Pleistocene, the area experienced probably three major glaciations. The ice sheet (by most estimations) covered the region as recently as 11,000 years B.P. (Armstrong, 1957). Deposits indicate that when the land was depressed, only the lowest reaches of the North Alouette were under sea water. Mathewes (1973) has shown that marine deposits occur up to present-day elevations of 107 m. This presumably would include the lowest two sampling stations (see Fig. 1B).

The rocks in the streambed are acid granitic and consist largely of quartzdiorite, diorite, and gabbro (Roddick, 1965). These materials are recognized as poorly soluble and lend little in the way of dissolved minerals to the water (Northcote and Larkin, 1963; Golterman, 1975). Through humic substances of the parent material and large numbers of boggy areas, the waters of the catchment have a characteristically yellow-brown color.

C. CLIMATE AND VEGETATION

Climate in the area has been classified (Köppen, 1936) as Cfb; a warm
maritime-mesothermal, which is humid to rainy. Conditions are characterized
by mild temperatures with frequent cloudiness. Mean annual rainfall is in
excess of 220 cm. Summers are cool and relatively dry, whereas most of the
precipitation occurs during the winter. The driest month, however, may
have up to 16.5 cm of rainfall (Krajina, 1969). Snow is infrequent at
lower elevations, and may contribute less than 1% of the total annual
precipitation (Krajina, 1969), although at elevations over 350 m it may
accumulate for a number of months.

All portions of the watershed studied are located within the Coastal
Western Hemlock biogeoclimatic zone (Krajina, 1965, 1969). The stream
source and some upper elevational reaches not considered here lie within
subalpine and alpine tundra zones. The forest consists primarily of Tsuga
heterophylla (Raf.) Sarg., Pseudotsuga menziesii (Mirbel) Franco., and
Thuja plicata Donn. The understory is diverse, and the shrubs include
Rubus spectabilis Pursh, Gaultheria shallon Pursh, and Vaccinium parvifolium
Smith. The ferns Polystichum munitum (Kaulf.) Presl. and Blechnum spicant
(L.) Roth are also common, as well as many mosses. The riparian vegetation
differs somewhat, and Alnus rubra Bong., Acer circinatum Pursh, A. macro-
phyllum Pursh, Populus trichocarpa T. & G., and Oplopanax horridum (Smith)
Miq. occur. For further details on the vegetation in this area, Orloci
(1965), Klinka (1976), and Krajina (1965, 1969) should be consulted.

D. HISTORY OF USE AND RESEARCH

The study area lies within forests which have burned periodically over the past 400 years and logged in some portions by a number of private logging companies between 1924 and 1931 (Cochrane, 1972). Logging (clear-cutting) and planting operations are still being carried out by the U.B.C. Forestry classes for training and funding purposes. The watershed nonetheless contains many old growth stands commonly 200 to 300 years in age, and some as much as 800 years (Klinka, 1976). Secondary growth in the vicinity of the stream varies in age from relatively young 20 year, to 130 year old trees, largely of planted Douglas fir. The area within and adjacent to the Research Forest includes many roads for access in logging and research. Public usage is restricted to hiking trails, and further uses (e.g., hunting, fishing) have been prohibited. Although the lowest 10 km of the North Alouette River lie within the municipality of Maple Ridge, it is not subject to any apparent effects of pollution. The North Alouette River has been proposed for use as a supplementary water supply for Maple Ridge (G.V.W.D., 1961; cited in Cochrane, 1972). The proposals of dam construction and reservoir management for this system at present have not been undertaken.

Research in biological and forestry related fields in the immediate area have been extensive, owing in large part to the establishment of the forest for research purposes in 1949. A few works are of relevance to the present study. Klinka (1976) considered terrestrial vegetation and plant synecology, including surficial geology and soils. Other significant studies included the palynology (Mathewes, 1973), road and bridge construction (Pasicnyk, 1976), and water use (Cochrane, 1972) in the North Alouette watershed, as well as nutrient chemistry of streams in an adjacent

(Spring-East Creek system) watershed (Feller, 1977).

The majority of published work on aquatic biota resulted from the IBP studies of Jacob's (Marion) Lake, whose objective was to determine the factors which control energy transfer in the lake ecosystem. The work was summarized by Efford (1967) and a more complete literature assembled by Hall and Hyatt (1974). Accounts of algal communities within the program (Dickman, 1969; Gruendling, 1971) and separate from it (Stein and Gerrath, 1968; Kristiensen, 1975) have been restricted to lakes and ponds.

E. DESCRIPTION OF SAMPLING STATIONS

In this study the North Alouette will be regarded as a stream, contrary to its name. This is owing to its conditions of slope, current velocity, large substrates, and other characters (see Ricker, 1934; Illies, 1961). The stations were selected as representative of the range of conditions present over the length of the stream. These were based on the following criteria:

(1) reasonable access so that necessary equipment and materials were brought into the field;

(2) lack of influence from human disturbance; and

(3) a diversity and overlap of obvious physical characteristics, particularly current velocity, shading, and substrate.

The seven stations are distributed along the watercourse as shown in Fig. 1B. Station 1 is the site of most intensive investigation and is given a more thorough description than the other six stations. A length of ca. 50 m was used for sampling at these stations and nearly a 100 m segment at Station 1. The use of stream orders follow Strahler (1964) and for flow

classes, Bishop (1973). In the latter: cascades are defined as extremely rapid, turbulent ("white") water; riffles are moderately agitated or laminar; and pools are recognized to have little or no flow, and are often deep.

Station 1 represents the lowest segment of the stream (130 m elev.) which is rapidly flowing. It is a third (3°) order tributary with current frequently averaging 1 m·sec^{-1}. Substrate consists of large and small boulders with few small stones. The mean size is between 75-100 cm in diameter. Riffles are most common, although cascades are also present. Pools are less frequent, being restricted to the shoreline and leeward sides of large boulders. Depth is variable, both within the basin and seasonally with the mean depth ca. 30 cm.

Station 1 shows a pronounced difference in physical conditions with respect to nearness to the shore. The basin is wide, nearly 18 m, hence only about 25% of the stream is covered by canopy. Midstream is character-ized by greater flow and sunlight availability, with extreme algal growth. Algae are primarily attached in encrusting and filamentous forms. The moss, Blindia acuta (Hedw.) B.S.G., is the predominant bryophyte in this portion, particularly in areas of extreme flow. Along the shore, the waters are pooled and shaded, and the algal growth forms are largely upright tufts and mucilaginous films. The leafy liverwort, Jungermania obovata Ness is the common bryophyte in this shore habitat. Local accumulation of detritus is present during low flow periods.

Of the other stations, five lie upstream from the main Station and one downstream (Fig. 1B). The downstream Station 7 occupies an area of reduced slope and current, consisting of riffles and pools with few cascading reaches. By this stage, the North Alouette is a fourth order (4°) tributary occupying land (15 m elev.) which is largely Fraser River floodplain (Armstrong, 1957), unlike any of the other stations.

Station 6, the uppermost (330 m elev.) site, is an unnamed second order (2°) creek of the Jacob's Creek system. It will be referred to as "Tributary B". The station is a steep series of cascades and pools in a narrow (4 m) streambed and has extensive overstory shading. Depth is highly heterogeneous and pools may be greater than 1 m deep.

Less than 500 m downstream from Station 6, Tributary B flows into the upper arm of Jacob's Creek, also a 2° tributary. This is the location of Station 5. Below the junction, the stream order is increased to 3° and is near the bottom of the Jacob's Creek valley (305 m elev.) where the current slackens considerably. The substrate consists of small stones and few large rocks. Flow patterns are predominantly pools with riffles very widely spaced. The stream is alternately shaded and open. An emergent vascular plant, Juncus ensifolius Wikst. is found in the pools during the summer.

Jacob's Lake is Station 4 (ca. 302 m elev.) and receives inputs primarily from Tributary B and Jacob's Creek. It is a small bog lake with a mean depth of only 2.4 m (Efford, 1967). The bottom consists of soft mud and ooze. This in conjunction with the rapid flushing rate of less than three days during high flow has resulted in the benthic components being of greater importance than the planktonic (Efford, 1967; Hargrave, 1970). Recently, however, construction of beaver dams near the lake outlet has resulted in a rise in the lake level as well as reduced outflow. Littoral development by a number of macrophytes include Nuphar polysepala Engelm., Potamogeton natans L., P. epihydrus Raf., Menyanthes trifoliata L., and Isoetes occidentalis Henders (Gruendling, 1971). The recent invasion of Utricularia intermedia Hayne has been observed, but was not reported previously.

Below the lake, ca. 0.5 km downstream on Jacob's Creek is Station 3 (elev. 300 m). The water runs smoothly until reaching a series of jagged rock outcrops where riffles form. Cascades are infrequent and some deep pools form. Jacob's Lake tends to exert a regulating effect on flow so that extremes are not as pronounced as in other stations. Shading is moderate and much of the stream receives nearly full sunlight. The growth of Utricularia extends to this point. The sponge Spongilla lacustris L. is common throughout much of the year.

Jacob's Creek, which joins the North Alouette River 1 km below Station 3, is a 2° tributary before the junction. Station 2 is located at this junction and is 4.1 km upstream from the main Station (1). Station 2 is at an elevation of 208 m and is much like Station 1 in flow regime, substrate, and shading.

III. MATERIALS AND METHODS

A. THEORETICAL AND PRACTICAL CONSIDERATIONS

The array of species in the stream is organized (sensu Hutchinson,
1953) as a scattering of clusters or patches which appear in some instances
to be random and at other times, ordered in some more definite way. Ideally
then, these individual clumps should be examined individually, rather than
assuming homogeneity and assessing the association(s) only as a whole. The
physical and chemical environment is also in some ways heterogeneous, with
respect to changes both in space and time. Some compromise should be made
which will adequately portray these subtleties, but restrict the number of
samples and measurements to a workable size. Only Station 1 is considered
in detail for within-habitat variations in the algal community and finer
grained measurements of abiotic factors.

The diversity in morphology of the algal species in this system
individually and collectively also presents some problems with respect to
methodology. In planktonic systems, a basic unit for species enumeration
is the cell (e.g., Vollenweider, 1969). In terrestrial environments or
with macroalgae, plants or plant weight can be used for this purpose
(Mueller-Dombois and Ellenberg, 1974; Holme and McIntyre, 1971, respectively).
The qualities of both are found in the lotic system, where microphytes
and macrophytes may each become dominant. If mixed stands and epiphytes
are also considered, the traditional phytoplankton techniques become
entirely inappropriate. In this study, the relative proportions of the
species are quantified without recognition of absolute amount. These values

could, if desired, be related to estimates of total algal biomass measured by chlorophyll or carbon (Marker, 1976; Bott et al., 1978; Tett et al., 1978).

A further consideration is that of inputs of algal inocula from lake sources, primarily Jacob's Lake. The means of distinguishing "accidental" species from opportunistic or merely ubiquitous ones is not clear. However, some lake species may be "aggressive" colonizers and represent something more than transient components from the drift. For this, a classification of growth forms (see Section III-D) is proposed, and this is used in conjunction with differences in relative abundance to answer this problem.

B. COLLECTION OF ALGAL SAMPLES

Many technical problems in sampling lotic algae are considered by Sanders and Eaton (1976), and some of their recommendations are incorporated here. Artificial substrates were not used in the bulk of this study in that, (1) a number of authors (Sladeckova, 1962; Tippet, 1970; Siver, 1977; Kann, 1978; Munteanu and Maly, 1978) found their use to be selective or unrepresentative, and, (2) the complexities mentioned previously (III-A) which may be fundamental to understanding aspects of community structure, are eliminated by creating a uniform microenvironment.

All descriptions and methodology in this section will refer to Station 1 unless otherwise mentioned. The stream was crossed with a series of transect lines using 0.5 cm diam. nylon rope. The transects were placed perpendicular to stream flow at ca. 25 m intervals. The lines were marked in decimeter points along their length (after Blum, 1957). Sampling points were selected from a stratified series for routine collections, following

Cummins (1962). Below a given point the nearest ten boulders perpendicular to the transect with algal patches were selected for sampling. These were generally within a one meter length and were combined in one sample representative of a particular locality in the stream. Initially, 12 of these combined samples (=120 points) were taken, until time restrictions reduced this to an average of 8. Methods for more detailed comparisons are discussed in Section III-E.

The apparatus used for removing the algae and bryophytes at all stations was a modification of the half-bottle designed by Douglas (1958). In the streams studied, substrates with algal assemblages were frequently larger than could be easily removed. Two 1-liter polypropylene bottles were fused together and fitted with a strip of 8 mm thick foam rubber around the neck, extending 3 mm beyond the rim. This was fastened with a 1 cm diam. rubber vacuum hose, which had a heavy wire inside to secure it. This allowed for a reasonable seal against a submersed rock so that water plus algae were isolated from the current. The scraper follows the original design of Douglas (1958). The loosened material was siphoned off using a large bore pipette attached to rubber tubing. For awkward angles and in calm waters, a sharpened, U-shaped spatula was employed by hand. Most conditions allowed these procedures to be made in hip-length boots, but wet suits were worn during winter and for peak flow periods.

At Jacob's Lake (Station 4), a series of five horizontal plankton tows were made using a #25 mesh Wisconsin net. Epiphytic collections were made from scrapes of at least five macrophytes and/or floating logs. Bottom samples were collected using a plastic tube (5 mm I.D.) for ten sediment cores, after Round (1953).

Seventeen collections were made through the year at Station 1, from 7 June 1977 to 29 June 1978. The sampling frequency followed biweekly to monthly periods, largely dependent on flow conditions. During the period mid-November through December, however, sampling was curtailed due to floods. For the other stations, four sampling periods were made over the year, although Station 7 was not initiated until 15 February 1978. All the flowing water stations (2, 3, 5-7) were collected similarly to that at Station 1, but using only 2 to 4 composite samples, each collected from ten separate rocks. In all, samples were returned to the laboratory in an ice chest live and observed upon arrival. They were kept in 3, 5, 10, or $15^{\circ}C$ culture chambers, depending on field temperatures.

C. QUANTIFICATION

As mentioned, absolute values of algal biomass of each species were not estimated. Levandowsky (1972) has indicated that in phytoplankton counts, significant differences between numbers lie primarily in orders of magnitude. The scales of cover used by Braun-Blanquet (1965) and Daubenmire (1968) for terrestrial vegetation and in streams by Backhaus (1967) are adaptable to this lognormal measure. A series of ranks (1-5) used by Holmes and Whitton (1977) were employed in this study, representing the relative amounts of biomass contributed by each species. They are: 0=absent; 1=<0.1%; 2=0.1-1.0%; 3=1.0-5.0%; 4=5.0-10.0%; and 5=>10%. The method was designed for estimation of macrophytes and so was modified for both macro- and microphytes.

Samples in the laboratory were partially shredded with forceps and mixed in a 350 ml observation dish. Four 5 ml subsamples were taken from

each and the combination preserved in Lugol's iodine. Portions of fresh material were prepared for observation and scanned under 300X using a Leitz-Wetzar microscope. Five strips across the field constituted "microtransects" whose width (330 μm) was determined by the width of the ocular grid on the microscope. Cover estimates for the series of strips resulted in an average value for all species encountered in the subsample. This procedure was repeated eight times for a total of forty microtransects per sample. Errors due to randomness were possible but not likely to exceed the broad range (one-half to one order of magnitude) of an assigned cover class.

Diatoms were never highly abundant (rank of 5) in the streams and thus for more than 95% of all species no enumeration was necessary. The few numerous diatom species were assigned their average cover estimate, and further counts and identification of rare cells were made of frustules cleaned as follows. Six 10 ml subsamples were removed from each sample and placed in a 150 ml beaker. Cleaning and mounting followed Patrick and Reimer (1966), using Hyrax ($\underline{n}$=1.71) and made in duplicate. These were examined in the same routine as with fresh material, but observed with a Zeiss standard UPL phase microscope (ocular grid 290 μm wide). In Station 4 diatoms often predominated, so counts of live cells were made before detailed observation of cleaned frustules.

D. TAXONOMIC AND ECOLOGICAL CLASSIFICATION

The general classification of algal groups follows Stein (1975), with the exception of the diatoms, where Silva (1962) is recognized. The Cyanophyta (=Cyanobacteria of Stanier et al., 1978) were identified using

Geitler (1932) and Desikachary (1959). In specific instances, Kann (1972, 1973) was used for Chamaesiphon, Kann and Komárek (1970) and Komárek (1972) for Phormidium, Komárek and Kann (1973) for Homeothrix, and for Tolypothrix, Golubić and Kann (1967) were used.

Preliminary identification of Chlorophyta followed Prescott (1962) and Bourrelly (1966). Specifically, the Ulotrichales and Chaetophorales followed Printz (1964); for the Zygnematales Transeau (1951) and Randhawa (1959) were used in the Zygnemataceae, with West and West (1904, 1905, 1909, 1912), West et al. (1923), Smith (1924), and Stein and Gerrath (1968) used for the Mesotaeniaceae and Desmidiaceae. Chlorella species were identified using Prescott (1962) and Fott and Nováková (1969), although symbionts in distinctly different associations were regarded as ecologically separate in this study.

The Chrysophyta (Chrysophyceae) were identified using Bourrelly (1957) and Huber-Pestalozzi (1941), whereas the Prymnesiophyceae followed Parke et al. (1962). Bacillariophyta taxonomy follows Patrick and Reimer (1966, 1975), Cleve-Euler (1951, 1952, 1953a,b, 1955), Hustedt (1927, 1930a,b, 1961, 1964), Huber-Pestalozzi (1942), and Hohn and Hellerman (1963). For specific problems, Koppen (1975) was consulted for Tabellaria, Belcher and Swale (1977) for Thalassiosira, and Lange-Bertalot (1976) for some species of Nitzschia. The nomenclatural revisions of Van Landingham (1967-1975) were followed, except where superseded by more recent accounts.

Euglenophyta were identified using Prescott (1962) and Huber-Pestalozzi (1955). The Cryptophyta and Pyrrophyta follow Bourrelly (1970) and Huber-Pestalozzi (1950). The general taxonomy of the Rhodophyta agrees with Bourrelly (1970), but specific identification followed the papers of Skuja

(1935), Israelson (1942), Whitford and Schumacher (1969), Haraguchi and Kobayasi (1969), and Mori (1975).

When observed, all species were given a three letter, two number species code and classified according to growth habit(s) when possible. The categories are after Round (1964) and reflect substrate preferences. These are: (a) epiphytic -- attached to plants or other algae; (b) epilithic -- attached to rocks; (c) epipelic -- associated with sediments; (d) metaphytonic -- associated with plants or other substrates but not attached and often from drift; and, (e) planktonic -- freely floating in the water column.

E. HABITAT VARIATIONS

Experiments were designed to examine differences in the algal community temporally and spatially. Spatial heterogeneity and substrate selectivity were examined at Station 1.

Colonization of bare substrates was followed during August 1977. Three granite boulders (ca. 0.5 cm diam.) chosen were similar in weight and texture and scrubbed clean with nylon brushes and surface sterilized with 95% ethyl alcohol. They were placed in a riffle adjacent to each other, where current, depth, and shading were measured to be nearly equivalent for the three. Next to these, three Plexiglas sheets (35 x 22 x 1 cm) were bolted to concrete blocks, after Stockner and Shortreed (1976). One substrate of both types was removed successively after 1, 2, and 4 weeks, following Patrick et al. (1954), Weber and Raschke (1970), Wihlm et al. (1977), and others cited in these. Because replicates were not made, this design was used only to assess differences between substrates and colonization time, not conditions of the stream overall.

In May 1978, a more detailed analysis was made of the variations in the array of species spatially along an apparent gradient of current from one margin of the stream to the other (see Fig. 2). In this, the transect points were located at eight intervals 2 m apart. Samples were taken along perpendicular lines as in routine work (section III-B), but 7 algal patches, rather than 10, were removed along each perpendicular, and these were kept in separate vials. Thus, 56 distinct samples were compared with each other in this matrix. Factors of temperature, dissolved O_2, pH, current velocity, and light availability were also examined along this transect.

F. PHYSIOCHEMICAL METHODS

Field: Temperature was measured using an Etco field mercury thermometer and pH with a Markson (model 85) portable pH meter, accurate to ±0.05 pH units. Both pH and temperature were measured at five points along a given transect and taken at five, two-hour intervals during the sampling day. The variance of these are expressed as a standard deviation from the mean of the 25 measurements. Depth profiles were measured to the nearest cm, and the mean then calculated.

Incident light was determined by means of a Belfort Instruments recording pyrheliometer placed on a rock outcrop which received an average amount of shading as determined by a series of individual measurements. Damage to the instrument, however, prevented continuous data collection. Shading effects due to canopy for this and the gradient analysis were estimated using a Licor (model LI-185A) quantum meter taken at 2.0 m intervals along the transects. Current velocity was measured with a General Oceanics (model 2030) digital flowmeter, taken at 10 points along two transects.

streamflow

TR 3

TR 2

N

TR 1

TR 4
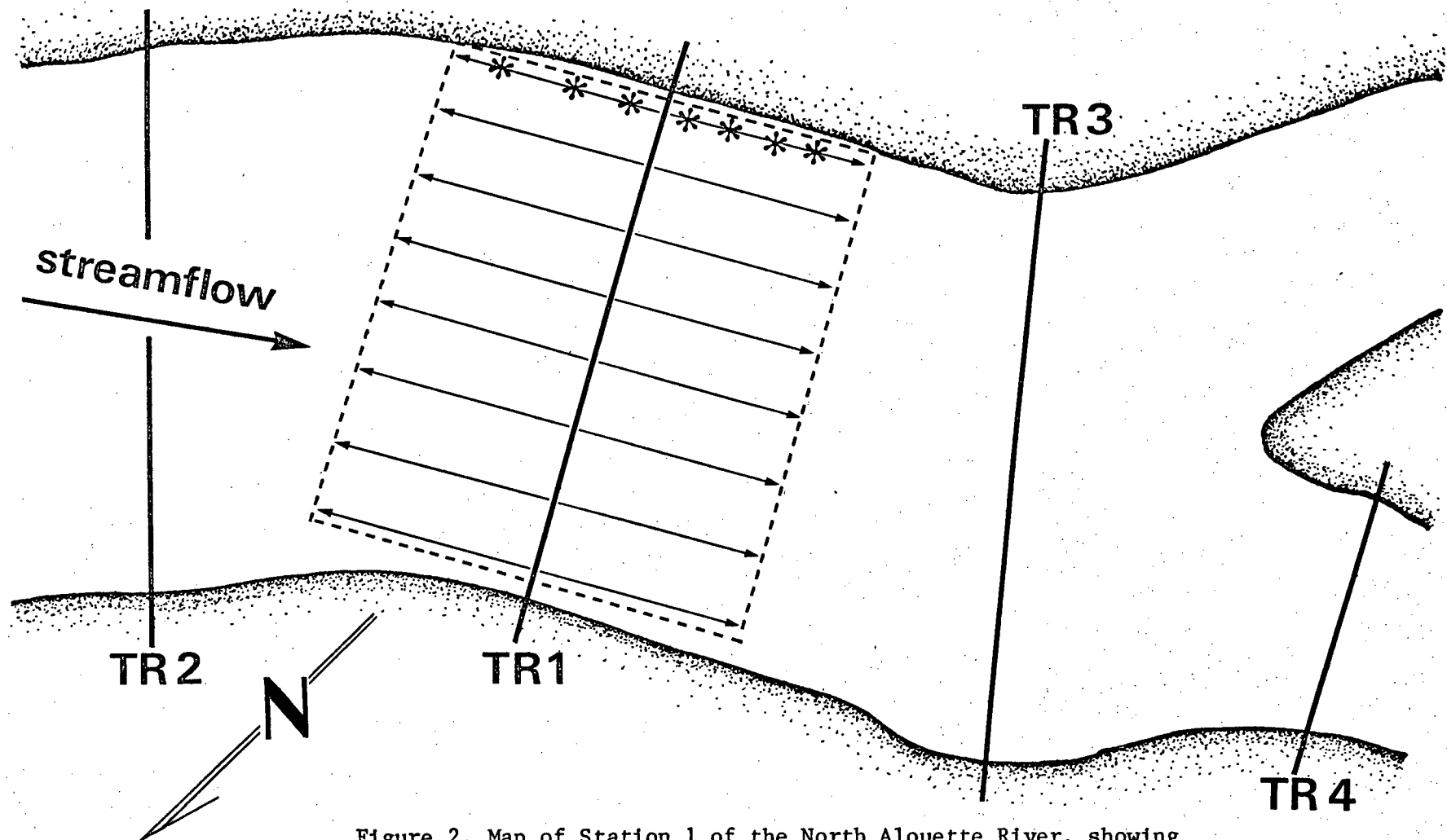
Figure 2. Map of Station 1 of the North Alouette River, showing
location of transects and sampling grid for gradient analysis.

Triplicate measurements were made at each point and then averaged.

All of the above measurements in situ were at Station 1 on the dates of

algal sampling plus one day (29 October 1977) when floods prevented algal

collections. At the other stations, only current velocity, pH, and

temperature were estimated. Station 1 water samples were also taken for

further analysis. Samples for nutrient determinations were collected in

1 liter polypropylene bottles in duplicate, rinsing these with stream water

three times, filled, and capped underwater (after Stainton et al., 1974).

Most regions of the stream were well mixed and thus spatial variations in

dissolved minerals were not considered. A 500 ml water sample was taken

each date for alkalinity (as HCO_3^-) determinations. Five 300 ml water

samples were collected at different points at Station 1 in glass BOD bottles

held underwater. The first two O_2 reagents were added in the field to

prevent losses during storage. All samples were transported to the labora-

tory in an ice chest.

Laboratory: The two nutrient samples were separated and 1 liter was

filtered (Whatman GF/C glass fiber). Both samples were rapidly frozen

($-15^{\circ}C$) for future analysis. The filtering precaution to remove particulate

fractions (Strickland and Parsons, 1972) was later found to have a

negligible effect. At the time of analysis, the frozen samples thawed for

24 hours at room temperature and were well mixed to redissolve any ions

precipitated during freezing (Golterman, 1969).

All anion (PO_4^{3-}, NO_3^-, Cl^-, SO_4^{2-}), dissolved SiO_2, and NH_4^+ concentra-

tions were determined using a Technicon Autoanalyzer II, following standard

methods outlined by the manufacturer (Technicon Industrial Systems, 1971a-d,

1973). Cations (Ca^{2+}, Na^+, K^+, Mg^{2+}, $Fe^{3+/2+}$, Mn^{2+}, Al^{3+}) were determined

using atomic absorption spectrophotometry (Varian-Techtron, Ltd.; model AA-5).

Samples for alkalinity (HCO_3^-) determinations were not frozen but were analyzed within 8 hours of collection. For this, titrations were done using standardized 0.02 N H_2SO_4 (A.P.H.A., 1965) with a pH meter rather than color indicators. Dissolved O_2 levels were determined within 12 hours after acidification via the azide modification of the Winkler techinque (A.P.H.A., 1965). Percent saturation was calculated after Lind (1974).

G. STATISTICAL METHODS

For statistical analysis, the abundance ranks were converted to their median values. This allowed calculation of the mean abundance for each species on a given date and place, but preserving differences in the orders of magnitude. In presenting results of species composition between stations or dates (where total cover values may differ), species importance was used (Whittaker, 1970). The importance ($\underline{I}_a$) of species $\underline{a}$ would be:

$$I_a = \frac{\text{Mean Abundance of One Species}}{\text{Mean Abundances of All Species}} = \frac{\overline{A}_{x_a}}{\sum\limits_{x=1}^{n} \overline{A}_x} \quad , \quad (1)$$

where $\overline{A}_x$ is the mean abundance of species $\underline{x}$ and $\underline{n}$ is the total number of species. This is comparable to relative dominance (Mueller-Dombois and Ellenberg, 1974). The values range between 1, for absolute dominance (i.e., the only species) and 0, if absent. Diversity of species was expressed in two ways. These were simple species number ($\underline{S}$) and species diversity ($\underline{H}'$), using the Shannon-Weiner index:

$$H' = -\Sigma p_i \cdot \ln p_i, \tag{2}$$

where p_i is the relative importance value of the ith species (Shannon and Weaver, 1949).

For multivariate analyses of affinities between dates and stations, an ordination similar to Principle Components Analysis (Orloci, 1966) was used. This method, Principle Coordinates Analysis (P-Co-A), or Gower ordination (Gower, 1966), is more efficient for data in which the number of variables (species) is much greater than cases (dates or stations). The specific program used here is that of Bradfield (1977). The similarity index for this is based on the cosine of the angle between each vector summarizing the abundance of each species. In data with more than two variables, the cosine function takes the form:

$$\text{Similarity between Cases i and k} = S_{ik} = \frac{\sum_{j=1}^{m} x_{ij} \cdot x_{kj}}{\sqrt{\sum_{j=1}^{m} x_{ij}^2 \cdot \sum_{j=1}^{m} x_{kj}^2}}, \tag{3}$$

where x_{ij} is the value of the jth species in case i, x_{kj} is the value of the jth species in case k, and m is the total number of species. When these similarities are computed, a geometric representation of all similarities between all cases is produced, reflected in the distances between their plotted positions. Generally, each component axis contributes successively less of the total variability expressed by all the date-place units. Thus, the first two axes are of greatest importance in any ordination, although the third axis is also given. The nearness of all points

will reveal similarities but does not necessarily classify the cases into groups, emphasizing the continuum nature of species distribution (Mueller-Dombois and Ellenberg, 1974).

A simple linear correlation (Anderson, 1958) was used to compare the seasonal behavior of physiochemical factors with the seasonal succession of species over the year. The coordinate scores provided by P-Co-A were used in defining the temporal variation of the algal community, after Bartell et al. (1978).

For purposes of describing variations within Station 1, additional statistics were employed. Similarity between two assemblages colonizing bare substrates was judged using the Sørensen similarity coefficient:

$$IS = \frac{2 \ MW}{MA + MB} \ , \tag{4}$$

where $\underline{MW}$ = the sum of the smaller of the species abundances of all species in common to both substrates, $\underline{MA}$ and $\underline{MB}$ are the values for all species present on substrate $\underline{A}$ and $\underline{B}$, respectively (Sørensen, 1948). The comparison of species associations along a transect for gradient analysis was made to recognize groups of difference, rather than the continuous nature of the species themselves. For this, a cluster analysis of samples was used (Orloci, 1975). The algorithm was that of Ward (1963).

IV. BIOLOGICAL RESULTS

A. GENERAL TAXONOMIC AND ECOLOGICAL FEATURES

From June 1977 through June 1978, 266 algal taxa were identified from the seven stations (Table 1). 59 taxa are new records for British Columbia (Stein and Borden, 1978) as indicated (*) in the table. The enumeration of species by date for Station 1 and by station for four dates at the other six stations are listed in Appendix A and B, respectively. Although diatoms were extremely rich in species, the streams were typified by stands of green and bluegreen algae.

A few major species exhibited extremes in morphological variability. <u>Phormidium</u> <u>autumnale</u> was common in many stations but within a given stand on any one date many differences were encountered: i) the trichome apex varied from bluntly rounded to tapered-capitate and curved; ii) cell dimensions were not constant $[(4.0)-4.5-5.5-(6.8) \ \mu m$ diam.$]$ within a single filament, and varied from shortened disks to quadrate cylinders; iii) macroscopic color ranged from yellow-brown to dark brown and deep blue-green.

Another common species, <u>Klebsormidium</u> <u>rivulare</u>, was extremely plastic with respect to cell diameter $[(5.5)-6.5-10.0-(11.5) \ \mu m]$ and chloroplast form. The plastid was a flattened plate in 2-8 celled "germlings" but in larger filaments, was a parietal band which extended between half and nearly the entire cell length. This band sometimes was wrapped around the cell interior from one-quarter to one-half the diameter of the filament.

<u>Batrachospermum</u> <u>moniliforme</u> occurred as clumps in pools at all lotic stations except Station 2. Generally, it was of typical morphology and reproduction, with a broad color range of reddish brown to grey-green. It

was observed to perennate in grey or brownish crusts. Sometimes the plumose

thallus would originate from these crusts, and at other times the simply

branched "chantransia" stage would arise from the same. No difference in

the appearance of the crustose growth was observed during the year. Efforts

to maintain crude cultures were not successful.

Table 1 gives information pertaining to the high degree of selectivity

among many species as to growth habit and substrate. 30% (81 taxa) were

exclusive to one of the five defined ecological regimes. Slightly more than

half of these (46 taxa) were encountered in the metaphyton and likely repre-

sent a drift component from an upstream source.

Generally the stream system was dominated by epilithic forms, consist-

ing predominantly of Zygnema insigne, Klebsormidium mucosum, as well as

Phormidium autumnale and K. rivulare, mentioned earlier. In some reaches,

the epilithon was also characterized by Stigonema mamillosum, Bulbochaete

pygmaea, and Audouinella hermanni. One bluegreen alga, Homeothrix varians,

was an encrusting species exclusively restricted to cascading segments

directly under the strike of rapid water. Mougeotia sp. (sterile) was the

only major species that frequently occupied an epiphytic habit. Desmids

and diatoms were ecological "generalists", occupying commonly more than one

habit.

In some instances, growth habits were, as in epiphytic forms, "host"

specific. In particular, the members of the Chamaesiphonales were

restricted to one or two particular substrates. Chamaesiphon confervicola

(Cyanophyta) was the most common of these, and was found attached only to

Zygnema insigne (Chlorophyta). During periods when the host was uncommon,

the epiphyte did not grow on other dominant filamentous species. Clastidium

setigerum was present throughout the year in the North Alouette (Station 1) and nearly all observations were as attached to the moss Blindia acuta and never on associated algae or the rock to which the moss was anchored.

Planktonic species were uncommon, even in Jacob's Lake. Those encountered in lotic stations were amongst filamentous or mucilaginous forms as metaphyton. A comparison of all species from the lake was made with all downstream stations to determine the importance of the lake as an inoculum source (Appendix C). A large proportion of the lake taxa (82%) were transported to the stream (Table 2). Only 27% of all lake species were capable of colonization in an attached habit. Many of these character-istically were dominants in the flowing stations but uncommon in Jacob's Lake, such as Z. insigne or K. rivulare. Epipelic species, predominantly diatoms, reached significant proportions in the lake and were successful colonizers of the streams, although never abundant (rank of 5).

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Table 1. List of species identified from all stations of the watershed, with their assigned species codes and dominant growth habit(s) (* = taxon previously unrecorded in British Columbia; XX = common growth habit; X = growth habit observed but uncommon; -- = not observed in particular growth habit).

CODE	SPECIES	HABIT				
		Epiphyton	Epilithon	Epipelon	Metaphyton	Phytoplankton
	CYANOPHYTA - Chroococcales					
CCØ01	*Chroococcus* sp. (7-9 µm)	--	--	--	--	XX
XEN01	*Coelosphaerium pallidum* Lemm.	X	--	--	XX	XX
GØC01	*Gloeocapsa sanguinea* (C. A. Ag.) Kütz. *	XX	--	--	X	--
MPD01	*Merismopedia punctata* Meyen	--	--	--	X	XX
MIC01	*Microcystis* cf. *marginata* (Menegh.) Kütz.	--	--	--	X	XX
	Chamaesiphonales					
CHM01	*Chamaesiphon confervicola* A. Braun. *	XX	--	--	--	--
CHM03	*C. confervicola* v. *elongatus* (Nordst.) Kann *	XX	--	--	--	--
CHM02	*C. fuscus* (Rostaf.) Hansg.	XX	X	--	--	--
CHM05	*C. incrustans* Grun.	XX	X	--	--	--
CHM06	*C. minutus* (Rostaf.) Lemm. *	XX	--	--	--	--
CHM04	*C. rostafinskii* Hansg. *	XX	--	--	--	--
CLS01	*Clastidium setigerum* Kirchn. *	XX	--	--	--	--
	Nostocales					
ANB01	*Anabaena flos-aquae* (Lyngb.) Bréb.	--	--	--	X	XX
CAL02	*Calothrix epiphytica* W. & W.	XX	--	--	--	--
CAL01	*C. fusca* Born. & Flah.	XX	X	--	--	--
ENC01	*Homeothrix varians* Geitl. *	XX	--	--	--	--
LYG01	*Lyngbya* sp. A (6-7 µm diam.)	XX	--	--	XX	--
LYG06	*L.* sp. B (1.4-2.4 µm)	--	--	--	XX	--
LYG05	*L. bipunctata* Lemm. *	--	--	--	XX	--
LYG04	*L. hieronymusii* Lemm.	--	--	--	XX	--
LYG03	*L. kützingii* Schmid. *	XX	--	--	--	--
ØSC01	*Oscillatoria* sp. A (< 2 µm diam.)	--	--	XX	XX	--
ØSC02	*O.* cf. *nigra* Vauch.	XX	--	--	XX	--
ØSC03	*O.* cf. *splendida* Grev.	--	--	--	XX	--
PHR01	*Phormidium autumnale* (C. A. Ag.) Gom.	--	XX	--	--	--
PHR02	*P. tenue* (Menegh.) Gom.	XX	--	--	X	--
RVU01	*Rivularia minutula* (Kutz.) Born. & Flah.	--	XX	--	--	--
CSP01	*Spirulina* sp. A	--	--	--	XX	--
TXP01	*Tolypothrix penicillata* Thur.	X	XX	--	--	--

Table 1. Continued.

CODE	SPECIES	Epiphyton	Epilithon	Epipelon	Metaphyton	Phytoplankton
	CYANOPHYTA - Stigonemales					
HPL01	*Hapalosiphon* sp. A	--	---	--	XX	--
STG01	*Stigonema mamillosum* (Lyngb.) C.A. Ag.	X	XX	--	--	--
	CHLOROPHYTA - Volvocales					
CDY01	*Chlamydomonas* sp. A	--	--	--	X	XX
EØD01	*Eudorina* cf. *elegans* Ehr.	--	--	--	--	XX
	Tetrasporales					
SHC01	*Schizochlamys gelatinosa* A. Br. ex Kütz.	--	XX	--	--	--
TTR01	*Tetraspora cylindrica* (Wahl.) C.A. Ag.	--	XX	--	--	--
TTR02	*T. lubrica* (Roth) C.A. Ag.	--	XX	--	--	--
	Ulotrichales					
UKL01	*Klebsormidium mucosum* (Boye-Petersen) Silva *et al.* *	--	XX	--	X	--
UKL03	*K. rivulare* (Kutz.) Silva *et al.* *	X	XX	--	X	--
MCP01	*Microspora pachyderma* (Wille) Lag.	X	XX	--	--	--
	Chaetophorales					
CET01	*Chaetospaeridium globosum* (Nordst.) Kleb.	X	--	--	X	XX
DPR01	*Draparnaldia plumosa* (Vauch.) C.A. Ag.	--	XX	--	--	--
SGC01	*Stigeoclonium subsecundum* Kütz. *	--	XX	--	---	--
	Chlorococcales					
AKD01	*Ankistrodesmus falcatus* (Corda) Ralfs.	--	--	--	XX	X
AEC01	*Asterococcus superbus* (Cienk.) Scherff.	--	--	--	--	XX
CRA02	*Characium* cf. *ambiguum* Herm.	XX	--	--	X	--
CRA01	*C. falcatum* Schroed.	XX	--	--	X	--
CØV01	*Chlorella vulgaris* Beij. (zooxanthellae in *Spongilla lacustris* L.)	--	XX	--	--	--
CØV02	*C. vulgaris* Beij. (zooxanthellae in *Ophrydium* sp.)	--	XX	X	--	--
CML01	*Coelastrum cambricum* Arch.	--	--	--	--	XX
ØST01	*Oocystis borgei* Snow	--	--	--	X	XX
PDI01	*Pediastrum boryanum* (Turp.) Meneg.	--	--	X	--	XX
SCD01	*Scenedesmus quadricauda* (Turp.) Bréb.	--	--	--	X	XX
	Oedogoniales					
BUL01	*Bulbochaete pygmaea* Pring.	X	XX	--	--	--

Table 1. Continued.

CODE	SPECIES	Epiphyton	Epilithon	Epipelon	Metaphyton	Phytoplankton
	CHLOROPHYTA – Oedogoniales (Cont.)					
ØED01	*Oedogonium* sp. A (nannandrous; 17-25μ)	X	XX	--	--	--
ØED02	*O.* sp. B (reproduction unk.; 6-7μ)	XX	--	--	--	X
	Zygnematales Mesotaeniaceae					
DSM46	*Gonatozygon monotaenium* de Bary	--	--	--	--	XX
DSM03	*Netrium digitus* (Ehr.) I. & R.	--	--	--	XX	X
DSM12	*N. digitas* v. *naegelii* (Bréb.) Krieg.	--	--	--	XX	X
DSM43	*Spirotaenia condensata* Bréb.	--	--	--	XX	--
	Desmidiaceae					
DSM23	*Bambusina borreri* (Ralfs.) Cl.	--	--	--	X	XX
DSM02	*Closterium abruptum* W.	--	--	--	XX	X
DSM08	*C. abruptum* v. *brevius* W. & W.	--	--	--	XX	--
DSM26	*C.* sp. A (370μm, lunate)	--	--	--	XX	--
DSM35	*C. dianae* Ehr.	--	--	--	XX	--
DSM28	*C. gracile* Bréb.	--	--	--	XX	XX
DSM38	*C. intermedium* Ralfs	--	--	--	XX	XX
DSM32	*C. jenneri* Ralfs	--	--	--	XX	--
DSM18	*C. juncidum* v. *elongatum* Roy & Biss.	--	--	--	XX	XX
DSM13	*C. parvulum* Naeg.	--	--	--	XX	--
DSM14	*C. pritchadianum* Arch.	--	--	--	XX	X
DSM22	*C. setaceum* Ehr.	--	--	--	XX	--
DSM04	*Cosmarium* sp. A (semicells 10 X 12.5 μm; granulate)	--	--	--	XX	--
DSM01	*C. blyttii* Wille	--	--	X	XX	--
DSM56	*C.* spp. B (∿ 20μm)	--	--	--	XX	--
DSM15	*C. caelatum* Ralfs	--	--	--	XX	--
DSM05	*C. monomazum* v. *polymazum* Nordst. *	--	--	--	XX	--
DSM51	*C. obtusatum* Schmid.	--	--	--	XX	--
DSM27	*C. ornatum* Ralfs	--	--	X	XX	--
DSM25	*C.* cf. *pachydermum* Lund	--	--	--	XX	--

Table 1. Continued.

CODE	SPECIES	HABIT				
		Epiphyton	Epilithon	Epipelon	Metaphyton	Phytoplankton
	CHLOROPHYTA - Zygnematales					
	Desmidiaceae (Cont.)					
DSM57	*Cosmarium praegrande* Lund	--	--	--	--	XX
DSM07	*C. reniforme* (Ralfs) Arch.	X	--	--	XX	X
DSM29	*C. simii* Roy & Biss. *	--	--	--	XX	--
DSM19	*C. subcucumis* Schmid.	X	--	--	XX	X
DSM47	*Desmidium baileyi* (Ralfs) Nordst.	--	--	X	--	XX
DSM24	*Euastrum bidentatum* Naeg.	X	--	--	XX	--
DSM50	*E. didelta* (Turp.) Ralfs	XX	--	--	--	--
DSM10	*E. inerme* (Ralfs) Lund.	--	--	X	XX	--
DSM42	*Hyalotheca dissiliens* (Sm.) Bréb.	--	--	--	XX	XX
DSM31	*H. mucosa* (Dillw.) Ehr.	--	--	--	XX	--
DSM44	*Micrasterias radiata* Hass.	X	--	--	X	XX
DSM37	*M. sol* (Ehr.) Kütz.	--	--	--	X	XX
DSM34	*Penium minutum* v. *crassum* W. West	--	--	--	XX	--
DSM11	*P. polymorphum* Perty	--	--	--	XX	--
DSM45	*Pleurotaenium maximum* (Reinsch) Lund	--	--	--	XX	XX
DSM09	*Spondylosium planum* (Wolle) W. & W.	--	--	--	XX	--
DSM54	*S. pulchrum* (Bail.) Arch.	--	--	--	--	XX
DSM48	*Staurastrum arctiscon* (Ehr.) Lund.	--	--	X	--	XX
DSM53	*S.* sp. A	--	--	--	XX	XX
DSM49	*S. gladiosum* Turn.	XX	--	XX	--	--
DSM40	*S. gracile* Ralfs	X	--	X	XX	X
DSM16	*S. muticum* Bréb.	--	--	--	XX	--
DSM20	*S. ophiura* Lund.	--	--	--	XX	--
DSM36	*S. polymorphum* Bréb.	--	--	--	XX	--
DSM06	*S. punctulatum* Bréb.	--	--	--	XX	X
DSM30	*S. teliferum* Ralfs	--	--	--	XX	--
DSM39	*Staurodesmus dejectus* (Bréb.) Teil.	--	--	X	XX	--
DSM41	*Triploceras verticillatum* Bail.	X	--	--	X	XX
DSM21	*Xanthidium antilopaeum* (Bréb.) Kütz.	--	--	--	XX	XX
DSM52	*X. armatum* v. *fissum* Nordst.	--	--	--	--	XX

Table 1. Continued.

CODE	SPECIES	Epiphyton	Epilithon	Epipelon	Metaphyton	Phytoplankton
	CHLOROPHYTA - Zygnematales					
	Desmidiaceae (Cont.)					
DSM55	*Xanthidium cristatum* Bréb.	--	--	--	X	XX
	Zygnemataceae					
MØU01	*Mougeotia* sp. A (diam. ≃ 12 - 34 µm)	XX	XX	XX	X	X
SPI01	*Spirogyra* sp. A (diam. ≃ 27 µm)	X	XX	--	X	XX
ZYG01	*Zygnema insigne* (Hass.) Kutz.	X	XX	--	X	--
ZYG02	*Z.* sp. B (diam. = 20 µm)	XX	--	--	X	--
	CHRYSOPHYTA - Chromulinales					
CIP01	*Chromulina parvula* Conr. *	--	--	--	X	XX
CXP01	*Chysopyxis bipes* Stein	XX	--	--	--	--
	Ochromonadales					
DNB02	*Dinobryon bavaricum* Imh.	--	--	--	--	XX
DNB01	*D. divergens* Imh.	--	--	--	X	XX
MAL01	*Mallomonas caudata* Iwan.	--	--	--	XX	X
MAL02	*M. doignonii* Bourr. *	--	--	--	XX	X
ØCR01	*Ochromonas* cf. *mutabilis* Klebs *	--	--	X	XX	XX
SRN01	*Synura sphagnicola* Korsch.	--	--	X	--	XX
	Prymnesiales					
CRY01	*Chrysochromulina parva* Lack. *	X	--	XX	XX	XX
	BACILLARIOPHYTA - Eupodiscales					
CØS01	*Actinoptychus* cf. *undulatus* Ehr.*	--	--	--	XX	--
CYC02	*Cyclotella meneghiniana* Kütz.	X	--	--	XX	--
CYC01	*C. stelligera* Cl. & Grun.	--	--	X	XX	XX
MEL02	*Melosira distans* (Ehr.) Kütz.	--	XX	XX	XX	X
MEL01	*M. granulata* (Ehr.) Ralfs	--	--	X	X	XX
SDC01	*Stephanodiscus astrea* (Ehr.) Grun.	X	--	--	XX	X
COS02	cf. *Stephanopyxis broschii* Grun. *	--	--	--	XX	--
THA01	*Thalassiosira fluviatilis* Hust. *	--	--	--	XX	--

Table 1. Continued.

CODE	SPECIES	HABIT				
		Epiphyton	Epilithon	Epipelon	Metaphyton	Phytoplankton
	BACILLARIOPHYTA – Fragilariales					
AST01	Asterionella formosa Hass.	--	--	X	XX	X
DAT02	Diatoma anceps (Ehr.) Kirchn.	XX	--	--	XX	X
DAT01	D. hiemale v. mesodon Ehr. (Grun.) *	XX	XX	--	--	--
FGL02	Fragilaria constricta Ehr.	--	--	XX	XX	--
FGL03	F. constricta f. stricta (A. Cl.) Hust. *	--	--	--	XX	XX
FGL05	F. construens (Ehr.) Grun.	--	--	--	--	XX
FGL01	F. crotonensis Kitt.	--	--	--	XX	XX
FGL04	F. pinnata Ehr.	--	--	--	XX	--
SYN02	F. virescens Ralfs	XX	XX	--	--	--
HAN01	Hannea arcus (Ehr.) Patr.	XX	XX	--	X	--
HAN02	H. arcus v. amphioxys (Rabh.) Patr. *	XX	XX	--	--	--
MDN01	Meridion circulare v. constrictum (Ralfs) V.H.	XX	XX	--	X	X
SMB01	Semiorbis hemicyclus (Ehr.) Patr. *	--	--	XX	XX	--
SYN05	Synedra sp. B (22 μm)	--	--	--	XX	--
SYN07	S. sp. C (sigmoid, 20 μm)	XX	--	--	XX	--
SYN04	S. delicatissima W. Sm.	XX	--	--	XX	--
SYN06	S. filiformis Grun.	XX	XX	--	--	--
SYN03	S. rumpens Kütz.	XX	--	--	XX	X
SYN01	S. ulna (Nitz.) Ehr.	XX	XX	X	X	--
TAB02	Tabellaria fenestrata (Lyngb.) Kütz.	X	--	XX	X	XX
TAB01	T. flocculosa (Roth) Kütz.	XX	XX	X	XX	X
TCY01	Tetracyclus lacustris Ralfs	--	--	--	XX	XX
	Eunotiales					
ATN01	Actinella punctata Lewis	--	--	XX	XX	XX
EUN10	Eunotia sp. A (reflexed, 16 μm)	--	--	--	XX	--
EUN21	E. bactriana Ehr.	--	--	XX	X	X
EUN11	E. sp. B (stout, 11 μm)	XX	--	--	--	--
EUN08	Eunotia curvata (Kütz.) Lagerst.	X	--	XX	XX	X
EUN12	E. elegans Østr.	--	--	XX	XX	X
EUN13	E. exigua (Bréb. ex Kütz.)	X	--	XX	XX	XX

Table 1. Continued.

CODE	SPECIES	HABIT				
		Epiphyton	Epilithon	Epipelon	Metaphyton	Phytoplankton
	BACILLARIOPHYTA - Eunotiales (Cont.)					
EUN07	*Eunotia flexuosa* Bréb. ex Kütz.	XX	---	X	XX	X
EUN02	*E.* cf. *hexaglyphis* Ehr. *	--	---	XX	XX	--
EUN19	*E. naeglii* Migula *	--	---	XX	X	--
EUN04	*E. parallela* Ehr. *	XX	---	XX	X	X
EUN01	*E. pectinalis* (Dillw.) Rabh.	XX	XX	X	XX	X
EUN05	*E. perpusilla* Grun. *	--	---	X	XX	XX
EUN14	*E. septrionalis* Østr.	--	---	XX	X	--
EUN20	*E. serra* Ehr.	--	---	XX	--	--
EUN06	*E. serra* v. *diadema* (Ehr.) Patr.	--	---	XX	XX	X
EUN16	*E. soleirolii* (Kütz.) Rabh. *	--	---	--	XX	X
EUN17	*E. sueica* A. Cl.	--	---	X	XX	--
EUN03	*E. tenella* (Grun.) Hust.	XX	XX	--	XX	X
EUN15	*E. vanheurckii* Patr.	--	—	X	XX	XX
EUN18	*E. vanheurckii* v. *intermedia* (Krasske ex Hust.) Patr.	--	---	--	XX	X
PER01	*Peronia fibula* (Breb. ex Kütz.) Ross.*	--	---	XX	XX	--
	Achnanthales					
ACN05	*Achnanthes lanceolata* (Bréb.) Grun.	XX	---	---	XX	--
ACN04	*A. lanceolata* v. *dubia* Grun. *	XX	---	---	XX	--
ACN01	*A. minutissima* Kütz.	XX	XX	---	XX	X
ACN03	*A. stewartii* Patr. *	XX	---	---	XX	X
CNS01	*Cocconeis placentula* v. *euglypta* (Ehr.) Grun. *	XX	XX	---	X	X
	Naviculales					
APH02	*Amphora ovalis* v. *libyca* (Ehr.) Cl.*	--	---	---	XX	--
APH01	*A. coffeaeformis* (Ag.) Kütz.	--	---	---	XX	--
NVA15	*Anomoemeis follis* (Ehr.) Cl.	XX	---	XX	X	X
NVA29	*A. serians* (Bréb. ex Kütz.) Cl.	XX	---	XX	X	XX
NVA04	*A. serains* v. *brachysira* (Bréb. ex Kütz.) Hust.	X	XX	XX	XX	X
NVA08	*A. vitrea* (Grun.) Ross	XX	X	XX	XX	XX
CYM03	*Cymbella* sp. A (Both margins convex, ∿41 μm)	X	---	XX	XX	X
CYM06	*C.* sp. B (strongly arched, 36 μm)	--	---	---	XX	--

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Table 1. Continued.

CODE	SPECIES	HABIT				
		Epiphyton	Epilithon	Epipelon	Metaphyton	Phytoplankton
	BACILLARIOPHYTA - Naviculales (Cont.)					
CYM08	*Cymbella* cf. *cistula* (Hempr.) Kirchn.	XX	--	--	XX	--
CYM02	*C. cesatii* (Rabh.) Grun. *ex* A.S.	X	--	XX	XX	X
CYM05	*C. gracilis* (Ehr.) Kütz.	XX	X	XX	XX	XX
CYM13	*C. hauckii* V.H. *	--	--	XX	X	--
CYM10	*C. heteropleura* v. *subrostrata* Cl. *	--	--	XX	X	--
CYM04	*C. minuta* Hilse *ex* Rabh. *	XX	XX	--	XX	X
CYM07	*C. minuta* f. *latens* (Krasske) Reim. *	XX	XX	--	X	--
CYM09	*C. muelleri* Hust. *	--	--	--	XX	--
CYM12	*C. naviculiformis* Auersw. *ex* Heib.	X	--	XX	XX	--
CYM11	*C.* cf. *proxima* Reim. *	XX	--	--	--	--
DPN01	*Diploneis oblongella* (Naeg. *ex* Kütz.) Ross	--	--	XX	XX	--
DPN02	*D. finnica* (Ehr.) Cl.	--	--	XX	XX	--
EPM02	*Epithemia smithii* Carruth. *	--	--	XX	--	--
EPM01	*E. sorex* Kütz.	X	--	--	X	XX
FRU03	*Frustulia rhomboides* (Ehr.) DeT.	X	XX	XX	XX	X
FRU01	*F. rhomboides* v. *capitata* (A. Mayer) Patr.	X	XX	XX	XX	XX
FRU02	*F. rhomboides* v. *saxonica* (Rabh.) DeT.	--	--	XX	XX	--
GPN06	*Gomphoneis herculeana* (Ehr.) Cl.	XX	--	--	--	--
GPN07	*Gomphonema acuminatum* Ehr.	--	--	XX	--	--
GPN01	*G. angustatum* (Kutz.) Rabh.	XX	XX	--	X	X
GPN05	*G. apicatum* Ehr. *	--	--	--	XX	--
GPN02	*G.* sp. A (ends not set off, ~23 µm)	--	--	--	XX	--
GPN08	*G.* sp. B (two isolated punctae, ≃naviculoid)	--	--	--	XX	--
GPN03	*G. montanum* v. *media* Grun.*	XX	XX	X	X	X
GPN04	*G. parvulum* (Kütz.) Kütz.	XX	XX	X	X	--
NVA01	*Navicula* sp. A (ends ± capitate, 48 µm)	XX	--	--	XX	--
NVA32	*N. cocconeiformis* Greg. *ex* Grev.	--	--	XX	XX	--
NVA11	*N. cuspidata* (Kütz.) Kütz. *	--	--	--	XX	--
NVA05	*N.* sp. D (ellipsoid-rhombic ~16 µm)	--	--	--	XX	--
NVA24	*N. explanata* Hust. *	--	--	--	XX	--

Table 1. Continued.

CODE	SPECIES	Epiphyton	Epilithon	Epipelon	Metaphyton	Phytoplankton
	BACILLARIOPHYTA - Naviculales					
NVA13	*Navicula* sp. E (Ends capitate, striae indistinct, ∿27μm)	XX	--	XX	X	XX
NVA36	*N. levanderi* Hust.	--	--	--	XX	--
NVA27	*N. minima* Grun.	XX	XX	XX	XX	X
NVA10	*N.* cf. *monmouthiana-stodderi* Yerm. *	XX	--	--	X	XX
NVA35	*N. placenta* Ehr. *	--	--	XX	--	--
NVA26	*N. polystoma* v. *pantocsekii* Wisl. & Kolbe *	--	--	XX	X	--
NVA16	*N. pseudoscutiformis* Hust.	XX	--	X	XX	--
NVA19	*N. pupula* Kütz.	XX	--	--	X	--
NVA30	*N. pupula* v. *elliptica* Hust. *	--	--	--	XX	--
NVA25	*N. pupula* v. *rectangularis* (Greg.) Cl. & Grun.	--	--	XX	X	X
NVA09	*N. radiosa* Kütz.	XX	X	XX	XX	X
NVA22	*N. rhynchocephala* v. *elongata* Grun. *	--	--	XX	X	X
NVA07	*N.* cf. *scutiformis* Grun ex A.S. *	--	--	--	--	XX
NVA31	*N. subtilissima* Cl.	--	--	XX	XX	--
NVA28	*N.* cf. *validicostata* Cl.-Eul.*	--	--	--	XX	XX
NVA21	*N. vanheurckii* Patr. *	X	--	--	XX	--
NVA20	*N. viridula* (Kütz.) Ehr.	--	--	--	XX	X
NEI01	*Neidium affine* (Ehr.) Pfitz.	X	--	XX	X	X
NEI02	*N. iridis* v. *amphigomphus* (Ehr.) A. Mayer	X	--	XX	X	X
NEI03	*N. tumescens* (Grun.) Cl. *	--	--	XX	--	--
NVA34	*Pinnularia biceps* Greg.	X	--	XX	--	--
NVA06	*P. hilseana* Jan. *	X	X	XX	XX	XX
NVA33	*P. maior* (Kütz.) Rabh.	--	--	XX	--	X
NVA18	*P. parvula* (Ralfs) Cl.-Eul.	--	--	XX	X	--
NVA12	*P. microstauron* Ehr. Cl.	--	--	XX	X	XX
NVA14	*P. viridis* (Nitz.) Ehr.	--	--	XX	X	X
SNS02	*Stauroneis anceps* f. *gracilis* Rabh.	--	--	---	XX	X
NVA23	*S. ignorata* Hust.	--	--	XX	X	--
NVA17	*S. phoenicenteron* (Nitz.) Ehr.	XX	--	XX	X	X
SNS01	*S. phoenicenteron* f. *gracilis* (Ehr.) Hust.	X	--	XX	X	X

Table 1. Continued.

CODE	SPECIES	Epiphyton	Epilithon	HABIT Epipelon	Metaphyton	Phytoplankton
	BACILLARIOPHYTA - Bacillariales					
NZA02	*Nitzschia* sp. A (attenuate, 36 μm)	--	--	--	XX	XX
NZA03	*N.* sp. B (stout, ~25 μm)	--	--	--	XX	--
NZA05	*N. capitellata* Hust.	--	--	--	XX	X
NZA07	*N.* cf. *fonticola* Grun.	--	--	--	X	XX
NZA04	*N. gracilis* Hantz. *ex* Rabh. *	XX	--	X	XX	X
NZA06	*N. intermedia* Hantz.	XX	XX	X	XX	--
	Surirellales					
NZA01	*Stenopterobia intermedia* Lewis	X	--	XX	XX	X
SUR01	*Surirella biseriata* Bréb.	--	--	XX	X	XX
SUR03	*S. biseriata* v. *constricta* Grun.	XX	--	X	X	X
SUR02	*S. delicatissima* Lewis *	--	--	--	XX	XX
	EUGLENOPHYTA - Euglenales					
EGL01	*Euglena acus* Ehr.	--	--	X	--	XX
	PYRROPHYTA - Peridiniales					
PDN01	*Peridinium* cf. *pusillum* (Pern.) Lemm.	--	--	--	--	XX
GLD01	*Peridiniopsis* sp. A	X	--	X	X	XX
	CRYPTOPHYTA - Cryptomonadales					
CPT01	*Cryptomonas ovata* Ehr.	X	--	X	XX	X
	RHODOPHYTA - Nemaliales					
AUD01	*Audouinella hermanni* (Roth) Duby	XX	XX	--	--	--
BAT01	*Batrachospermum moniliforme* Roth	XX	XX	--	--	--
BAT02	*B.* sp. C (unidentified chantransia stages)	--	XX	--	--	--
BAT03	*B. vagum* v. *keratophyllum* Bory	--	XX	--	--	--

Table 2. Proportions of algal taxa, by group, from Jacob's
Lake present downstream (drift or attached) and in attached
habits, expressed in numbers (n) and decimal fraction (P) of
the original number (N) of taxa (based on data of Appendix C).

ALGAL GROUP	TAXA IN JACOB'S L. N	PRESENCE DOWNSTREAM n	PRESENCE DOWNSTREAM P	COLONIZED IN ATTACHED HABITS n	COLONIZED IN ATTACHED HABITS P
Cyanophyta	16	13	.81	5	.31
Chlorophyta	57	43	.75	12	.21
Chrysophyta	9	6	.67	1	.11
Bacillariophyta	101	90	.89	33	.33
Euglenophyta	1	0	.00	0	.00
Pyrrophyta	2	1	.50	0	.00
Cryptophyta	1	1	1.00	0	.00

B. LONGITUDINAL PATTERNS OF THE ALGAL COMMUNITIES

In comparing species assemblages at all stations, there are a few
recurrent associations in the stream (summarized in Table 3). Most flowing
stations were typified by the presence of filamentous greens and bluegreens.
The warmer months (June, August) are largely dominated by Zygnema insigne
and Phormidium autumnale, whereas Klebsormidium rivulare showed a predomin-
ance in the February period. In this winter collection, Station 1 was sampled
on 27 January 1978 and Station 2 on 3 March 1978, due to floods (see also
Section IV-C).

Stations 1, 2, and 7 of the North Alouette were Zygnema dominated much
of the year, although P. autumnale was abundant in early fall (9 August
1977). Due to the larger size of the stream at these stations, streamside
pools were often deep, and contained associations differing from the main.
Here, Batrachospermum moniliforme, Stigonema mamillosum, and Tolypothrix
penicillata were abundant. Station 7 also exhibited many tufts of
Audouinella hermanni.

Stations 5 and 6 were somewhat similar to the North Alouette stations,
but more often were colonized by K. mucosum, which unlike Z. insigne or
most other filamentous species, had few algal epiphytes. It was not
apparent from light microscope observations whether mucilage or other
mechanisms were involved. The winter maximum of K. rivulare occurred only
at the upper (Station 6) of these stations, although propagules were
present and available to Station 5, in that these were no more than 500 m
apart.

As noted, few plankton taxa occurred at Jacob's Lake (Station 4),
which was primarily characterized by attached forms, mainly a sterile

Mougeotia sp. and _Frustulia_ _rhomboides_ (2 varieties). This station was the only region of the watershed where diatoms were present in dominant (rank of 5) proportions. These attached forms contributed nearly all the "resident" stream flora (see Appendix A).

The outflow (Station 3) of Jacob's Creek had a unique quality in the presence of associations of _Chlorella_ _vulgaris_ as endosymbionts in two different sessile animals (_Spongilla_ _lacustris_ and _Ophrydium_ sp.). The associations differed also in their seasonal maxima. The dominant algae were _Stigonema_ _mamillosum_ year round, while others, such as _Bulbochaete_ _pygmaea_ and _K._ _rivulare_ were more seasonal. Accumulation of diatom epiphytes were more common than at all other stations.

The species data do not provide immediately recognizable distinctions between stations, although a few generalizations can be made: i) most flowing stations (1, 2, 5-7) were characterized by a number of unbranched filamentous green and bluegreen algae, which are epilithic; ii) the lake outflow (Station 3) was mostly comprised of branched greens and bluegreens which were epilithic, and two symbiotic associations of _Chlorella_; and iii) Jacob's Lake (Station 4) was generally a non-planktonic system where those species found in the water column are often more abundant in the sediments or attached to submersed plants, and diatoms were most frequently encountered.

The algal communities at each station when summarized in terms of species number and diversity show that generally, there was no strong relation between species number and diversity expressed as H' (Table 4). Thus H' only will be referred to as diversity here. Further, the seasonal trends for each station are not altogether similar. The stations downstream

from the lake (1, 2, 7), excluding the outflow, exhibited the lowest diver-
sity during the winter (15 February 1978). On the other hand, the two
upstream stations (5, 6) were less diverse during early fall (9 August
1977). Peaks of diversity occurred at all stations during spring (18 May
1978), but the other months did not pattern similarly. In summary,
patterns of species diversity (H') indicate the stations may be grouped into
three segments: i) a downstream reach can be identified which is beyond the
immediate effects of lake outflow (Stations 1, 2, 7) which showed reduced
diversity in winter and greatest in late spring (May/June); ii) an upstream
area near the lake (Stations 5, 6, and perhaps 3) is distinguished by
lowest diversity in early fall (9 August 1977), secondarily in the winter
(15 February 1978), and species rich conditions during May and June;
iii) a lake zone (Station 4) where species diversity was reduced slightly
during the winter, but generally high all four sampling periods.

A comparison of the entire species assemblage at each station along
the stream for each of the dates has been made by multivariate analysis.
Each sampling period is considered separately and a summary of the ordination
results are at the end of this section. Ordination of the August data set
for Stations 2-6 is shown in Fig. 3. These data were summarized so that
more than 99% of the total variance was accounted for in the first three
axes. Of this, nearly 55% was described by the first axis (Fig. 3A). The
plot indicates that Stations 5 and 6 are nearly identical in species
composition in August, differing only slightly along the third coordinate
axis. Site 2 also bears strong resemblance to these stations, although it
separated along the third axis (Fig. 3B). Overall, the stations above
Jacob's Lake are furthest from the point representing Station 4, measured

along the first axis. The outflow Station (3) on the other hand, is more similar to the lake than the other flowing station (2, 5, 6). Station 2, which is further downstream, is considerably more similar to the upstream stations than to the nearest station at Jacob's Creek (3). Stations 5 and 6 were characterized by the dominance of Klebsormidium mucosum, and at Station 2 it was codominant with Zygnema insigne. This can be interpreted that the stations differ from each other along the first axis as determined by the presence of K. mucosum. It appears that the first and possibly the second axes are related to proximity to the lake. The specific influences of Jacob's Lake, whether from species loading or through some physical factors, will be considered after the abiotic data (Section VI-A).

The ordination using February data produced axes where the first three dimensions described a total of more than 83% of the variance. The first and second individually contained nearly 36 and 30%, respectively, of the variance. The plot (Fig. 4) includes Station 7, the lowest collecting station on the North Alouette. Generally, there is a cluster of the upper-most (6) and lowermost (7) stations rather strongly on all three axes, but the outflow (3) bears resemblance to these along the first and second axes as well. The other upstream Station (5) appears similar to these along the second axis.

The point swarm for the February data exposes a less distinct separation of flowing stations from Jacob's Lake (4). The lake was covered by a translucent ice layer (ca. 3 cm thick) which may have affected absolute levels of standing crop (not measured). Station 2 is relatively distinct along the first and third axes. The later sampling date of this station (3 March) will be considered later (Sections VI-A,B). The variable most

important in discriminating between stations is K̲. rivulare, which was not

abundant at Station 2. Aside from Station 2, the February period appears

to show less longitudinal patterning of species assemblages than did the

August period.

In the ordination of species data for Stations 2-7 during May (Fig. 5),

the first three axes cumulatively represented nearly 86% of the total

variance, with the first axis individually, 41%. At this time, the lake (4)

is positioned as most dissimilar to all other stations, with the outflow

(3) bearing resemblance to it only along the first axis. The downstream

Stations 2 and 7 cluster strongly away from these, and would appear to

diverge more than the upstream Stations, 5 and 6.

The spread along the second axis is not easily understood if considered

strictly from the standpoint of the stream gradient. During this time all

flowing stations except the outflow (3) had a dominance of Z̲. insigne, and

one other alga. Stations 5 and 6 were joined by an abundance of K̲. mucosum,

whereas Stations 2 and 7 had very little of this. Codominant in these

downstream stations was P̲. autumnale. The nearness of these two along the

second axis is at present uninterpretable. The third coordinate axis adds

little further information as to the similarity of the stations, and differs

mostly in reversing the positions of the 2/7 and 5/6 clusters, rather than

revealing new affinities (Fig. 5B). It appears the relative differences

in the importance of Z̲. insigne and secondary dominants were characteristics

of comparison for this period.

By June, the species data of alternate Stations 2-7 are more efficient-

ly summarized than earlier, where 93% of the total variance is expressed by

the first three axes and nearly half by the first axis alone. The gradient

downstream from the lake is more clearly expressed along the first axis (Fig. 6), where the outflow of Jacob's Creek (3) is in an intermediate position of similarity and longitudinal position. The flowing Stations 2, 5, 6, and 7 are also more definitely clustered along all three axes than in February and May. The spatial pattern of the affinities between stations expressed in the first two dimensions of the ordination is similar to that in August, although the lake (4) and its outflow (3) are reversed along the second axis. The third axis in the June plot exposed one major difference at the outflow, likely due to the occurrence of Stigonema mamillosum, which at this time is poorly represented elsewhere. It would appear that the algal community at this Station (3) is less like that at Jacob's Lake (4) than in August of the previous year. All stream stations were continued to be characterized by an abundance of Zygnema, and increasingly so for the Jacob's Creek outflow Station.

A consideration of the species abundance, diversity, and ordination results between stations produces a number of generalizations. These are:

1. For much of the year, there are distinct differences in species composition along the stream-watershed, which appear to be related to the stream gradient, although not for the winter (February/March).

2. Jacob's Lake differs most strongly from all the stream stations, but is not entirely without species common to them.

3. Although many stations are species rich, only the lake has an even proportion of species and hence high diversity (H') at all four times of the year sampled.

Conversely, the stream stations exhibited periodic low
and high diversity over the year.

4. At certain times, particularly June, the stations
    appreciably downstream from the lake (2, 7) bear strong
    resemblance to lotic stations above the lake (5, 6).

Table 3. Abundance of major species at seven sampling stations, expressed as species importance (Ia, see III-G) on four dates (see Table 1 for species codes, * = Station 2 data on 9 October 1977, ** = Station 1 data on 3 March 1978, -- = not observed, ND = no data available).

		SPECIES	IMPORTANCE		
STATION	MAJOR SPECIES	9 AUG 1977*	15 FEB 1978**	18 MAY 1978	23 JUN 1978
1: Main station, North Alouette River	ZYGO1	.27	.12	.43	.52
	UKLO3	.00	.61	.16	.00
	PHRO1	.26	--	.00	.23
	UKLO1	.18	.00	.11	.12
	STGO1	.00	.12	.11	.01
2: Stream Junction	ZYGO1	.45	.89	.45	.59
	PHRO1	.01	.00	.45	.34
	UKLO1	.45	--	.00	--
	UKLO3	.01	.03	.04	.02
	TXPO1	.00	.12	.11	.11
3: Jacob's Creek at lake outflow	STGO1	.42	.41	.28	.30
	BULO1	.42	.21	.02	.04
	CØVO2	.45	--	.00	--
	UKLO3	--	.22	.28	--
	ZYGO1	.02	--	.02	.27
4: Jacob's Lake	FRUO1	.10	.34	.20	.20
	MØUO1	.10	.30	.23	.20
	MELO2	.00	.30	.17	.20
	TXPO1	.54	--	--	--
	DNBO1	--	--	--	.20
5: Upper Jacob's Creek	UKLO1	.81	.41	.28	.31
	ZYGO1	.04	.40	.38	.24
	STGO1	--	--	.38	.01
	SPIO1	.04	--	.02	.22
	BATO1	--	--	.00	.20
6: Tributary B	UKLO1	.88	.41	.28	.31
	ZYGO1	.01	.02	.24	.29
	UKLO3	--	.41	.02	.01
	STGO1	.00	.08	.24	.00
	SPIO1	.00	--	.02	.29
7: Lower North Alouette River	PHRO1	ND	.00	.22	.23
	ZYGO1	ND	.00	.22	.22
	UKLO3	ND	.44	.00	.00
	SPIO1	ND	--	.23	.22
	AUDO1	ND	.40	.03	.01

Table 4. Comparison of species diversity at seven sampling
stations at four dates, expressed as species number (S) and
ecological diversity (H') (* = Station 2 data on 9 October
1977, ** = Station 1 data on 3 March, 1978, ND = no data).
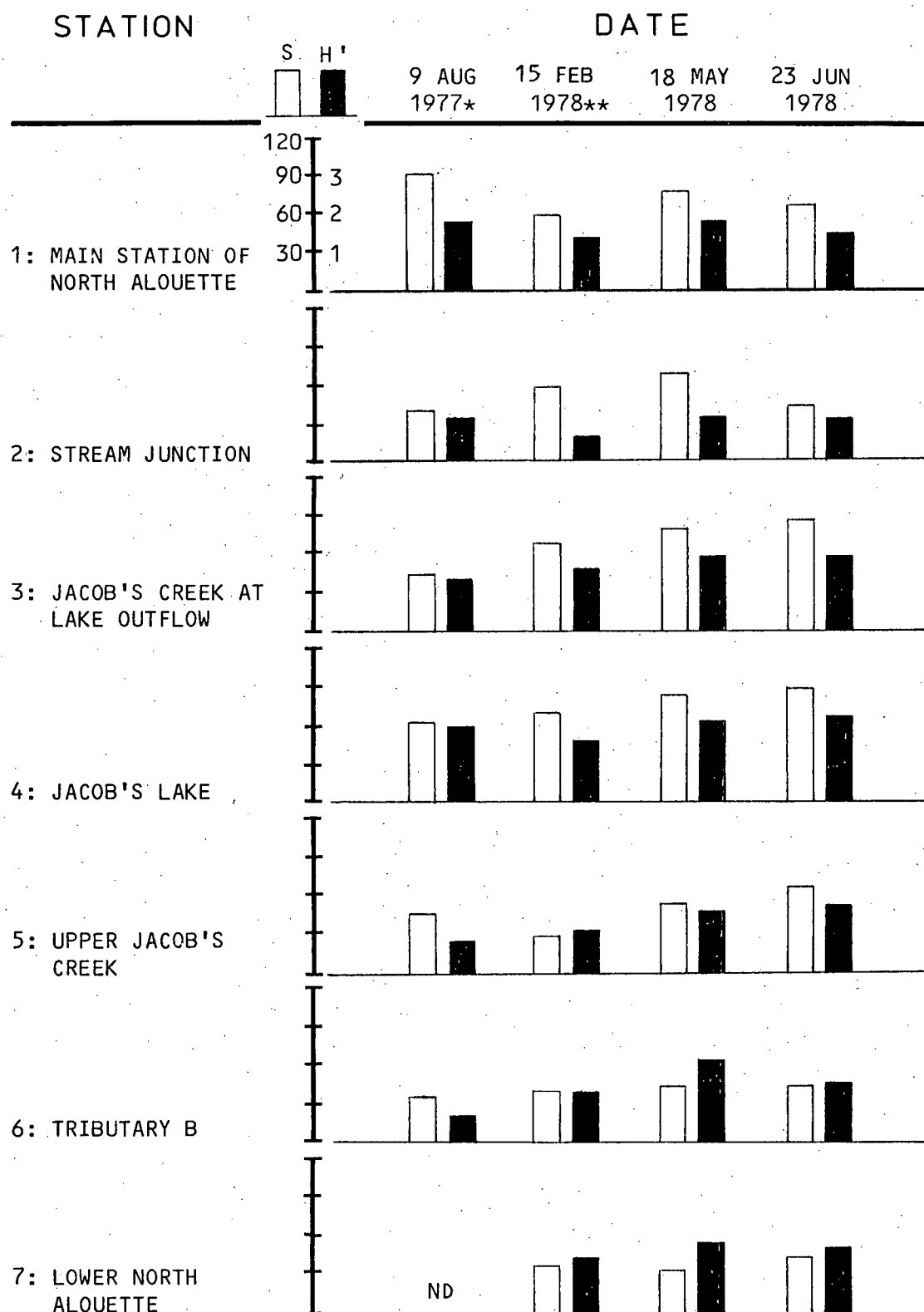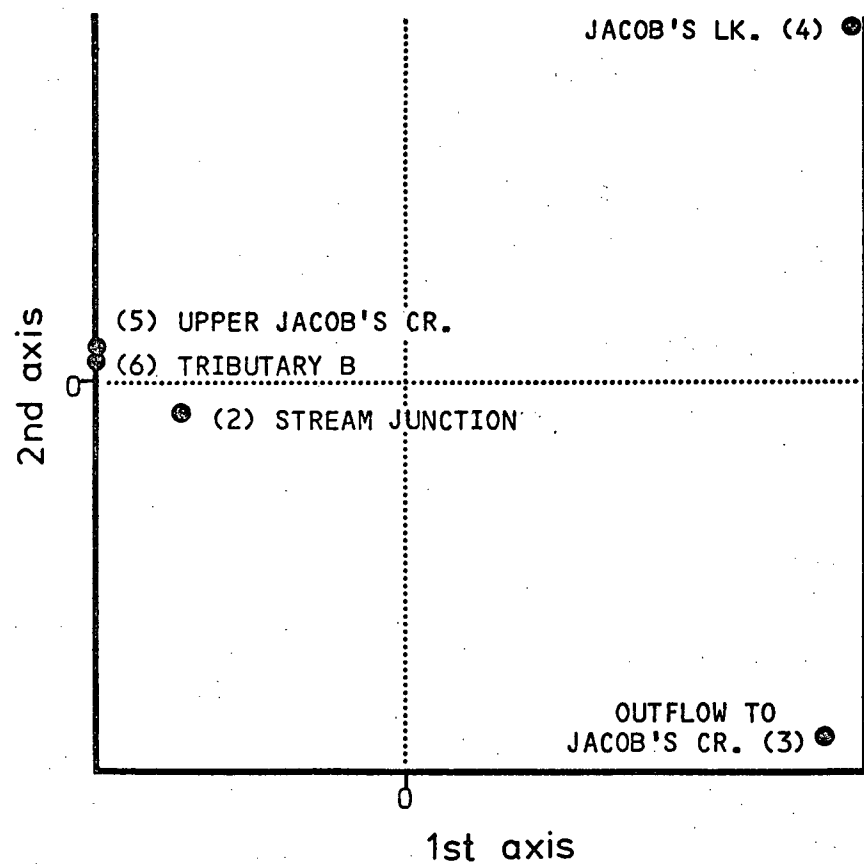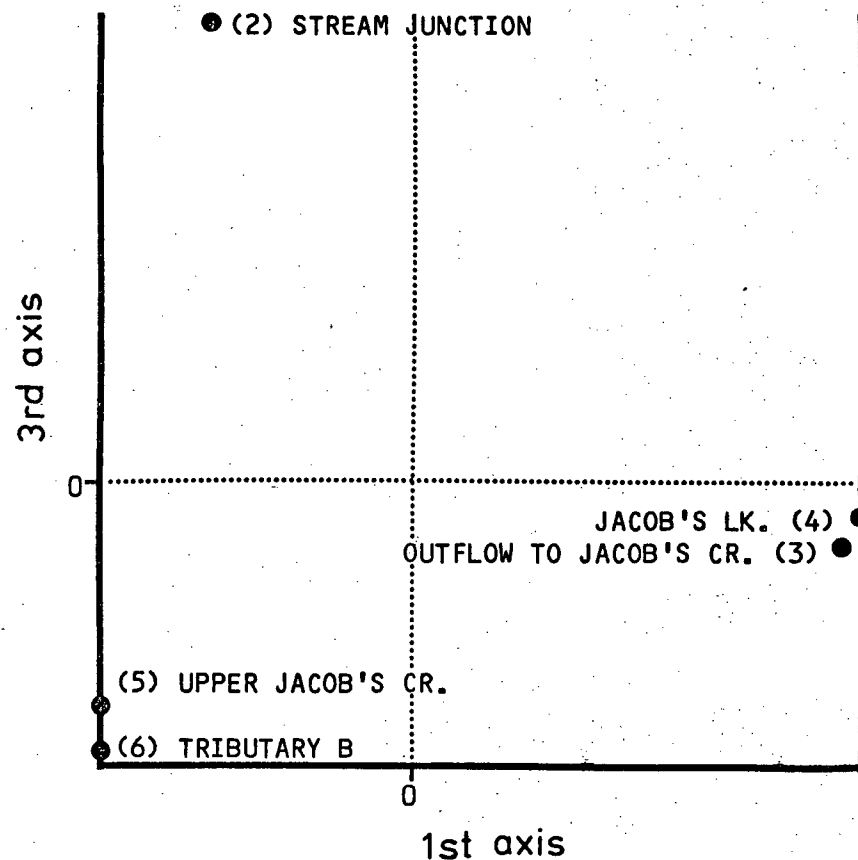
Figure 3. A plot of the similarities between five alternate collecting stations (2-6) for 9 August 1977, expressed by P-Co-A in the first and second (A) and first and third (B) coordinate axes (see Fig. 1 for station locations).
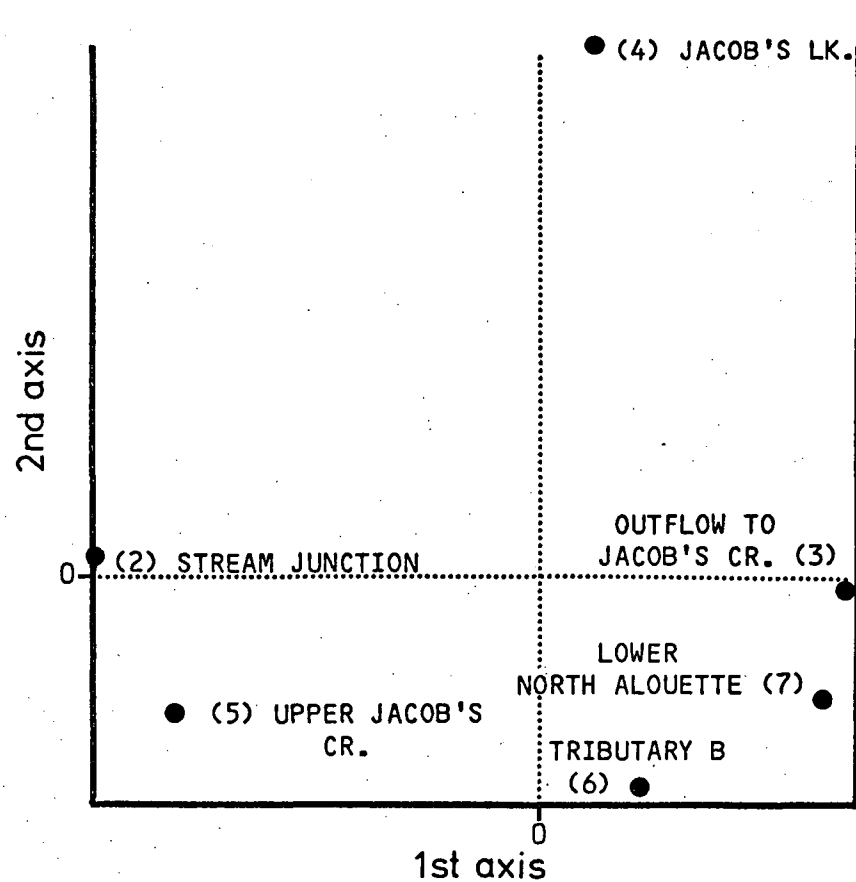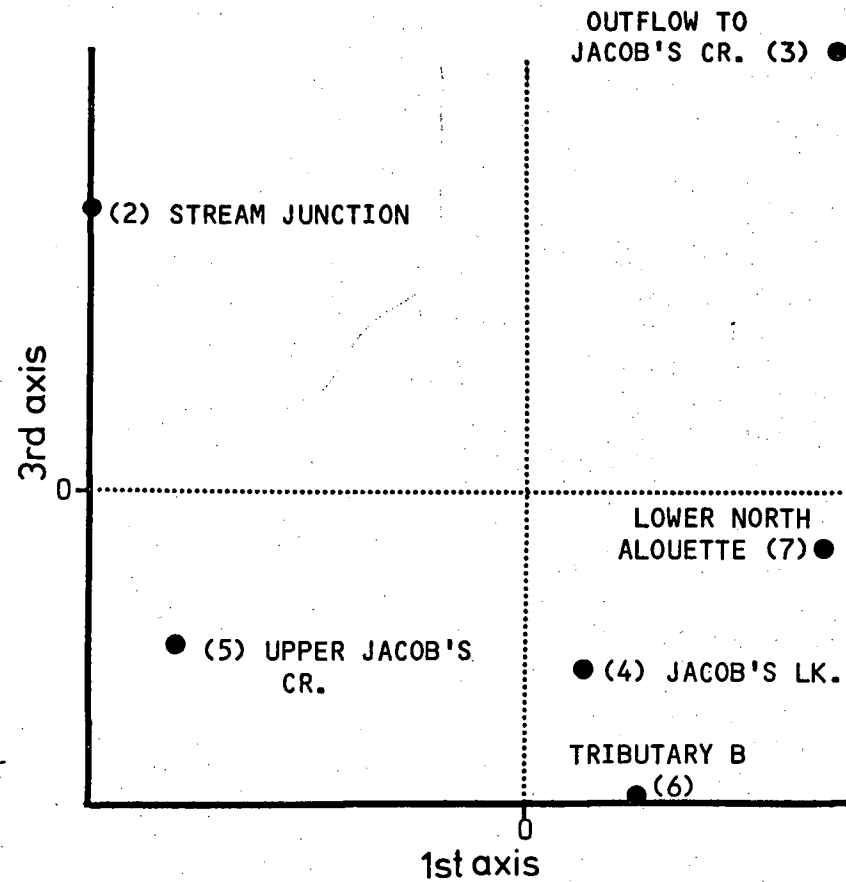
Figure 4. A plot of the similarities between six alternate collecting stations (2-7) for 15 February 1978, expressed by P-Co-A in the first and second (A) and first and third (B) coordinate axes (see Fig. 1 for station locations).
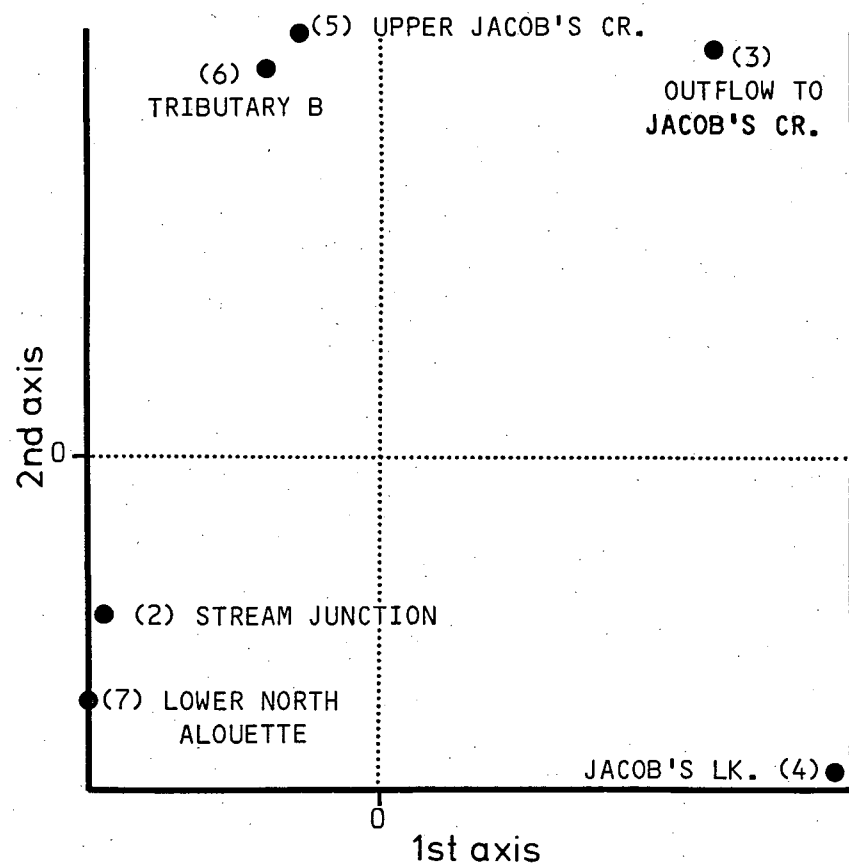
A
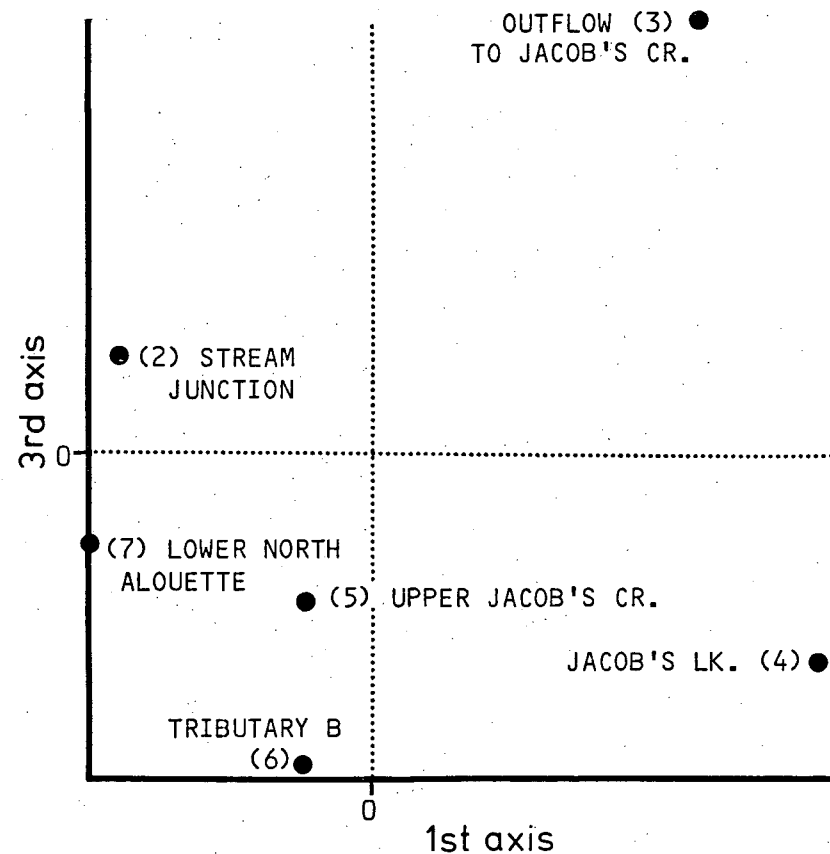
B

Figure 5. A plot of the similarities between six alternate collecting stations (2-7) for 18 May 1978, expressed by P-Co-A in the first and second (A) and first and third (B) coordinate axes (see Fig. 1 for station locations).
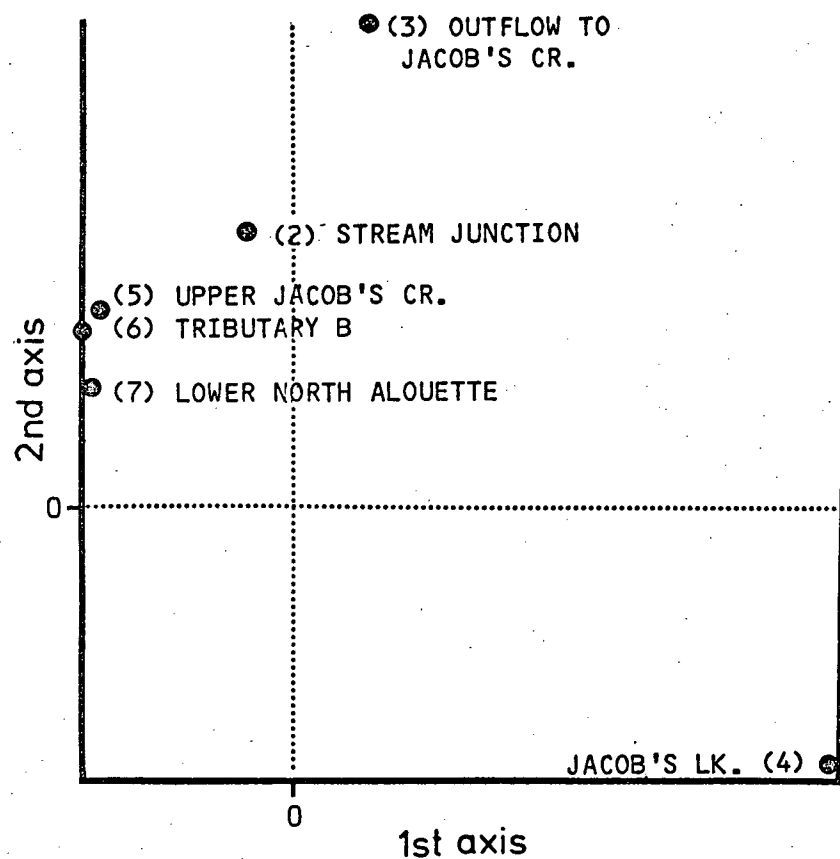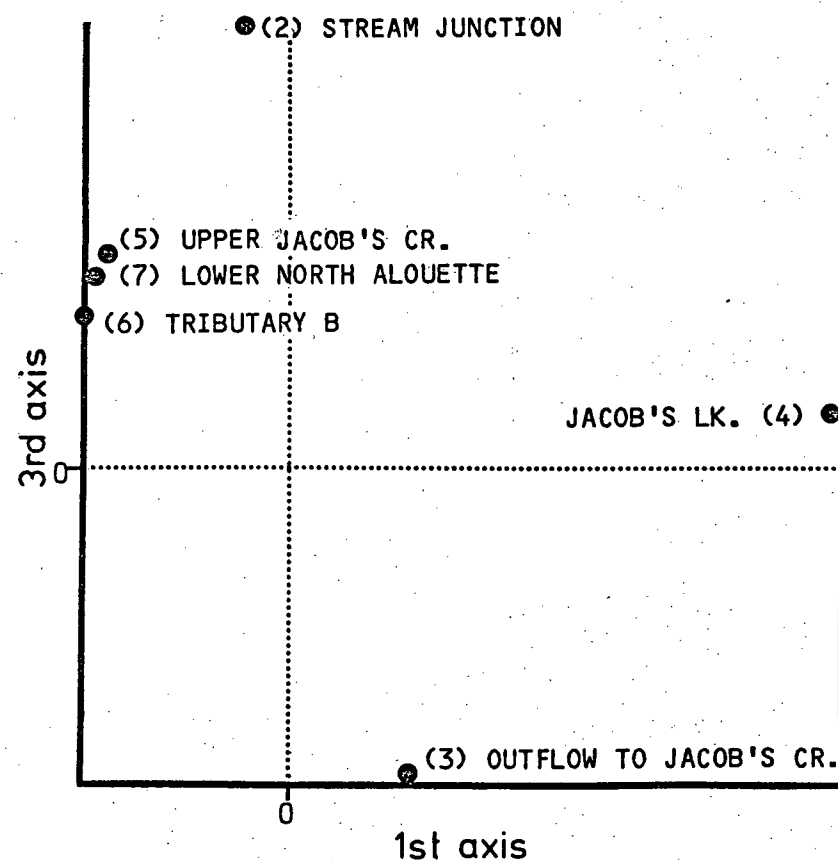
Figure 6. A plot of the similarities between six alternate collecting stations (2-7) for 23 June 1978, expressed by P-Co-A in the first and second (A) and first and third (B) coordinate axes (see Fig. 1 for station locations).

C. WITHIN-HABITAT VARIATIONS IN THE ALGAL COMMUNITY

OF STATION 1

The temporal variation in the abundance of seven dominant species is compared in Fig. 7 and expressed as importance values (Ia). As the observations are for 13 months, they are sufficient to generalize for only one year. These data indicate a gradual progression from one dominant species to the next. None of these, however, was absent or in significantly low quantities to have been missed in the enumeration process. Most species were readily observable at all times of the year and did not "disappear" or alternate between resting stages (e.g., zygospores in the Zygnemataceae) and the vegetative condition.

The major species can be separated into classes of occurrences, which are reasonably distinct from each other. Z. insigne and K. mucosum predominate in the late spring-summer until P. autumnale and Oedogonium sp. A expand in importance in the early autumn. The large burst of K. rivulare is marked by a low abundance of other species during the winter months, where both bluegreen and diatom epiphyte growth is also reduced. During later winter and early spring, Tolypothrix penicillata peaked, while spring and summer forms began their increase again. The temporal variation in abundance of Stigonema mamillosum was not predictable, as it had periodic peaks and lows throughout the year.

The temporary periods between peaks are times of relatively even species coexistence. This is supported by the seasonal changes in species diversity (Fig. 8). The pulse of greatest diversity (H') was in early September, before K. rivulare had reached large proportions with a second,

less extreme peak occurring the following May. Here again, changes in species number (S) does not mimic the pattern of diversity (H'), particularly during the increase to its highest levels (H' = 2.33) in August-September. Community diversity appears to follow a pattern outlined for dominant species, where the late-spring is separate from autumn-winter. These are likely distinct from a group of late winter-spring months.

The temporal pattern was also considered through ordination methods. In this, the comparison was between sampling dates. The 17 sampling dates with 203 variables (species) produced vectors where the first coordinate axis accounted for nearly 50%, and cumulatively the first three axes, 87% of the total variance (Fig. 9). The similarity between sampling dates reveals a cyclic pattern from June 1977 to June 1978, considered by the first two axes (Fig. 9A). This model can be envisioned as a disk, where the seasonal succession of species follows the course around the edge and completes the cycle in one year. The third axis is less obvious, and only contributes another 7% of the information content to the total picture (Fig. 9B). The three dimensions together would appear as a disk which exhibits some "wobble", rather than as a flat plate. Nonetheless, the analysis shows the succession proceeded in a cyclic manner, where the beginning and end meet.

The ordination also reveals a few properties of the date-units individually. Bartell et al. (1978) indicate that the length of the lines between successive points in such a plot are roughly proportional to the rate of change in species composition between dates. The long period from mid-October to January did not show a significant change in the community. The two dates (9 October 1977, 27 January 1978) were both characterized by

a predominance of K. rivulare. The most dramatic change in composition

occurred two sampling dates earlier, between late January and early March.

This response can be correlated with a large drop in importance of K.

rivulare and the succeeding increase in Z. insigne.

When observing the mosaic of algal species in the field at Station 1, it

appeared that there was not an even or random distribution along the

streambed. Some species were found only on a specific position on a rock

or only on rocks in some places. The colonization experiment, to a degree,

supports these observations (Table 5). As indicated by the large change in

species composition (small similarity value) of both substrate types with

time, a difference in species composition was shown for different exposure

periods. In this short-term succession, the two substrates had low similar-

ity to each other in the initial and final stages of the experiment. A

period of convergence did occur after the second week, but it was short-

lived. By week 4, smaller forms (diatoms) were selected for on the

artificial substrate, in contrast to the natural substrate, which then had

an assemblage of filamentous greens. This latter association was also true

for the stream overall at this time of year (Fig. 7; Appendix A).

The spatial patterning of algal species across the stream was analyzed

by cluster analysis (Fig. 10). The major result is the production of two

large clusters which differ largely in nearness to the shore. The right-

hand group are those low and high numbered samples from the extremes of the

transect. The bulk of the left-hand cluster is made up of samples from

midstream. Choice of the number of clusters is in part arbitrary, but the

analysis also produced a step-wise listing of the error associated with

each successive grouping. Thus, within a range of 4-12 clusters desired

(for the eight perpendiculars), the clustering associated with the lowest error jump is at the 10-cluster level. This is considered the most "natural" grouping of the data. Beyond the two major clusters, the other eight fall nearer to one or the other.

The clusters can be superimposed on the sample map (Fig. 11). The matrix of 56 samples can be placed on the grid which indicates their relative position to the transect and order along the perpendicular. The clustered groups are identified by contour lines (not drawn to scale). The pattern reveals a very large, distinct group of assemblages that occur near midstream and for much of the northwest margin. The other large group does not follow strictly with nearness to the shore, although this and most anomalous groups have no representatives in the midstream region. Some of the margin samples from each side have been clustered together. Thus, algal species and associations encountered at Station 1 exhibited a number of structural aspects which vary in space and time. They can be summarized by these two aspects.

Temporal: i) The dominant species at Station 1 fluctuated over the period of one year, but at no time were any of the species locally extinct.

ii) Species diversity was greatest during early autumn (August/September) and spring (April/ May) and depressed during winter (January/ February).

iii) A cyclic pattern was recognized in the seasonal change of species (succession), although two drastic changes in community composition were

revealed (September and January/March) and

occurred in a short span of time.

Spatial: i) A complex of species assemblages exists in the

stream which are not evenly or randomly dis-

tributed.

ii) A short-term succession was found to differ

in structure between the two substrate types.

iii) Many species show affinities to particular

substrates and localities within the stream,

and do so in a recognizable pattern.

Figure 7. Seasonal changes in the abundance of the major algal species at Station 1 of the North Alouette River, expressed as importance (I_a) values. Species are presented in order of their first peak from the beginning of the study (see Table 1 for species codes).

MAJOR SPECIES

IMPORTANCE (I_a) OF
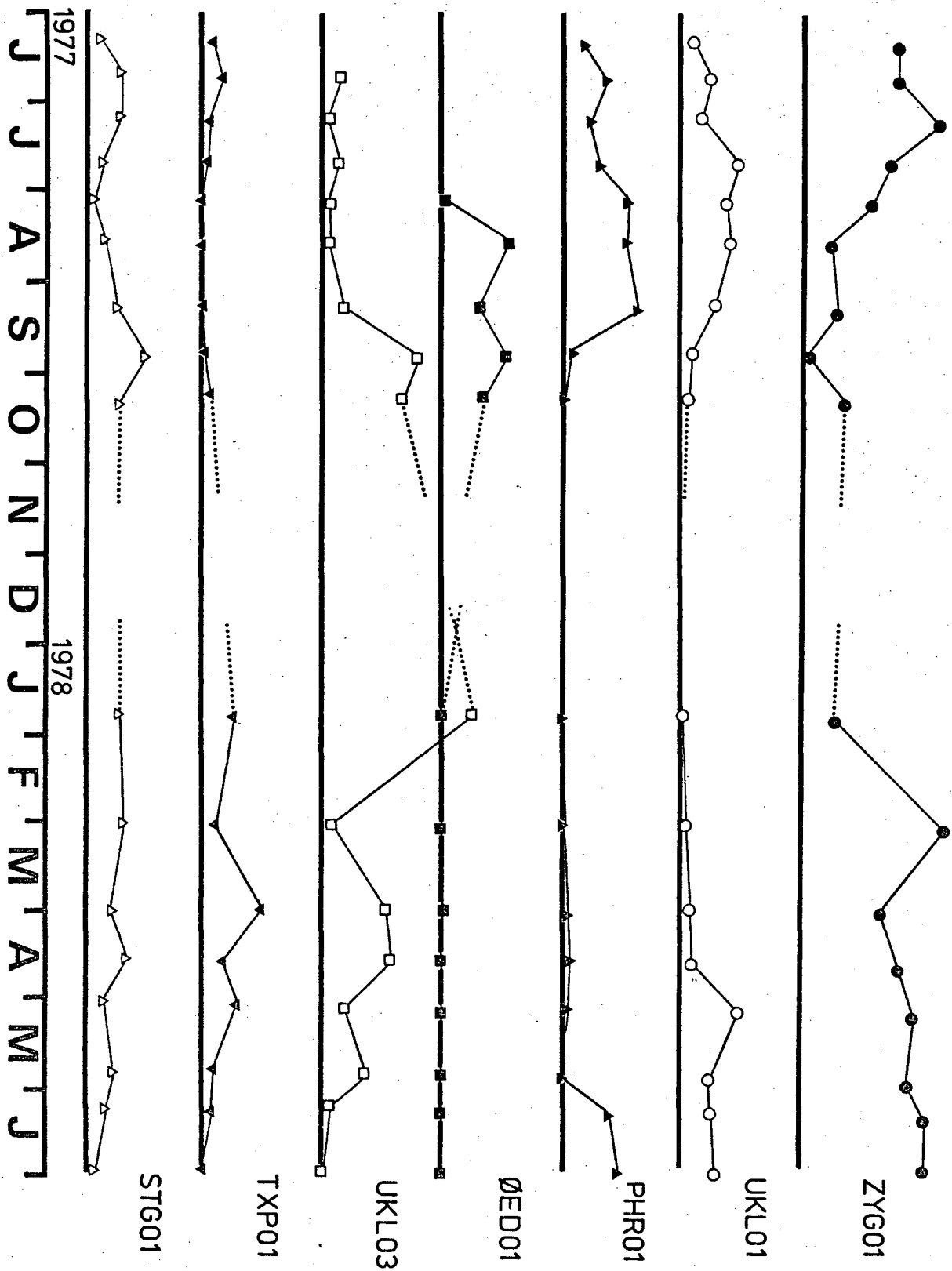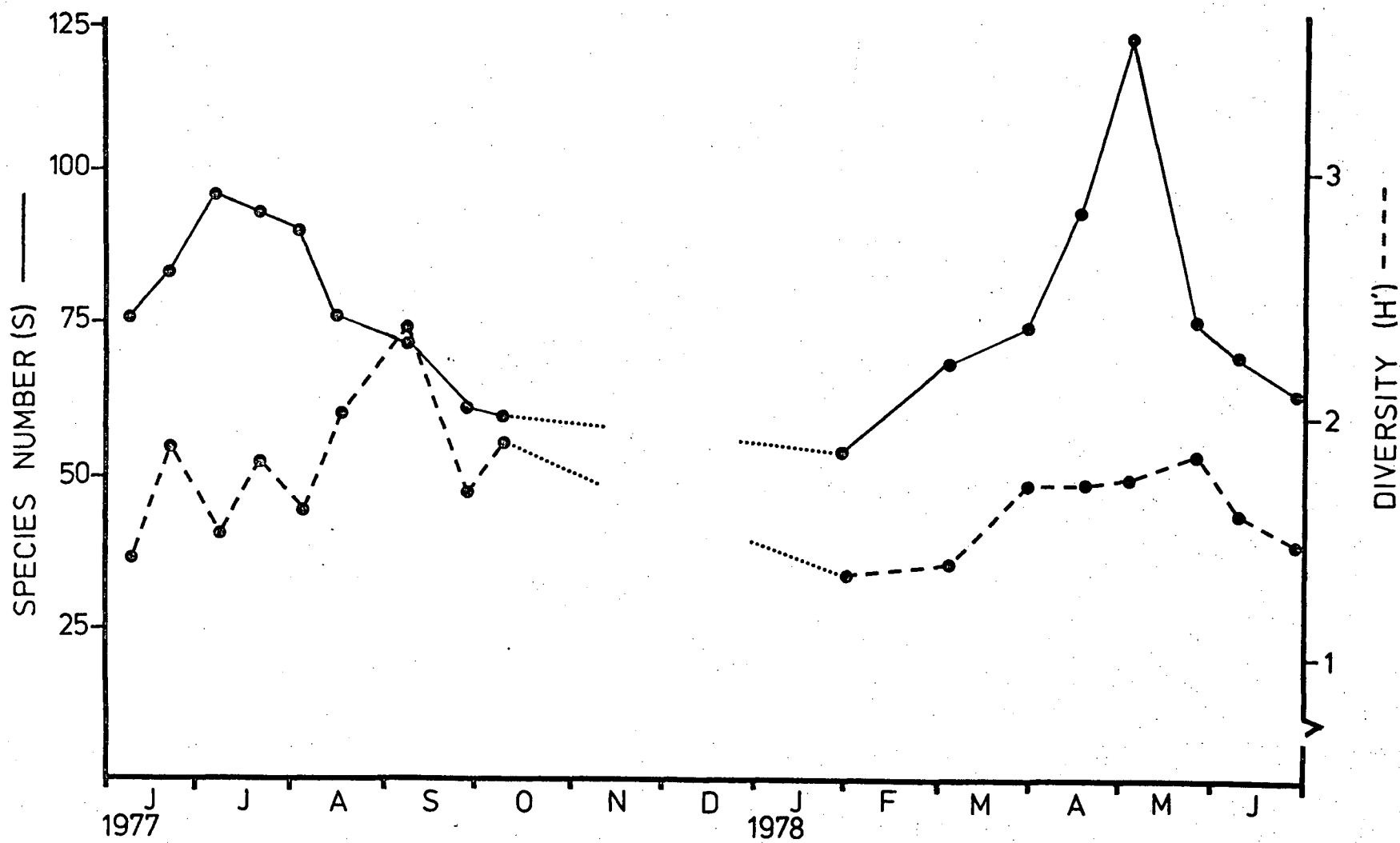
Figure 8. Seasonal changes in species diversity of the algal community at Station 1 of the North Alouette River. Diversity is expressed as species number (S) and ecological diversity (H').
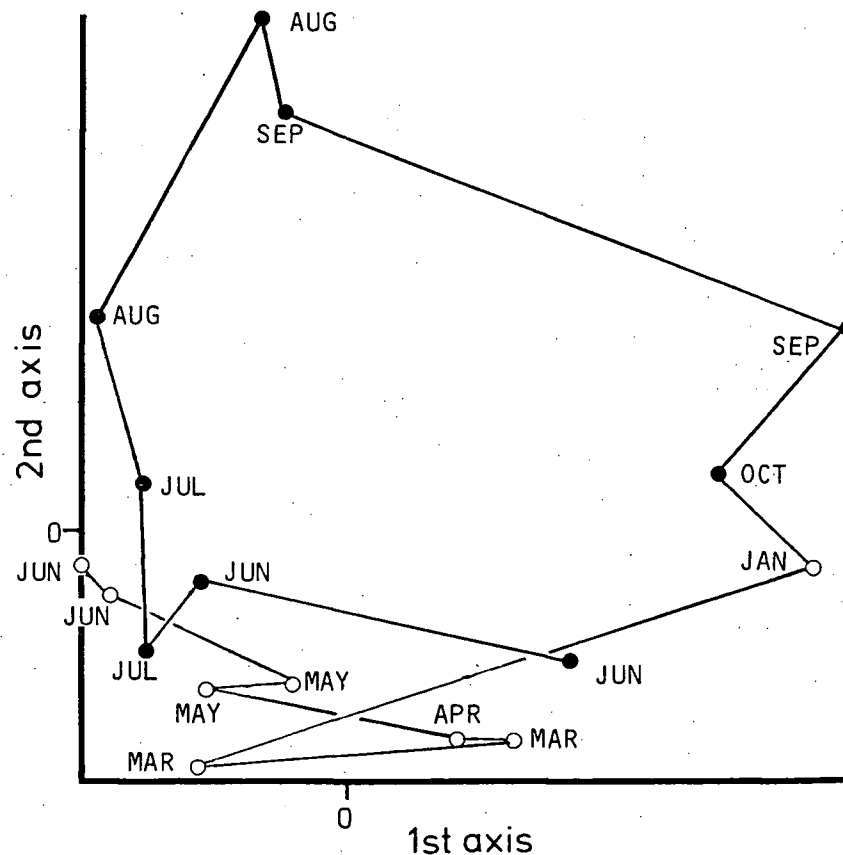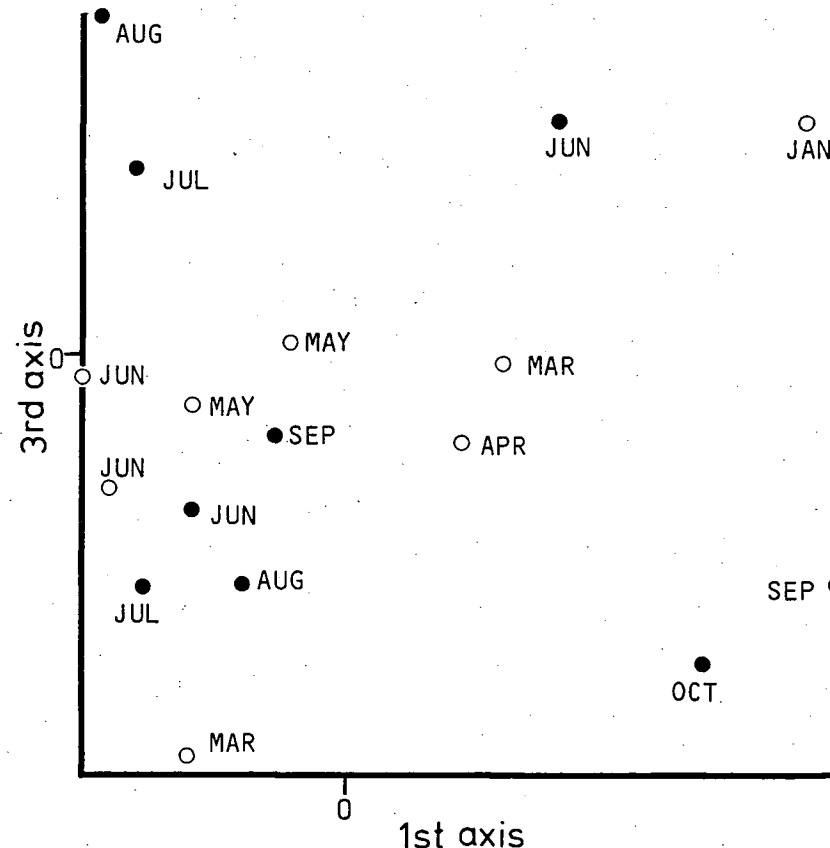
Figure 9. A plot of the similarities between algal communities on 17 sampling dates at Station 1 of the North Alouette River, expressed by P-Co-A in the first and second (A) and first and third (B) coordinate axes. The chronological trajectory of points are connected by lines whose length correspond to the relative amount of change in species composition (● = 1977, ○ = 1978).

Table 5. Comparison of species assemblages at three successional stages for two substrate types, expressed as similarity (I_S of Sørensen, 1948), where 1 = complete and 0 = no similarity (refer to Table 1 for species codes).

TEMPORAL DIFFERENCES	COMPARISON	WEEKS		
		1 vs. 2	2 vs. 4	1 vs. 4
	Within the Plexiglas assemblage	.16	.11	.23
	Within the granite assemblage	.02	.64	.13

SUBSTRATE DIFFERENCES		Week 1	Week 2	Week 4
	Major species on Plexiglas	SPIO1	ZYGO1	GPNO1
		SYNO1	SYNO1	ACNO1
		ACNO1	UKLO3	SYNO1
	Major species on granite	STGO1	ZYGO1	ZYGO1
		TXPO1	SPIO1	STGO1
		ACNO1	TABO1	SPIO1
	Similarity (I_S) between substrates	.06	.61	.11

Figure 10. Cluster analysis of algal associations on separate stones collected along a cross-stream gradient, Station 1 of the North Alouette River, 4 May 1978.
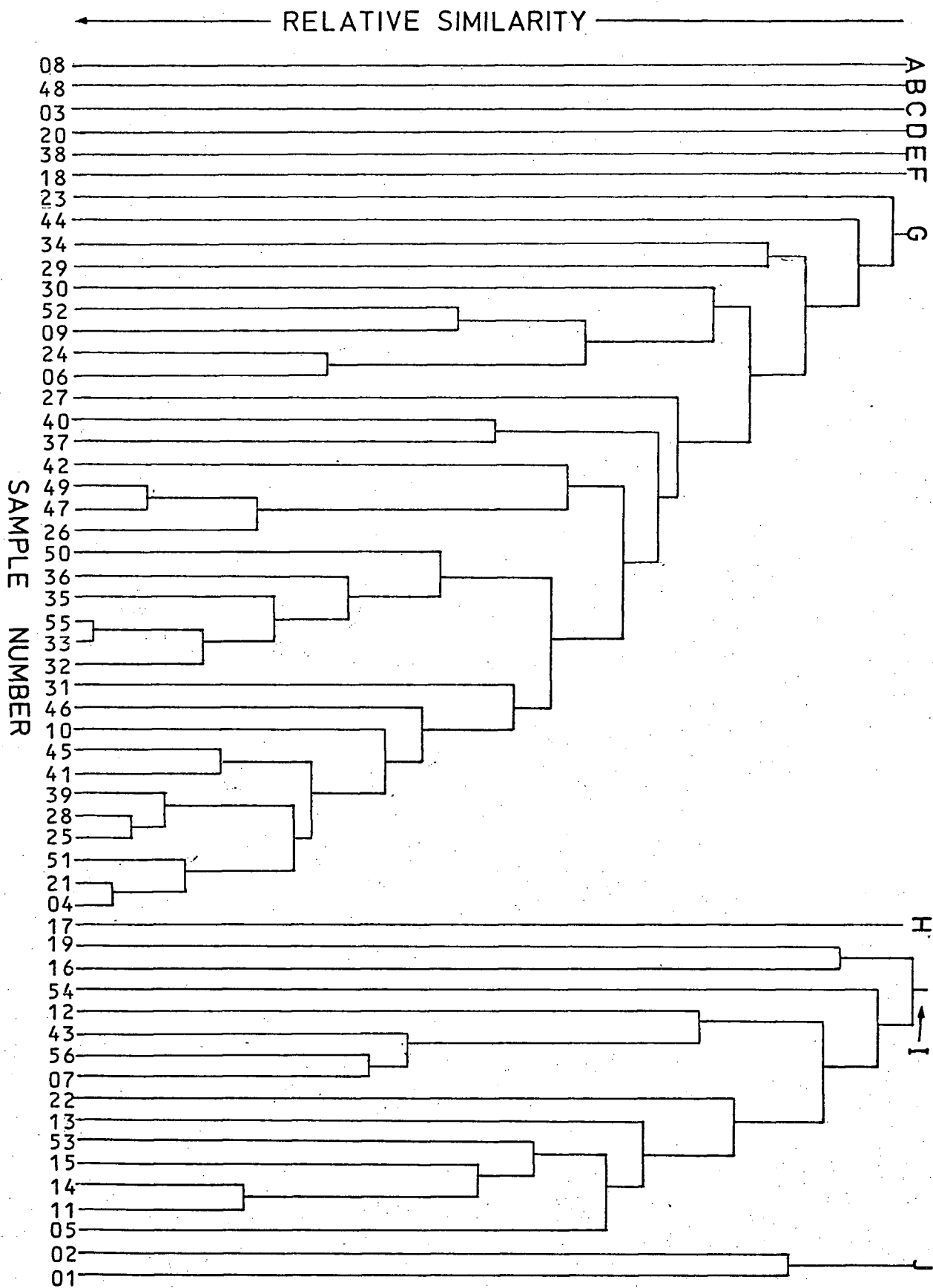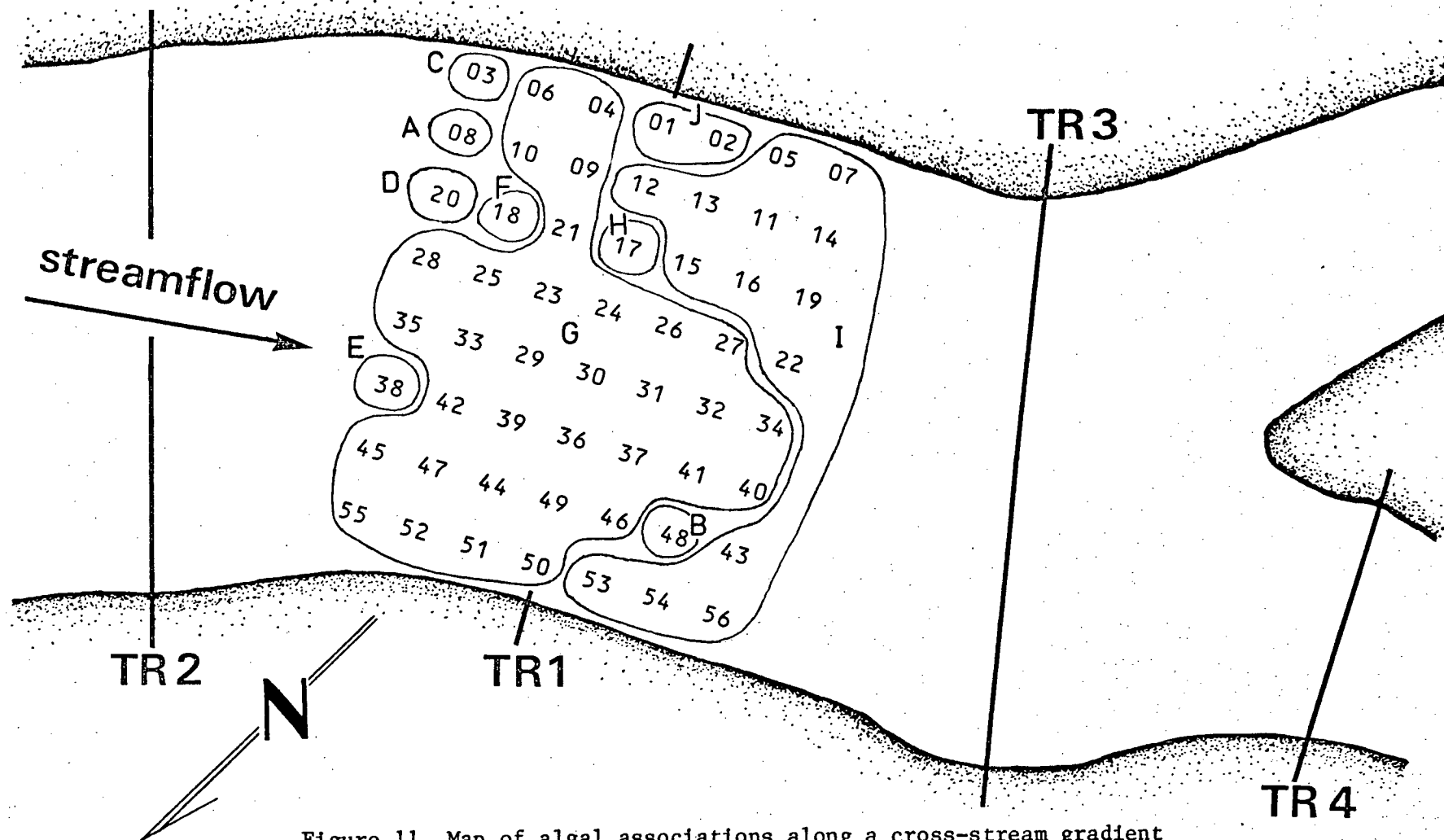
Figure 11. Map of algal associations along a cross-stream gradient on 4 May 1978 (groups identified through cluster analysis, see Fig. 10; figure not drawn to scale).

V. PHYSIOCHEMICAL RESULTS

A. COMPARISON OF STATIONS ALONG THE STREAM

The abiotic data collected on dates of algal sampling for alternate

Stations (2-7) include only temperature, pH, and current velocity (Table 6).

Characteristics of altitude, stream width (and hence relative shade),

slope, substrate size, and position relative to the lake are considered for

comparison.

The temperature trends were similar between stations seasonally.

February was the coldest and August the warmest month of the four dates in

all stations. Interestingly, the Jacob's Lake epilimnion was in February

the coldest station, whereas during the other periods, it was warmer than all

others. Evidently, surface water temperature of the lake changes more

rapidly than in any of the shallower streams. This indicates that some

stratification likely occurs, even though the lake is regarded as nearly

constantly mixed (Efford, 1967). Overall however, it can be assumed that all

stations behave similarly with respect to seasonal temperatures.

The pH appears less regular both between stations and dates. All

stations were largely circumneutral, although there were a majority of values

recorded between pH 6 and 7. Feller (1977) found that the soils of this

area have a good deal of mineral leaching, which results in a reduction in

the concentration of hydrogen ions from the rainwater through to the stream.

Patterns in pH, although not particularly strong, can be outlined. Down-

stream, Stations 1, 2, and 7, as well as the upper Station 6, had high

values during February and low values in May. The outflow (Station 3) was

most erratic, but did not follow patterns in Jacob's Lake to any degree. Little change occurred for Station 5, varying ±0.15 pH units from a mean of 6.25. The three near-lake/lake Stations (3, 4, 5) apparently were independent of each other with respect to pH characteristics.

Current velocity generally was rapid at all stream stations with the exception of Station 5, which is characterized by large pools and infrequent, small riffles. In flow conditions, Station 5 was most dissimilar to all other stations, excluding Jacob's Lake. The main stem reaches of the North Alouette, particularly Stations 1 and 2, were most rapid, sometimes averaging over 1 m sec^{-1}. The lowest station on the North Alouette did exhibit a reduced current, where slope is much less than upstream stations. Average values can be ranked more or less in the order Stations $1 \gtrless 2 > 3 =$ $6 > 7 > 5 > 4$. Although the average values for Station 6 were similar to that of Station 3, they were quite dissimilar. Station 6 consisted of many extreme cascades alternating with large pools, and Station 3 was primarily riffles. The temporal pattern is similar for all stations, which may be expected. The stations all are interconnected and occur within a length of ca. 12 km, and hence, experience roughly similar climatic conditions.

These variables of temperature, pH, and current velocity can be summarized further in their relative value in comparing dates and stations. Current velocity exposed differences between stations regardless of time of year. Temperature was similar between stations, but highly seasonal. The values recorded for pH, however, did not easily define categories or temporal responses for these locations. Those characteristics which remained effectively constant, such as slope and stream width, will also be regarded as factors of comparison between stations.

Table 6. Temperature (°C), pH, and current velocity (cm sec^{-1}) measured at single times at seven collecting stations on four sampling dates (* = Station 1 on 3 March 1978, ** = Station 2 on 9 October 1977, ND = no data available, -- = assumed negligible).

STATION	9 AUGUST 1977[**]			15 FEBRUARY 1978[*]			18 MAY 1978			23 JUNE 1978		
	TEMP	pH	CURR	TEMP	pH	CURR	TEMP	pH	CURR	TEMP	pH	CURR
1: Main station, North Alouette River	18.3	7.20	58	3.1	7.15	95	8.1	6.50	119	13.4	6.80	61
2: Stream junction, North Alouette River	8.0	6.70	64	2.1	7.35	104	9.2	6.35	106	11.0	6.55	67
3: Jacob's Creek at lake outflow	19.0	7.00	53	3.0	5.85	87	10.2	6.40	89	17.0	6.85	56
4: Jacob's Lake	19.2	6.15	--	2.0	6.15	--	12.2	6.30	--	18.2	6.65	--
5: Upper Jacob's Creek	17.0	6.10	15	2.4	6.25	25	9.4	6.15	25	11.2	6.40	16
6: Tributary B	15.0	6.55	52	2.2	7.40	86	6.8	6.45	88	10.2	6.90	55
7: Lower North Alouette River	ND	ND	ND	4.0	7.00	73	11.8	6.45	73	13.8	6.25	47

B. TEMPORAL PATTERNS IN PHYSIOCHEMICAL PARAMETERS

   WITHIN STATION 1

The water chemistry and other abiotic parameters were measured in detail at Station 1. As duplicate samples for the nutrient chemistry were all that were taken (assuming well-mixed), no error bars are shown for the cation and anion concentrations. The low overall values for dissolved substances are within the range found for other Pacific coastal watersheds in British Columbia (Scrivener, 1975; Feller, 1977) and Washington (Triska and Sedell, 1976).

The patterns of the four dissolved anions plus ammonia are not entirely similar (Fig. 12). Trends in NO_3^- and NH_4^+ appear to show an inverse relation. SO_4^{2-} and Cl^- ions exhibit very little change over the year, although a slight increase occurred over winter. SO_4^{2-} and Cl^- were the most abundant anions on the average. PO_4^{3-} was somewhat erratic, but the mean value was less than that measured in an adjacent watershed (Feller, 1977) and the least concentrated of the group. The anions were generally highest during late summer and autumn. The order of their relative average concentrations plus SiO_2 (Fig. 14) were: $SO_4^{2-} > SiO_2 > Cl^- > NO_3^- > PO_4^{3-}$.

Of the seven cations measured, the concentrations of only four were within detectable limits (Fig. 13). $Fe^{2+/3+}$, Mn^{2+}, and Al^{3+} ions were never found in the dissolved fraction. This is similar to that recorded by Wali et al. (1972), where these minerals were not detectable in Jacob's Lake water, but appreciable concentrations occurred in the sediments. In contrast to the anions, the cations showed a remarkably high degree of similarity in temporal pattern. All showed their greatest level in mid-

August and generally so over much of the late summer/early fall. Low

levels were also synchronized in a number of periods during the spring and

assumedly through the winter. Generally, the order of concentrations was:

$$Ca^{2+} \simeq Na^+ > Mg^{2+} > K^+ > NH_4^+ >> Fe^{2+/3+} \overset{?}{=} Mn^{2+} \overset{?}{=} Al^{3+}.$$

The seasonal levels of alkalinity, pH, SiO_2, and O_2 are presented in

Fig. 14. The low alkalinity (as HCO_3^-) levels measured in the stream water

follow the general conditions outlined earlier for most areas in the Coast

Mountains (Northcote and Larkin, 1963). With this low buffering capacity

it is perhaps surprising the pH values did not vary greatly both within the

day (standard deviation) and seasonally. The slightly higher values during

June 1977 were not repeated the following June. The widest variations in pH

occurred when alkalinity was at its lowest, during winter. Dissolved SiO_2

was relatively abundant, averaging more than any other ion except SO_4^{2-}.

The seasonal pattern of SiO_2 was similar to the cations. A strong peak

occurred during mid-August and subsequently in early March. Dissolved oxygen

was always at or above saturation levels all times of the year. Absolute

values varied, largely responding to seasonal temperature changes, the major

factor influencing concentration (Golterman, 1975; Wetzel, 1975).

Although light energy was measured, equipment failures did not allow a

complete picture. Generally, data for average daily radiation showed a

gradual increase from early June (27 gm·cal cm^{-2} d^{-1}) to a maximum in early

and mid-August (32-36 gm·cal cm^{-2} d^{-1}), and then reducing to half the

maximum by November. The following spring this pattern appears similar

(data incomplete). The measurements for any week were marked by at least

a few cloudy days so that the annual picture varies only by a factor of

about two (17-40 gm·cal cm^{-2} d^{-1}). More continuous data of water tempera-

tures do reflect the seasonal character of sunlight available to the system.

The stream temperatures indicate a degree of diurnal flux by maximum and minimum values (Fig. 15). The water temperatures appear to follow a seasonal pattern much related to daylength, where August was the warmest month. During this period, the algal populations experienced a daytime flux of as much as 4°C. Whether the complete diurnal flux is any greater is unknown, but due to the canyon effect in this area, measurements were made over the time during which the direct effects of sunlight were present. The temperatures ranged nearly 5-fold over the year, although complete freezing never occurred.

Flow conditions, which are reflected in stream depth and current velocity, were highly varied seasonally and within Station 1 on any one date (Fig. 15). Both depth and current followed similar patterns and are considered here as two expressions of one phenomenon. Stream width might also be considered a function of flow, but varied less than 10% from the mean (17.5 m), hence provides little information concerning changes in stream levels. Stream flow was greatest in late autumn-winter. The decline after October may not be as immediate as shown (interpolated), as floods made sampling impossible during this period. Spring also exhibited a pulse in current velocity, although of less intensity. The time from late spring until the beginning of autumn (March-August) was one of calmer flow, but these dates were at times interrupted by brief spates.

When considered as a whole, the physiochemical environment of the stream may be reduced to a number of distinguishable patterns. Because differences in scale of the graphs may misrepresent similarities in pattern, a simple linear correlation between all variables was made (Table 7). The first group which can be identified may be regarded as the "cation group." K^+ is

least strongly (positively) correlated among these, but in addition to Ca^{2+}, Na^+, and Mg^{2+}, NO_3^- is also strongly and positively correlated. NH_4^+ did not produce a significant negative correlation as was assumed simply by observing Fig. 13. Although one cation, Na^+, did correlate reasonably well with the changes in stream depth, this will not be considered part of the assigned group, but will be mentioned later.

A second group changed gradually over the year, largely reflecting differences in daylength. This "daylength group" includes a strong correlation between temperature, dissolved O_2, and presumably light. A third associated group of variables includes Cl^-, SO_4^{2-}, NH_4^+, current, depth and SiO_2. In this "streamflow group", a strongly significant ($P<0.001$) correlation between current velocity and depth supports the earlier assumption that these behave similarly. All members of this group are positively correlated, with the exception of SiO_2. Whether pH is allied to this group (a very strong correlation with depth) or the cation groups (two lesser correlations out of five) is not clear. Two outliers, PO_4^{3-} and HCO_3^-, surprisingly had no strong correlations to any variables measured, and were for the most part, sporadic.

The inability to place all the physiochemical variables into separate classes is not surprising. The correlation between some members of the cation group with the streamflow group may reflect effects due to a phenomenon not directly measured, such as rainfall, which may alter the amounts of some dissolved minerals. The intercorrelations undoubtedly reflect the artificiality of the grouping process to some extent as well. Golterman (1975) states that temporal changes in stream-water chemistry frequently vary inversely with flow. The large number of negative correla-

tions with current velocity and depth follow this observation (Table 7).

The cations Ca^{2+} and K^+ also correlate strongly with the daylength group,

but possible biological interrelations cannot be assumed with any certainty.

The lack of any strong correlation between alkalinity, PO_4^{3-}, and all other

variables, although unexplained at present, does not indicate a lack of

importance, as these correlations merely point out the significance of

coincident phenomena. For example, PO_4^{3-} concentrations found in this study

are within or below levels found to be limiting growth of a number of

freshwater algal species (Müller, 1972; Rhee, 1973; Titman, 1976).
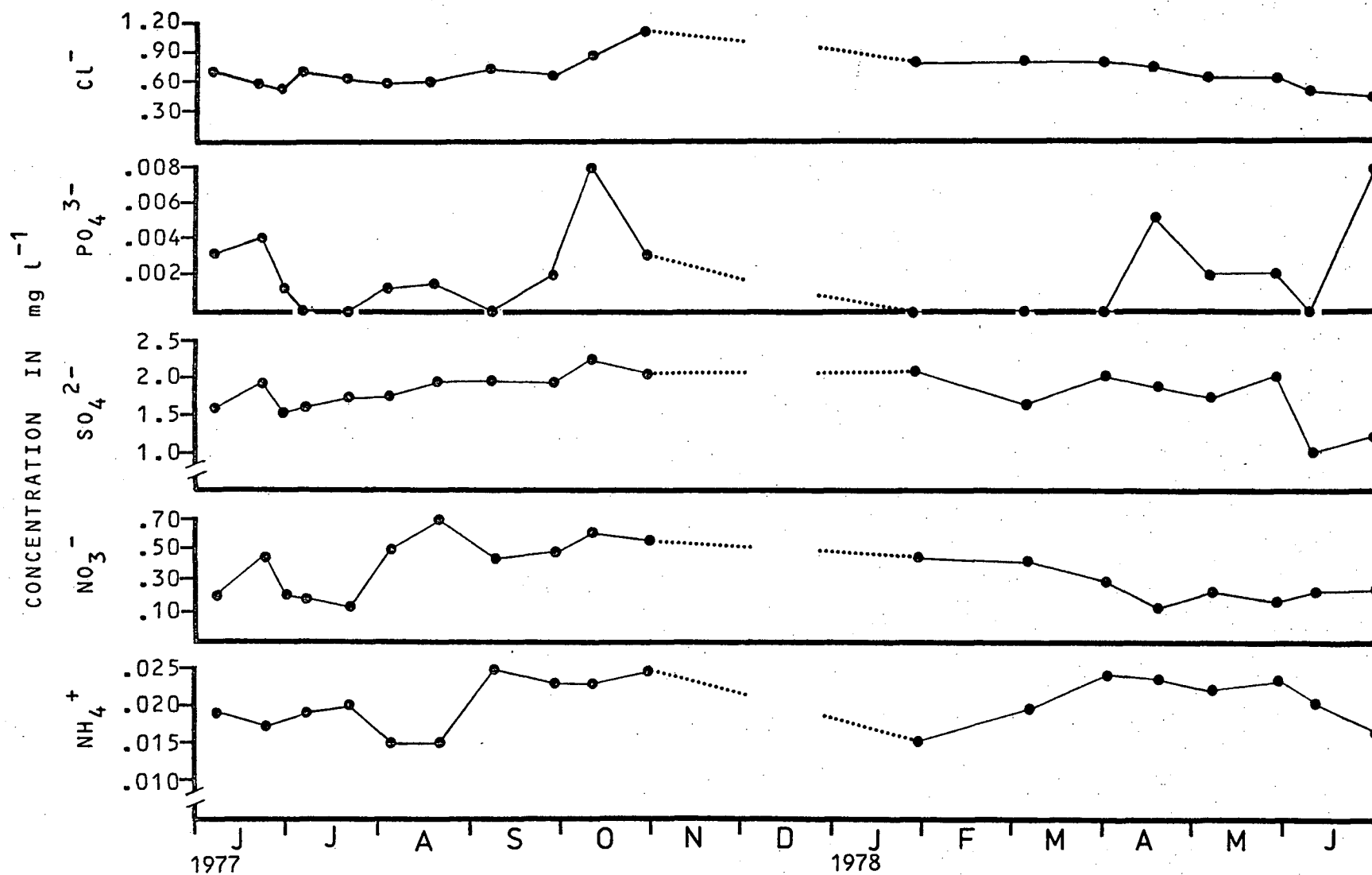
Figure 12. Temporal variability of anions (Cl^-, PO_4^{3-}, SO_4^{2-}, NO_3^-) and NH_4^+ at Station 1.
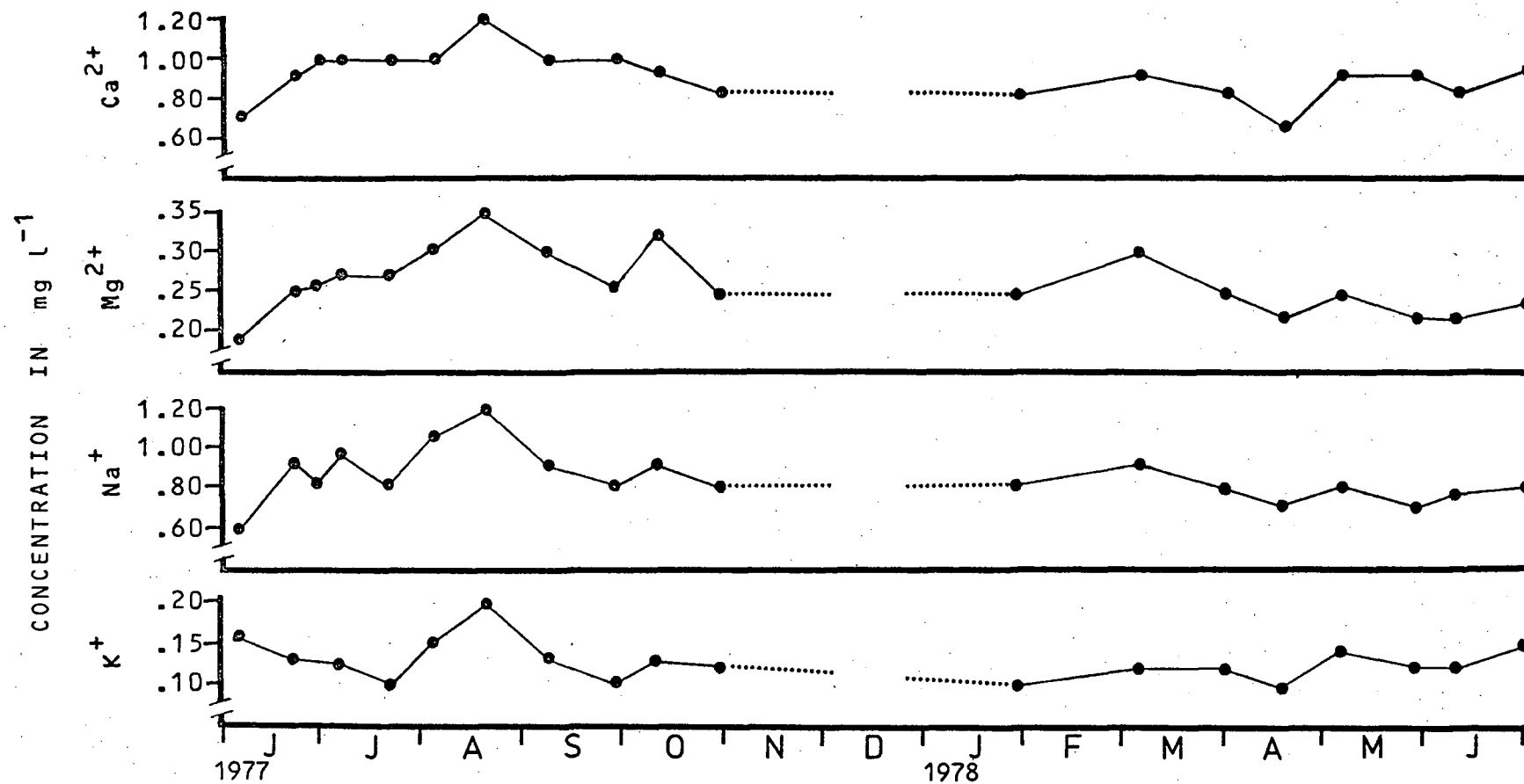
Figure 13. Temporal variability of cations (Ca^{2+}, Mg^{2+}, Na^+, K^+) at Station 1.
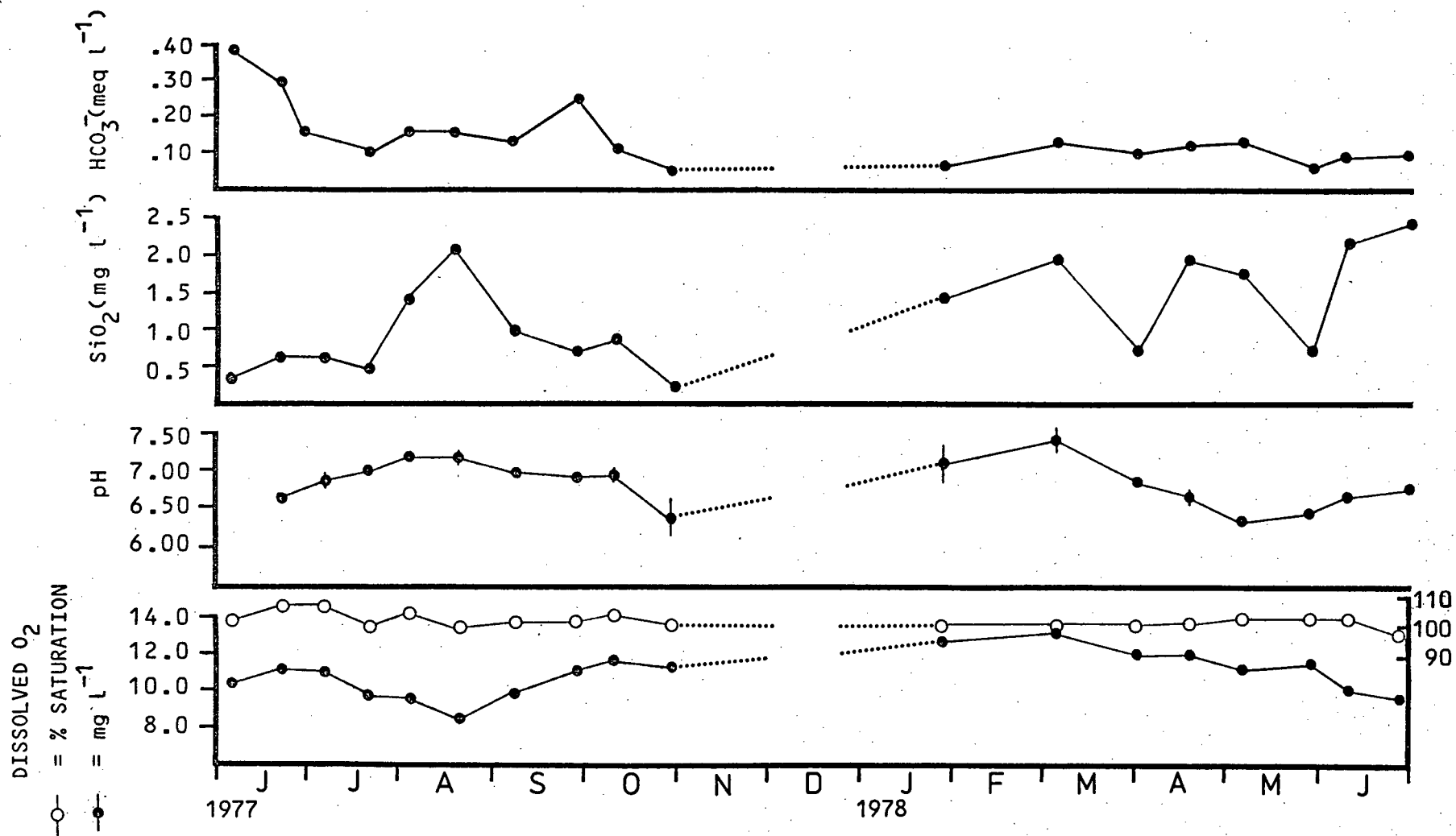
Figure 14. Temporal variability of alkalinity (HCO_3^-), SiO_2, pH, and dissolved O_2 at Station 1.
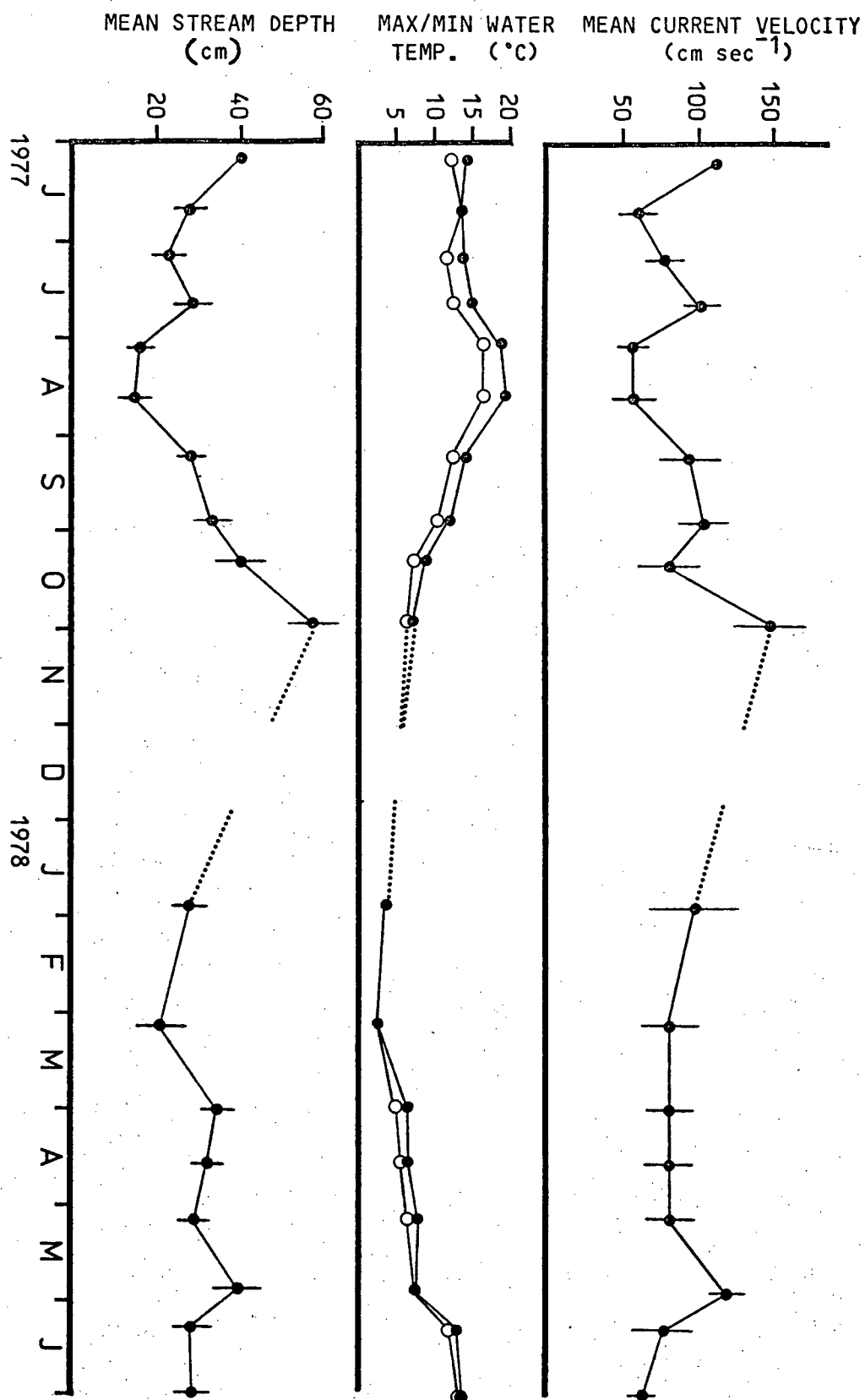
Figure 15. Temporal variability of current velocity, water temperature, and stream depth at Station 1.

Table 7. Linear correlation between all physiochemical variables for three levels of significance (* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$).

	PO_4^{3-}	HCO_3^-	Cl^-	SO_4^{2-}	CURRENT	DEPTH	Ca^{2+}	Na^+	Mg^{2+}	K^+	SiO_2	NO_3^-	NH_4^+	TEMP	O_2	pH
PO_4^{3-}	X															
HCO_3^-	.0656	X														
Cl^-	-.0217	-.1049	X													
SO_4^{2-}	-.0291	-.1369	.6440**	X												
CURRENT	-.1222	.0134	.6364**	.3360	X											
DEPTH	.2746	-.1016	.6530**	.4214	.8030***	X										
Ca^{2+}	-.0880	.0058	-.1875	.1743	-.3215	-.4200	X									
Na^+	-.1910	-.1830	.0072	.1350	-.5145*	-.5875*	.6550**	X								
Mg^{2+}	-.1092	-.2360	.2072	.3032	-.3570	-.4377	.5852*	.9302***	X							
K^+	.2206	.3502	-.1799	-.0950	-.2451	-.1474	.4727*	.3591	.1986	X						
SiO_2	.1933	-.3769	-.6289**	-.5468*	-.6126**	-.5157*	-.0640	.2131	.1001	.1229	X					
NO_3^-	.0516	.0751	.3795	.3987	-.1124	-.1055	.3815	.7043**	.7617***	.3990	-.0928	X				
NH_4^+	-.0811	-.2409	.5705*	.4657	.5528*	.6050**	.0007	-.1617	.0135	-.1961	-.4464	-.0430	X			
TEMPERATURE	.0314	.4078	-.3753	-.3803	-.2888	-.4343	.6315**	.3459	.1983	.6809**	-.0055	.2220	-.3132	X		
O_2	-.0971	-.2977	.3221	.3560	.2249	.3735	-.6850**	-.3700	-.2649	-.6824**	-.0422	-.2390	.2174	-.9586***	X	
pH	-.2649	-.0352	-.1065	.0346	-.4376	-.6744**	.1568	.5841*	.6475**	-.1415	.2553	.3910	-.3574	.0257	-.0152	X

C. GRADIENT ANALYSIS OF PHYSIOCHEMICAL VARIABILITY

AT STATION 1

In conjunction with the algal distribution analysis, within Station 1,
a number of factors were measured along the first transect at regular
intervals. These were pH, temperature, dissolved O_2, current velocity,
depth, and incident light. Measurements on the micro-scale were made in
weeks before (31 March, 17 April) and after (26 May, 8 June, 29 June) the
date of algal sampling, as well as on that date (4 May). Although absolute
values changed temporally, the patterns along the transect did not vary over
this time. Mean values of the six dates are given (Fig. 16). The first two
variables, pH and temperature, did not change significantly, and so were
measured only at three intervals. The equality of both of these on any of
the six dates (little standard deviation) supports this. Dissolved O_2
varied slightly but produced no evidence of a gradient.

Current velocity did vary across the stream. Midstream was the region
of greatest flow, but apparently the resistance offered by either stream
bank was not equal. This segment of the stream was at a bend, and as
indicated by Hynes (1970), tended to displace the idealized flow pattern.
Depth was also not uniform, where shallows were recorded at edge and
midstream. The availability of light also varied across the transect, but
apparently less irregularly than did current velocity. The orientation of
this segment of the stream was generally southwesterly, so that the
southeast bank was more strongly affected by shading. Further, as the sun
moved across the sky, different localities of the midstream were under full
irradiance. Hence, large standard deviations were observed at these
positions, and less so in the shaded parts.

In general, three factors were measured, depth, current velocity, and irradiance, which changed significantly along the transect. The experiment, however, was not designed to test between these variables. Nonetheless, the measurements do expose a degree of spatial heterogeneity within one locality, even though at present, similarly varying factors cannot be separated with any certainty.
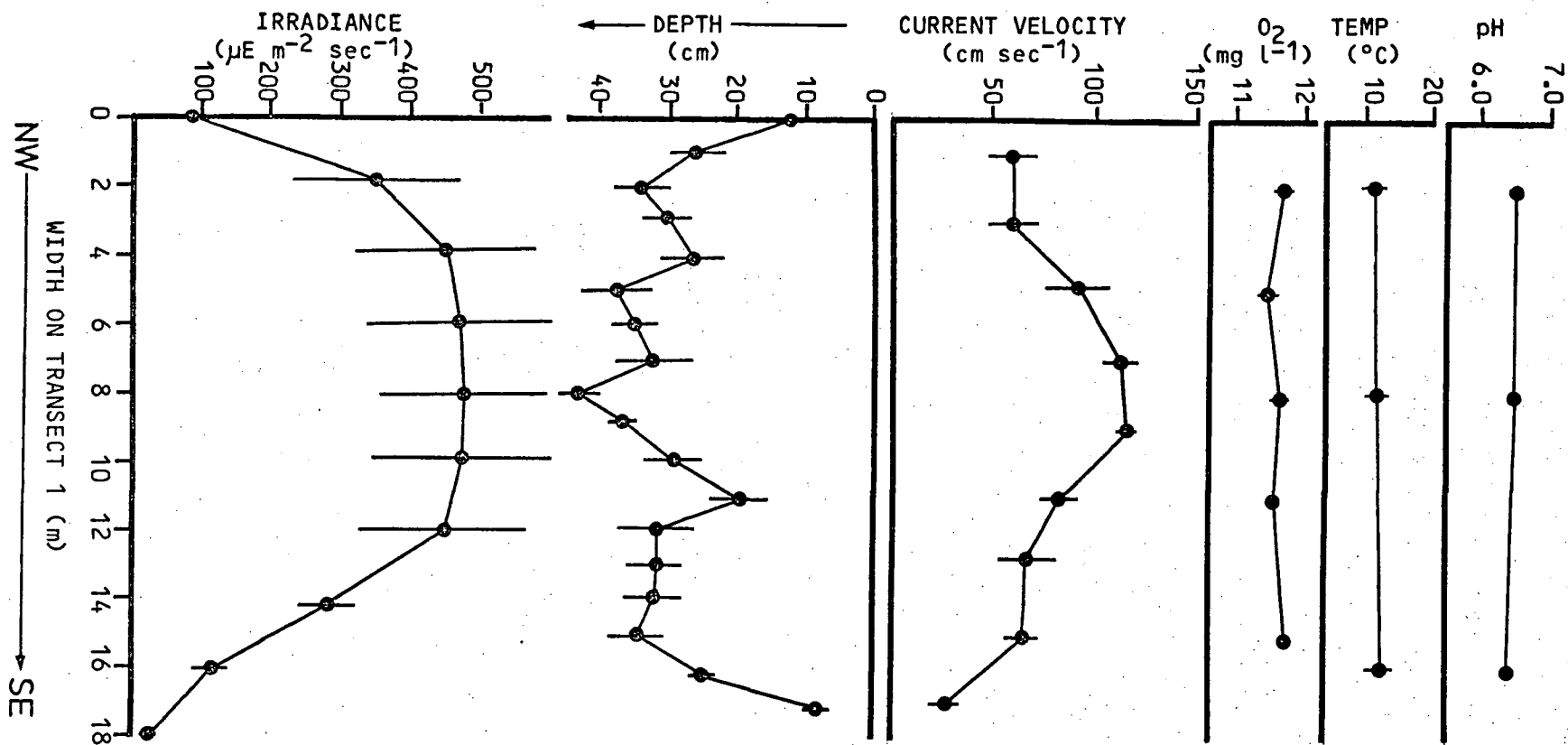
Figure 16. Cross-stream variability of pH, temperature, dissolved O_2, current velocity, depth, and irradiance at Station 1 on for six weeks during spring of 1978.

VI. DISCUSSION

A. SYNTHESIS OF BIOLOGICAL AND PHYSIOCHEMICAL RESULTS

Temperature distinguished between times of year for any given station, whereas variations in current velocity revealed differences between the stations themselves (Section V-A). These results suggest that flow characteristics may have been effectual in the production of different species composition along the stream gradient. Further consideration of the analyses indicates that this may not be entirely true. For example, neighboring Stations 5 and 6 were shown to have highly similar algal communities at all times of the year (Figs. 3-6), yet their flow regimes were not all alike (Table 6).

The picture of longitudinal differences along the stream is most likely characterized both by changes attributable to seasonal fluctuations and those features, like current velocity, are "fixed" in their relative differences between stations. The communities found at each station during the winter (February) are least clearly separable from each other, after considering dominant species (Table 3), species diversity (Table 4), and ordination of the complete assemblages (Fig. 5). The exception of a rather distinct Station 2 on the North Alouette can now be explained in that on this later collecting date (3 March), Zygnema insigne had taken an abrupt increase in importance (shown in Station 1, Figs. 8, 10). However, using these same criteria of dominant species, diversity, and the P-Co-A, the strongest clustering of stations occurred during June 1978 (Tables 3, 4, Fig. 6) and August (Tables 3, 4, Fig. 3). Here, four of five lotic stations were highly similar, but differed from the outflow stream, all of which diverged from

Jacob's Lake. An interpretation of this difference in patterning would suggest an overriding influence of the cold temperatures during winter, while at other times of the year species composition was largely influenced by current velocity.

The difficulty in explaining the causes of highly similar species composition at Station 5 and Station 6, however, has not been removed. Superficially, the algal vegetation and habitats of the two appear quite dissimilar. The slower flowing upper arm of Jacob's Creek (5) was very poorly colonized all year, except at the infrequently spaced riffles. Less than 500 m upstream, the fast flowing Tributary B (6) was heavily carpeted with algae and bryophytes. Owing to the proximity of the two stations, it may be assumed that the species pool from this cascading region served to colonize Station 5. Hence, it is not surprising that the two stations have many species in common. Accumulation of algae in the slower flowing station (5) was restricted primarily to the riffles, suggesting the upstream propagules had some specificity for a rheophilic habit. The lack of difference expressed by ordination, then, is a reflection of the enumeration method as well, in that only the proportion of each species was recorded, and not biomass.

The complex of physiochemical factors examined at Station 1 to describe temporal variation was simplified by identifying groups of factors that responded similarly over the year. The daylength group varied gradually, whereas the cation and streamflow groups, as well as the few erratically changing factors all had sudden peaks and lows in time. The seasonal progression of major species (Fig. 7) and the pattern from ordination results for the algal community (Fig. 9) exhibited periods that at times

changed smoothly and at other times, rapidly. Some of these accelerated

changes were during early to late September, late January to early March,

and early to mid-August. In general, these were times when the abundance

of <u>Klebsormidium rivulare</u>, <u>Zygnema insigne</u>, and <u>Phormidium autumnale</u> either

greatly increased or decreased. A more precise measure of the rate of change,

based on the measured distances from the P-Co-A plot between points versus

the number of days spanned, provides the following order: September (.36

cm/day) > August (.32 cm/day) > January-March (.24 cm/day).

When compared with the major fluxes in the physiochemical environment,

the large-scale species replacement of September corresponds with a time of

increasing current velocity and depth (Fig. 15), but not with the other

member of this group, dissolved SiO_2 (Fig. 14). The August species flux was

a period where all cations increased (Fig. 13), plus NO_3^- and SiO_2 (Figs. 12,

14). Finally, the January to March succession was marked by increases again

in dissolved SiO_2, as well as pH (Fig. 14), and slightly in the cations.

Current velocity here dropped.

The consideration of all species data made by correlating the coordin-

ates of the first three axes of the seasonal ordination (Fig. 10) with the

temporal flux of all physiochemical variables (Figs. 13-16) can be compared

in one unit (Table 8). The differences in species composition described

by the first coordinate axis correlates significantly with the anions Cl^-

and SO_4^{2-}, also current velocity and depth, all positively. This axis

correlates negatively with temperature. The first axis is associated

largely with the changes in importance between an association dominated by

<u>K</u>. <u>rivulare</u> and a <u>Z</u>. <u>insigne</u>/<u>P</u>. <u>autumnale</u> association. The <u>K</u>. <u>rivulare</u>

association thus was found at times of low temperature, high current velocity,

and greater concentrations of Cl^- and SO_4^{2-}. The $\underline{Z}$. $\underline{insigne}$/$\underline{P}$. $\underline{autumnale}$ association was more of a spring-summer occurrence, where greater temperatures were joined by reduced current, and Cl^- and SO_4^{2-} concentrations. This was also a period of greater plankton accumulation amongst the filamentous species from the drift, mostly of desmids.

The second coordinate axis correlated significantly and this time positively with temperature, and all members of the cation group, as well as negatively with O_2. The behavior of the second axis represented a distinction between a large number of minor species. One extreme was an association variously composed of $\underline{Oedogonium}$ sp. A, $\underline{K}$. $\underline{mucosum}$, $\underline{Batracho\text{-}}$ $\underline{spermum}$ $\underline{moniliforme}$, and $\underline{P}$. $\underline{autumnale}$. This is contrasted with an association of $\underline{Tolypothrix}$ $\underline{penicillata}$, $\underline{Stigonema}$ $\underline{mamillosum}$, $\underline{Audouinella}$ $\underline{hermanni}$ and again, $\underline{K}$. $\underline{rivulare}$. This less distinct axis is further complicated in that moderate levels of $\underline{Z}$. $\underline{insigne}$ were present on dates plotted on either ends of this vector. When compared with Fig. 9, however, species diversity was greatest on dates corresponding to the largest (positive) values on the second axis. Hence, species diversity was highest during periods of higher cation and NO_3^- concentrations, greater temperatures, and low dissolved O_2.

The third axis did not correlate significantly with any of the variables measured. In all, flow conditions and temperature flux were significantly correlated with, and may be influential in the patterning of species associations seasonally as well as between segments of the stream. Concentrations of dissolved substances, particularly SO_4^{2-} and Cl^-, may be factors affecting the presence of some dominant species over the year. The increased levels of cations, NO_3^-, and temperature were associated with periods of greater diversity at Station 1.

Synthesis of data collected for a cross-stream gradient at Station 1 provides finer details of the relation between algal distribution and abiotic factors. The midstream association was at this time dominated by Z. insigne, and to a lesser degree, K. rivulare. The marginal, or stream-edge habitat was characterized by an accumulation of T. penicillata, K. mucosum, and S. mamillosum. Shading caused by the streamside canopy differed for these two associations, as did flow regime. This suggests both may elicit some response in the algal distribution. Unlike the seasonal or longitudinal patterning, there was no evidence suggesting temperature was a factor in the microdistribution within Station 1. Further, both current and irradiance were more appreciably reduced toward the one margin where the bulk of the representatives of the stream-edge group were found.

The separation of these hypothesized causal factors cannot be easily accomplished from the data at hand. However, some evidence from between-station results (Section IV-B) may be of use in this respect. Tributary B is a narrow and well-shaded, but rapidly flowing stream. Upper Jacob's Creek is more openly lighted and slowly flowing. If current regime were most effectual in the Station 1 microdistribution, the species composition at Tributary B in May would be more similar to the midstream association, with Upper Jacob's Creek more similar to the stream-edge association. If light were more important, the reverse would be true. As mentioned, little difference in species composition was found between these two stations. During May, the principal representatives at both were K. mucosum, Z. insigne, and S. mamillosum, which at Station 1, occurred in distinct groups. It appears that instead of discriminating between two possible effects, these

two have remained intertwined. In any event, the results thus far suggest that light availability and current velocity were affecting the microdistribution of algal species at a wide reach of the North Alouette River on at least one date. It is presumed these factors were acting independently, but present methods were unable to discern between them.

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Table 8. Correlation between environmental factors and scores
of the first three coordinate axes of the date ordination,
given for three levels of significance (* = P < 0.05, ** = P <
0.01, *** = P < 0.001; data from Figs. 9, 12–15).

FACTORS	CORRELATION WITH COORDINATE SCORES		
	AXIS 1	AXIS 2	AXIS 3
PO_4^{3-}	.1123 NS	-.1093 NS	-.1293 NS
HCO_3^{-}	.0496 NS	.1334 NS	.0987 NS
Cl^{-}	.6448**	.0006 NS	-.0997 NS
SO_4^{2-}	.6433**	.0875 NS	.0469 NS
CURRENT	.5614*	-.1274 NS	.2342 NS
DEPTH	.6280**	-.3778 NS	.1164 NS
Ca^{2+}	-.1969 NS	.7263***	-.0412 NS
Na^{+}	-.2653 NS	.6478**	-.3479 NS
Mg^{2+}	-.0337 NS	.6570**	-.3711 NS
K^{+}	-.1901 NS	.5131*	.0552 NS
SiO_2	-.4298 NS	.0050 NS	-.2008 NS
NO_3^{-}	.3336 NS	.6873**	-.2536 NS
NH_4^{+}	.3970 NS	-.0211 NS	-.1674 NS
TEMPERATURE	-.4715*	.6548**	.2270 NS
O_2	.4135 NS	-.7171***	-.2701 NS
pH	-.1229 NS	.3586 NS	-.1724 NS

B. IMPORTANCE OF MAJOR SPECIES AND THEIR LONGITUDINAL

DISTRIBUTION

By and large, the two most widespread and abundant species of algae in

the North Alouette stream system during this study were the filamentous

greens, Zygnema insigne and Klebsormidium rivulare. These species have not

been reported widely in North American streams (Blum, 1956; Whitton, 1975),

nor specifically in nearby areas of Washington (Cushing, 1967), Oregon

(Sherman and Phinney, 1971; Hansmann and Phinney, 1973), Montana (Gumtow,

1955; Parker et al., 1973), Alberta (McCart et al., 1977), the Yukon (Bryan

et al., 1973), or Northwest Territories (Moore, 1977c). This is probably

as much a reflection of the scarcity of studies on British Columbia streams

(Stein, 1975; Stockner and Shortreed, 1976), as it is of the differences

that such systems have from more alkaline, continental systems. The lack of

Cladophora- or diatom-dominated communities (reported by the preceding

authors) in the North Alouette supports to a degree the generalizations of

Margalef (1960), for nutrient-poor mountain streams, which however, were not

discussed in any detail.

The major species of the North Alouette system are comparable with

floral types identified in Scandanavia (Israelson, 1949). In oligotrophic

regions these streams were regarded as the "Zygnema type", where in addition

to a number of sterile and a few reproductive species as dominants, further

parallels were present. Israelson noted the coexistence of Batrachospermum

moniliforme, Stigonema mamillosum, Mougeotia sp., Spirogyra sp. and

Bulbochaete sp. (the last three sterile). All were abundant in various

segments of the North Alouette watershed. The Scandanavian flora was also

characterized by a "subtype", in heavily shaded and pooled streams, with the
accumulation of humic substances. These were typified by large stands of
Batrachospermaceae, as found in segments of Upper Jacob's Creek and other
similar streams of the U.B.C. Research Forest not included in this study.
Observations of crustose growths of Batrachospermum in less shaded reaches
of Jacob's Creek, especially Station 5, may likely be due to light inhibition.

Klebsormidium, or related genera were not reported by Israelson (1949).
However, a number of species, including K. rivulare (as Hormidium rivulare),
have been reported in streams of lower pH in England (Say et al., 1977) and
Germany (Backhaus, 1968). Alpine streams in Austria with comparable nutrient
chemistry, flow, and substrate type also exhibit a similar community compos-
ition, including K. rivulare, Phormidium autumnale, Tolypothrix penicillata,
B. moniliforme, and a number of other species (Kann, 1978).

The probable causes for such a green and bluegreen dominated system in
the North Alouette are no more evident from this work than from the litera-
ture. A very large species pool of diatoms from Jacob's Lake was available
to the stream (Table 2). These were successful colonizers in number (33 taxa),
as compared with other algal groups, yet none were able to reach dominant
proportions (rank of 5) in flowing water any time of the year. Douglas
(1958) reported a reduction of diatom growth in streams of peaty areas as
compared with calcareous regions nearby. The same pH levels (Table 6) and
geology (Roddick, 1965) occur throughout the watershed, yet diatoms did
flourish in Jacob's Lake. This does not support Douglas' theory based on
alkalinity. Patrick and coworkers (1969) were able to demonstrate a
selection of bluegreen algae in manganese-poor water and diatoms where
levels were greater than 0.04 mg/l. Manganese was not measurable in the

stream water of this study, but concentrations were found to exceed 5 mg/l

in the sediments of Jacob's Lake (Wali et al., 1972), where diatoms predomin-

ated (rank of 5 in a majority of samples). Although this is highly suggestive,

the stream studied by Patrick was of considerably greater pH, alkalinity, and

nutrient levels, and their communities did not produce large amounts of green

algae, the principal group at the North Alouette.

The streams of the North Alouette system may possibly be considered a

less stable environment than lake sediment for diatom colonization, due to

scouring from the current. However, a number of species commonly regarded as

rheophilic, including Hannaea arcus, Cocconeis placentula, and Gomphonema

parvulum (Hustedt, 1937-1938; Patrick and Reimer, 1966; Lowe, 1974) were

common, but never dominant in the streams. In any event, the results for

the North Alouette River do not agree with previous findings (Patrick, 1967)

that the available species pool (e.g., diatoms from Jacob's Lake) and an

adequate "invasion rate" (via flushing from the lake epipelon) will necessar-

ily induce a diversified community. As there are few records in the

literature of algal communities in similar streams to the North Alouette,

an explanation of this discrepancy must await further study.

The comparisons between stations within the watershed indicate a degree

of similarity between Stations 1, 2, 5, 6, and 7 for each of the four times

of the year sampled. The concept of longitudinal zonation expressed for

many animals (Hynes, 1970) and less frequently for algae (Scheele, 1952;

Kawecka, 1971) in streams appears questionable for algal communities in the

North Alouette system. It may be that all stations lie within what Illies

and Botosaneanu (1963) regard as a single zone, the rhithron. Their

classification recognizes high flow rate, a lack of extremely warm tempera-

tures, and rocky substrates are important. Because these characteristics
pertained to the distribution of attached fauna, this category may not
adequately portray those limits to which algal species respond. Further,
it seems that rather than entire communities occurring in distinct zones,
the results indicate that many species were responding independently to
changing environmental constraints along the stream gradient, as observed
by Backhaus (1968). For example, although a _Zygnema_ or _Klebsormidium_
association was found in most instances at the lotic stations, _Audouinella_
hermanni was present only at the lower three stations, and attained dominant
proportions (rank of 5) in samples only from the lowest station (7).

Trends in species diversity longitudinally were also not distinct.
Mack (1953) found that in one Austrian stream system, algal communities were
increasingly diverse further downstream. In the present study (Table 4),
the greatest levels of diversity among the streams were at times upstream,
and in other instances, downstream. In either condition, no evidence was
found for patterns of increase or decrease longitudinally. The fact that
Jacob's Lake was more diverse than all other stations indicates that species
diversity, again, was not simply a matter of species loading to downstream
stations. Further, the above-lake Station 6 showed greater diversity for
three of the four periods than did the North Alouette at Station 2, which
was about 1.2 km below the lake outflow.

The ordination results (Figs. 3-7) indicate there were gradual differ-
ences in species composition between stations along the stream, but did not
clearly demonstrate a simple progression. For August, Jacob's Creek at the
lake outflow (3) was highly distinct from either of its nearest neighbors
among the flowing water stations (5, 2). Instead, the above-lake (6, 5)

and lowest (1, 2) stations sampled at this time were highly similar. This points out that the impoundment of Jacob's Creek precludes any possibility of a strictly altitudinal basis for zonation. The changes in species composition with time were such that the pattern of similarities between stations during February (Fig. 5) had little resemblance to that of August (Fig. 3). This flux of affinities between communities at different stations was true for May and June as well. These observations indicate that algal populations were sufficiently modified by either seasonal (e.g., temperature) or periodic (e.g., flow regime) events, so that no consistent zonal pattern occurred over the year.

C. TEMPORAL VARIABILITY AND SEASONAL SUCCESSION

AT STATION 1

Seasonal succession of algal species at Station 1 over one year did not

follow the general model where species build up and disappear in a "tree-

by-tree replacement process", as generalized by Horn (1976), and which

follows for most freshwater phytoplankton communities of lakes (Hutchinson,

1967; Round, 1971). In the North Alouette River there was a persistence of

the entire assemblage within which the wax and wane of certain species

occurred. Round (1972) found that epipelic algae in two pools had broader

seasonal peaks, resulting in longer periods of coexistence between species

than in phytoplankton. These species did not extend over the entire year,

as did epilithic algae in the North Alouette River. Figure 17 compares

hypothetical growth curves for phytoplankton and epipelon of lakes (Fig.

17A, B) with the pattern of epilithic algae from the stream in this study

(Fig. 17C). The growth of species 1 in the lotic system is similar to that

of Klebsormidium rivulare, species 2 as Zygnema insigne, species 3 as

Phormidium autumnale, and species 4 comparable to Oedogonium sp. A.

A greater degree of species coexistence in communities generally is

thought to be provided by greater niche space (Hutchinson, 1961). Lake

sediment may provide microhabitats for algal species (Round, 1972) and

certainly the results of the cross-stream gradient analysis suggest this is

true at Station 1 (Section VI-A). Some means of preventing species exclu-

sion would be acting, in that temporal separation is not a factor

(MacArthur, 1970) for this system.

The cycling pattern of succession (see Fig. 9) may not be a complete picture if the year to year variation is extreme. There is no reason to assume that pulses in current velocity and low temperatures will always coincide, as they did during the year of this study (1977-1978). If a spate were to occur during August on a following year, the seasonal pattern may be quite different from that presently outlined. The drastic changes in community composition over short periods (e.g., early to late September; early to mid-August) may be regarded as caused by catastrophic events, that is, floods and large nutrient pulses. In summary, the degree of environmental unpredictability (from an alga's viewpoint) reduces the evenness of seasonal patterning (Figs. 9, 17), and may affect the ability of invading species to colonize the system (Slobodkin and Sanders, 1969).
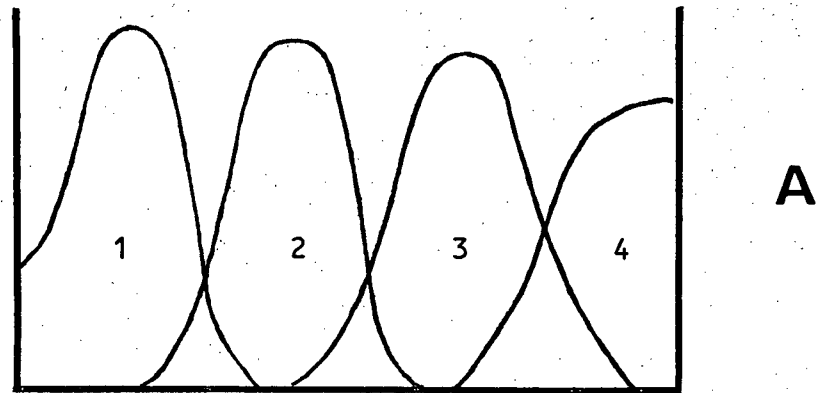
LENTIC PHYTOPLANKTON

A

LENTIC EPIPELON

B

LOTIC EPILITHON

C
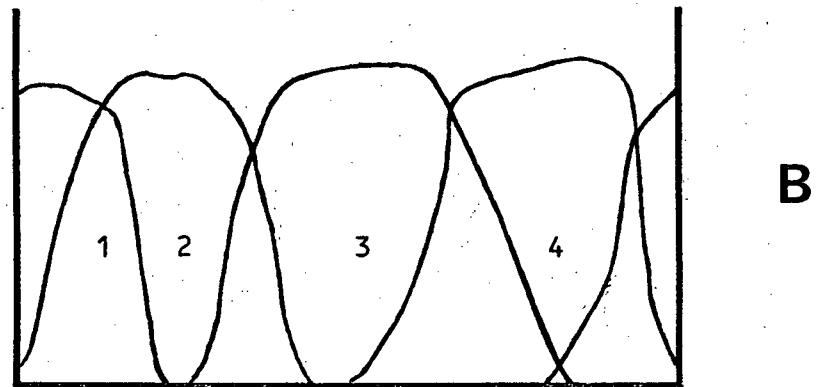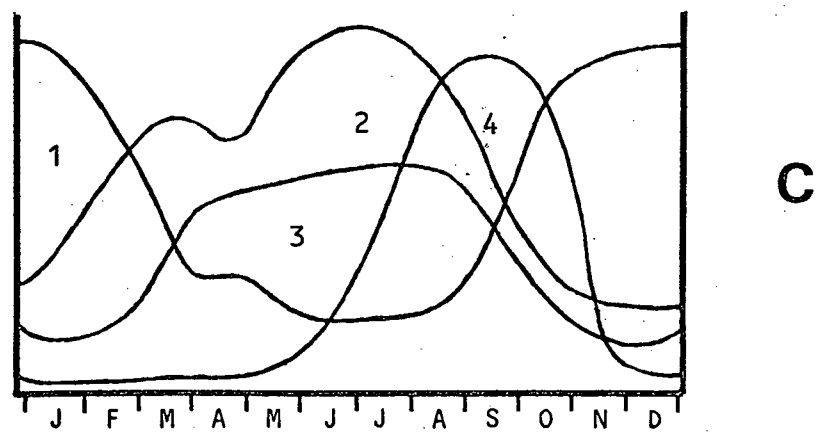
Figure 17A,B,C. Hypothetical gowth curves of major
algal species for three freshwater environments,
based on Round (1972: A,B) and the present study (C).

D. GENERAL PROBLEMS OF ENVIRONMENTAL HETEROGENEITY

The major thrust of argument has been that the stream environment of the North Alouette watershed is sufficiently varied that few species are excluded temporally (distinct seasonal communities) or spatially (longitudinal zones). This raises the question of whether such conditions should lead to high species diversity (Whittaker, 1969). In the year studied, large numbers of species coexisted within a localized region (Fig. 8), but much of the time the great majority of species were rare. Hence, there were few species of high importance. Periods of higher diversity did occur, particularly after abrupt changes in environmental conditions, and especially, current velocity. Thus, great changes in the composition (preceding section) and diversity peaks tended to coincide.

The incidence of disturbance has been suggested by Levin and Paine (1974) to bring about greater environmental heterogeneity by providing opportunity for random colonization and interrupting the normal succession process. Preliminary results in this study show that the otherwise gradual process of seasonal succession was drastically altered in August-September, corresponding to periods of high diversity (Fig. 9). This however, was not true for the large reshuffling of species between late January and early March, when diversity was much lower (Figs. 8, 9). Connell (1978) and Huston (1979) have recently reemphasized the importance of disturbance, but suggested that conditions of "intermediate disturbance" (frequency or intensity) will maintain high diversity rather than catastrophic events, which could eliminate all but a few highly adapted species.

The most diverse locality studied within the watershed, Jacob's Lake,

may have been subject to a more moderate disturbance (i.e., lake flushing; Efford, 1967) than the streams. Paine (1966) found that in space-limited communities (most sessile organisms), an absence of disturbance allowed competitive dominants to outcompete other species, hence reducing species diversity. The less dynamic conditions of June-July at Station 1 (Figs. 13-16) were periods when one species, _Zygnema insigne_, was highly abundant.

The data at present are not complete enough to produce convincing explanations as to the causes of local diversity patterns in this system. Nonetheless, the properties of such a highly fluctuating and heterogeneous environment suggest this system is worth further study. Possible approaches are considered in the following section. A fundamental problem is quantifying what level of current velocity, or any other abiotic factors, constitute a severe or catastrophic condition (Slobodkin and Sanders, 1969), and at what levels these become an "intermediate disturbance" (Connell, 1978). That is, when does a high flow condition become a flood? Further, if diversity of stream algae in the North Alouette is affected by a combination of variables, and not predictable from one element alone (shown in laboratory microcosms of phytoplankton; Reed, 1978), then the recognition of this is further complicated.

E. CONCLUSIONS AS TESTABLE HYPOTHESES

The objectives of this study were largely descriptive, as there is a paucity of basic information relating to the ecology of algal species and communities in coastal streams of British Columbia. In following with the "hypothetico-deductive philosophy" (Fretwell, 1972), experience is best summarized in the form of an explanation. Owing to the rather tentative understanding the data provide, the explanations must be approached with caution. The explanations from any descriptive study should then be formalized into hypotheses which can be tested (H_1 to H_4, following).

The preliminary problem concerned causes of differences in species composition and their distribution. Given that a large pool of green, bluegreen, diatom, and red algal species exist within the stream-watershed (Table 1, Appendix A) and that these species are freely transported between stations (Table 2), a complex of factors may be suggested in causing the presence of any particular species.

Heavily shaded segments of Jacob's Creek and shaded near-shore habitats were regions of greatest accumulation of species of Rhodophyta. It is assumed that

> distribution of red algae within this system is most
> strongly limited by availability of shade, and only
> secondarily by the absence of extreme current velocity.   (H_1)

The adverse effects of light have been supported to a degree by Rider and Wagner (1972) in laboratory experiments. One test of this in the field would involve the removal of a segment of stream-bank vegetation and the construction of artificial shading within an openly lighted stream (after Mundie, 1974). A second test of light as well as current would be provided

by transplant experiments of stones colonized by <u>Audouinella</u> or <u>Batrachosperm-</u><u>um</u> to nearby localities of the stream where current or irradiance would be the only factors altered. A similar experiment was done by Parker et al. (1973) with <u>Hydrurus</u>, <u>Monostroma</u> and <u>Batrachospermum</u>. Both tests could be used to discriminate between causes of microdistribution that was exposed along the transect within Station 1.

Determinants of community dominants may also be predicted. Based on the preliminary results and literature discussed earlier,

the occurrence of a green/bluegreen versus diatom
dominated community appears to be a result of some
chemical factor(s) (possibly manganese), rather
than current velocity or some other physical factor.   (H_2)

A test for this would involve the use of "header boxes" (Stockner and Short-reed, 1978) in the stream with a series of troughs in which are placed a random collection of stones with their associated algal assemblages. Some troughs would have continually added to them a flow of cations or other chemicals in order to reach the levels found in Jacob's Lake sediment, where diatoms were predominant. In a second test, a sample of the epipelic community from Jacob's Lake would be reinoculated into acid-washed, steril-ized lake sediment and placed in membrane-filter chambers (Schlichting, 1976) suspended immediately above the lake bottom. This would allow only the dissolved nutrients from the lake water to affect algal growth. If richer nutrients of the sediments were causal, a switch in species composi-tion in each manipulation would be expected. A lack of species change suggests physical factors may be more influential.

The pattern of seasonal succession observed over one year was a combin-ation of gradual and abrupt changes in the community. It was marked by a

greater degree of temporal coexistence than generally observed for lake

phytoplankton (Round, 1972; Fig. 17). A lack of temporal or local extinction

has been suggested to be a result of environmental heterogeneity (Hutchinson,

1957) and periodic disturbance (Paine, 1966). Hence,

> the seasonal changes in species composition of this
> stream are likely due to factors with a regular,
> cyclic pattern (e.g., daylength, temperature,
> irradiance); whereas abrupt or discontinuous
> events (e.g., nutrient pulses, floods) give rise
> to large-scale changes in the community. (H_3)

This aspect leads into the general problem of heterogeneity and diversity.

> The gradually varying environmental conditions in
> the stream lead to success of a few dominant species,
> whereas periodic disasters (or minor disasters?)
> prevent local extinction and result in higher
> diversity. (H_4)

A test of these two problems would be considered from the same experimental

design. Side channels of the stream could be constructed, after Warren et

al. (1964), which would allow different major manipulations. Through the use

of weirs or flow diversion, the current velocity could be more or less

constant, allowing the gradually varying factors to exert a greater effect

than periodic ones. Other channels could be artificially disturbed or

provided with additional structural heterogeneity (Reed, 1978).

If H_3 were true, the ordination of species succession in the flow-

controlled channel would be less erratic than shown by these preliminary

results (Fig. 9) or by controls. If H_4 were true, the more predictable

environment should lead to reduced species diversity. Also, there should be

greater temporal exclusion of species, approaching the situation for lake

phytoplankton. Other immediate stresses, such as nutrient pulses, can be tested in the same manner. The systems of enhanced heterogeneity (e.g., a diversity of substrate sizes) are predicted to do the opposite. If predictions are not met, the perturbation chosen may be (as a single causal element) excluded from consideration. Finally, the severity or frequency of an "intermediate disturbance" (Connell, 1978) can be considered in a step-wise comparison with species diversity directly.

VII. LITERATURE CITED

Allen, T. F. H. and J. F. Koonce. 1973. Multivariate approaches to algal
    stratagems and tactics in systems analysis of phytoplankton. Ecology
    54: 1234-1246.

American Public Health Association. 1965. Standard Methods for the Examin-
    ation of Water and Wastewater, Including Bottom Sediments and Sludges.
    12th ed. A.P.H.A., New York. 769 pp.

Anderson, T. W. 1958. An Introduction to Multivariate Statistical Analysis.
    John Wiley, New York. 374 pp.

Archibald, R. E. M. 1972. Diversity in some South African diatom associa-
    tions and its relation to water quality. Water Res. 6: 1229-1238.

Armstrong, J. E. 1957. Surficial geology of New Westminster map-area,
    British Columbia. Geol. Surv. Canada Paper 57-5; map 16-1957. 25 pp.

_____. 1961. Soils of the coastal area of southwest British
    Columbia. In R. F. Leggett, Ed. Soils in Canada: Geological,
    Pedological, and Engineering Studies. Roy. Soc. Canada Spec. Publ. 3,
    Univ. Toronto Press, Toronto, pp. 22-32.

Bartell, S. M., T. F. H. Allen, and J. F. Koonce. 1978. An assessment of
    principal component analysis for description of phytoplankton period-
    icity in Lake Wingra. Phycologia 17: 1-11.

Backhaus, D. 1967. Okologische Untersuchungen an den Aufwuchsalgen der
    obersten Donau und ihrer Quellflusse. I. Voruntersuchungen. Arch.
    Hydrobiol. Suppl. 30: 364-399.

_____. 1968. Okologische Untersuchungen an den Aufwuchsalgen der
    obersten Donau und ihrer Quellflusse. II. Die rauliche und
    zeitliche Verteilung der Algen. Arch. Hydrobiol. Suppl. 34: 24-73.

Belcher, J. H. and E. M. F. Swale. 1977. Species of Thalassiosira
    (Diatoms, Bacillariophyceae) in the plankton of English rivers.
    Br. Phycol. J. 12: 291-296.

Benedict, A. H., K. J. Hall, and F. A. Koch. 1973. A preliminary water
    quality survey of the lower Fraser River system. Westwater Research
    Centre, Univ. British Columbia, Tech. Rep. No. 2. 50 pp.

Bishop, J. E. 1973. Limnology of a small Malayan river Sungai Gombak.
    Monographiae Biologiae Vol. 22. W. Junk B. V. Publ., The Hague.
    485 pp.

Blum, J. L. 1956. The ecology of river algae. Bot. Rev. 21: 291-341.

_____. 1957. An ecological study of the algae of the Saline River, Michigan. Hydrobiologia 9: 361-408.

Bott, T. L., J. T. Brock. C. E. Cushings, S. V. Gregory, D. King, and R. C. Petersen. 1978. A comparison of methods for measuring primary productivity and community respiration in streams. Hydrobiologia 60: 3-12.

Bourrelly, P. 1957. Recherches sur les Chyrophycées. Morphologie, phylogenie, systematique. Rev. Algol. Mém. Hors-Serie 1: 1-412.

_____. 1966. Les Algues d'Eau Douce. Tome I. Les Algues Vertes. N. Boubée et Cie, Paris. 511 pp.

_____. 1970. Les Algues d'Eau Douce. Tome III. Les Algues Bleus et Rouges, Les Eugleniens, Peridiens et Cryptomonadins. N. Boubée et Cie, Paris. 512 pp.

Bradfield, G. E. 1977. Analysis of bushfire effects in the Dandendong Ranges, Victoria. Ph.D. Thesis, Botany Department, Monash University. Melbourne, Australia. 152 pp.

Braun-Blaquet, J. 1965. Plant Sociology: the Study of Plant Communities. Hafner, London. 439 pp.

Bryan, J. E., C. E. Walker, R. E. Kendel, and M. S. Elson. 1973. Freshwater aquatic ecology in northern Yukon Territory. Environmental-Social Committee Northern Pipelines Rep. 73-21. Information Canada, Ottawa. 64 pp.

Cleve-Euler, A. 1951, 1952, 1953a,b, 1955. Die Diatomeen von Schweden und Finnland. K. Svensk. Vedensk. Handl. 2(1): 3-163; 3(3): 1-153; 4(1): 1-158; 4(5): 1-255; 5(4): 1-232.

Cochrane, D. G. 1972. A preliminary feasibility study of the North Alouette watershed. B.Sc. Thesis, Faculty of Forestry, Univ. British Columbia, Vancouver. 51 pp.

Connell, J. H. 1978. Diversity in tropical rainforests and coral reefs. Science 199: 1302-1310.

Cummins, K. W. 1962. An evaluation of some techniques for the collection and analysis of benthic samples with special emphasis on lotic waters. Am. Midl. Nat. 67: 477-504.

Cushing, C. E. 1967. Periphyton productivity and radionuclide accumulation in the Columbia River, Washington, U.S.A. Hydrobiologia 29: 125-139.

Dale, M. B. 1975. On objectives of methods of ordination. Vegetatio 30: 15-32.

Daubenmire, R. F. 1968. Plant communities: a Textbook of Plant Synecology. Harper and Row, New York. 300 pp.

Deskachary, T. V. 1959. Cyanophyta. Indian Council Agricultural Research, New Delhi. 686 pp.

Dickman, M. 1969. Some effects of lake renewal on phytoplankton productivity and species composition. Limnol. Oceanogr. 14: 660-666.

Douglas, B. 1958. The ecology of the attached diatoms and other algae in a stony stream. J. Ecol. 46: 295-322.

Efford, I. E. 1967. The temporal and spatial differences in phytoplankton productivity in Marion Lake, British Columbia. J. Fish. Res. Board Can. 24: 2203-2307.

_____. 1969. Energy transfer in Marion Lake, British Columbia: with special reference to fish feeding. Int. Ver. Theor. Angew. Limnol. Verh. 17: 104-108.

Fabri, R. 1977. Végétation, production primaire et caractéristiques physico-chimiques d'une rivière de haute Ardenne (Belgique): la Warche supérieure. Lejeunia 87: 1-43.

Feller, M. C. 1977. Nutrient movement through Western Hemlock-Western Redcedar ecosystems in southwestern British Columbia. Ecology 58: 1269-1283.

Fott, B. and M. Nováková. 1969. A monograph of the genus Chlorella. The freshwater species. In B. Fott, Ed. Studies in Phycology. Academia Press, Prague, pp. 10-59.

Fretwell, S. D. 1972. Populations in a Seasonal Environment. Princeton Univ. Press. Princeton, New Jersey. 217 pp.

Geitler, L. 1932. Cyanopyceae. In L. Rabenhorst, Ed. Kryptogamen-Flora von Deutschland, Österreich, und der Schweiz. Vol. 14. Akad. Verlags., Leipzig. 1196 pp.

Golterman, H. L., Ed. 1969. Methods for Chemical Analysis of Fresh Waters. I. B. P. Handbook No. 8, Blackwell Sci. Publ., Oxford. 172 pp.

_____. 1975. Chemistry. In B. A. Whitton, Ed. River Ecology. Blackwell Sci. Publ., Oxford, pp. 39-80.

Golubić, S. and E. Kann. 1967. Zur Klarung der taxomischen Beziehungen zwischen Tolypothrix distorta Kutzing und T. penicillata Thuret. (Cyanophyta). Schweiz. Z. Hydrol. 29: 145-160.

Gower, J. C. 1966. Some distance properties of latent root and vector methods used in multivariate analysis. Biometrika 53: 325-338.

Gruendling, G. K. 1971. Ecology of the epipelic algal communities in Marion Lake, British Columbia. J. Phycol. 7: 239-249.

Gumtow, R. B. 1955. An investigation of the periphyton in a riffle of the West Gallatin River, Montana. Trans. Am. Microscop. Soc. 74: 278-292.

Hall, K. J. and K. D. Hyatt. 1974. Marion Lake (IBP) - from bacteria to fish. J. Fish. Res. Board Can. 31: 893-911.

Hansmann, E. W. and H. K. Phinney. 1973. Effects of logging on periphyton in coastal streams of Oregon. Ecology 54: 194-199.

Haraguchi, K. and H. Kobayasi. 1969. On the differentiation of the thallus of *Batrachospermum moniliforme* Roth directly from the prostrate thallus of the Chantransia-stage without forming erect parts. Bull. Jpn. Soc. Phycol. 17: 61-65.

Hargrave, B. T. 1970. The effect of a deposit-feeding amphipod on the metabolism of benthic microflora. Limnol. Oceanogr. 15: 21-30.

Hohn, M. H. and J. Hellerman. 1963. The taxonomy and structure of diatom populations from three eastern North American rivers, using three sampling methods. Trans. Am. Microscop. Soc. 82: 250-329.

Holme, N. A. and A. D. McIntyre, Eds. 1971. Methods for the Study of Marine Benthos. I.B.P. Handbook No. 16, Blackwell Sci. Publ., Oxford. 334 pp.

Holmes, N. T. H. and B. A. Whitton. 1977. The macrophytes of the River Tees in 1975: observed and predicted changes. Freshwater Biol. 7: 43-60.

Horn, H. S. 1976. Succession. In R. M. May, Ed. Theoretical Ecology: Principles and Applications. W. B. Saunders, Philadelphia, pp. 187-204.

Huber-Pestalozzi, G. 1941. Das Phytoplankton des Süsswassers. In: A. Theinemann, Ed., Die Binnegewässer. Band 16(2). Chrysophyceen, Farblose Flagellaten. Heterokonten. E. Schweizerbart Verlags, Stuttgart. 365 pp.

_____. 1942. Das Phytoplankton des Süsswassers. In: A. Theinemann, Ed., Die Binnegewässer. Band 16 (2:2). Diatomeen. E. Schweizerbart Verlags, Stuttgart, pp. 367-549.

_____. 1950. Das Phytoplankton des Süsswassers. In: A. Theinemann, Ed., Die Binnegewässer. Band 16(3). Cryptophyceen, Chloromonadien, Peridineen. E. Schweizerbart Verlags, Stuttgart. 310 pp.

_____. 1955. Das Phytoplankton des Süsswassers. In: A. Theinemann, Ed., Die Binnegewässer. Band 16(4). Euglenophyceen. E. Schweizerbart Verlags, Stuttgart. 1135 pp.

Hufford, T. L. and G. B. Collins. 1976. Distribution patterns of diatoms in Cedar Run. Ohio J. Sci. 76: 172-184.

Hustedt, F. 1927. Dies Kieselalgen Deutschlands, Österreichs und der Schweiz. In: L. Rabenhorst, Ed., Kryptogamen-Flora von Deutschland, Österreich, und der Schwiez. Band VII, Teil 1(1-5). Akad. Verlags, Leipzig.

_____. 1930a. Bacillariophyta (Diatomeae). In: A. Pascher, Ed., Die Süsswasser Flora Mittleeuropas. G. Fischer, Jena Heft 10: I-VII. 466 pp.

_____. 1930b. Die Kieselalgen Deutschlands, Österreichs, und der Schweiz. In: L. Rabenhorst, Ed., Kryptogamen-Flora von Deutschland, Österreich, und der Schweiz. Band VII, Teil 2(1-6). Akad. Verlags, Leipzig.

_____. 1937-1938. Systematische und Ökologische Untersuchungen über die Diatomeenflora von Java, Bali, und Sumatra. Arch. Hydrobiol. Suppl. 15: 131-177; 16: 187-296; 16: 393-506.

_____. 1961. Die Kieselalgen Deutschlands, Österreichs, und der Schweiz. In: L. Rabenhorst, Ed., Kryptogamen-Flora von Deutschland, Österreich, und der Schweiz. Band VII, Teil 3(1). Akad. Verlags, Leipzig.

_____. 1964. Die Kieselalgen Deutschlands, Österreichs, und der Schweiz. In: L. Rabenhorst, Ed., Kryptogamen-Flora von Deutschland, Österreich, und der Schweiz. Band VII, Teil. 3(3). Akad. Verlags, Leipzig.

Huston, M. 1979. A general hypothesis of species diversity. Am. Nat. 113: 81-101.

Hutchinson, G. E. 1953. The concept of pattern in ecology. Proc. Acad. Nat. Sci. Philadelphia 105: 1-12.

_____. 1957. Concluding remarks. Cold Spring Harbor Symp. Quant. Biol. 22: 415-427.

_____. 1961. The paradox of the plankton. Am. Nat. 95: 137-146.

_____. 1967. A Treatise on Limnology. Vol. II. Introduction to Lake Biology and the Limnoplankton. John Wiley, New York. 1115 pp.

Hynes, H. B. N. 1970. The Ecology of Running Waters. University of Toronto Press, Toronto. 555 pp.

Illies, J. 1961. Versuch einer allgemein biozonotischen Gleiderung der Fliessgewasser. Int. Rev. Gesamten Hydrobiol. 46: 205-213.

Illies, J. and L. Botosaneanu. 1963. Problems et méthodes de la classification et la zonation écologique des eaux courantes, considerées surtout du point de vue faunistique. Int. Ver. Theor. Angew. Limnol. Mitt. 12: 1-57.

Israelson, G. 1942. The freshwater Florideae of Sweden. Studies on the taxonomy, ecology, and distribution. Symb. Bot. Ups. 6(1): 1-134.

_____. 1949. On some attached Zygnematales and their significance in classifying streams. Bot. Not. 1949: 313-358.

Kann, E. 1972/1973. Zur Systematik und Ökologie der Gattaung Chamaesiphon (Cyanophyceae). 1. Systematic.; 2. Ökologie. Arch. Hydrobiol. Suppl. 41: 117-171; Arch. Hydrobiol. Suppl. 41: 243-282.

_____. 1978. Systematik und Ökologie der Algen österreichisches Bergbache. Arch. Hydrobiol. Suppl. 53: 405-643.

_____ and J. Komárek. 1970. Sytematisch-ökologische Bemerkungen zu den Arten des Formenkreises Phormidium autumnale. Schweiz. Z. Hydrol. 32: 495-518.

Kawecka, B. 1971. Zonal distribution of alga communities in streams of the Polish High Tatra Mountains. Acta Hydrobiol. 13: 393-414.

Klinka, K. 1976. Ecosystem units, their classification, interpretation and mapping in the University of British Columbia Research Forest. Ph.D. Thesis, Faculty of Forestry, Univ. British Columbia, Vancouver. 622 pp.

Komárek, J. 1972. Temperatur bedingte morphologische Variabilitat bei drei Phormidium-Arten (Cyanophyceae) in Kulteren. Presilia 44: 293-307.

_____ and E. Kann. 1973. Zur Taxonomie und Ökologie der Gattung Homeothrix. Arch. Protistenk. 115: 173-233.

Koppen, J. D. 1975. A morphological and taxonomic consideration of Tabellaria (Bacillariophyceae) from the north central U.S. J. Phycol. 11: 236-244.

Köppen, W. 1936. Das geographische system der Klimate. In; W. Köppen and G. Geiger, Eds. Handbuch der Klimatologie. Vol. 1(C), Gebruder Borntrager, Berlin.

Krajina, V. J. 1965. Biogeoclimatic zones and biogeocoenoses of British Columbia. Ecology of Western North America 1: 1-17.

_____. 1969. Ecology of forest trees in British Columbia. Ecology of Western North America 2: 1-146.

Kristiansen, J. 1975. Chrysophyceae from Alberta and British Columbia. Syesis 8: 97-108.

Lange-Bertalot, H. 1976. Eine revision zur taxonomie der Nitzschiae lanceolatae Grunow. Die Klassichen bis 1930 beschriebenen Süsswasserarten Europas. Nova Hedwigia 38: 253-307.

Leclercq, L. 1977. Végétation et charactéristiques physico-chimiques de deux rivières de haute Ardenne (Belgique): la Holle et la Roer supérieure. Lejeunia 88: 1-42.

Levandowsky, M. 1972. An ordination of phytoplankton populations in ponds of varying salinity and temperature. Ecology 53: 398-407.

Levin, S. A. and R. T. Paine. 1974. Disturbance, patch formation, and community structure. Proc. Nat. Acad. Sci. U.S.A. 71: 2744-2747.

Lind, O. T. 1974. Handbook of Common Methods in Limnology. C. V. Mosby, St. Louis. 154 pp.

Lowe, R. L. 1974. Environmental requirements and pollution tolerance of freshwater diatoms. U. S. Environmental Prot. Agency Publ. EPA-670/4-74-005. Cincinnati, Ohio. 334 pp.

MacArthur, R. H. 1970. Species packing and competitive equilibrium for many species. Theor. Popul. Biol. 1: 1-11.

Mack, B. 1953. Zur Algen und Pilzflora des Liesingsbaches. Wetter Leben 2: 136-149.

Margelef, R. 1960. Ideas for a synthetic approach to the ecology of running waters. Int. Rev. Gesamten Hydrobiol. 45: 133-153.

Marker, A. F. H. 1976. The benthic algae of some streams in southern England. I. Biomass of the epilithon in some small streams. J. Ecol. 64: 343-358.

Mathewes, R. W. 1973. A palynological study of postglacial vegetation changes in the University Research Forest, southwestern British Columbia. Can. J. Bot. 51: 2085-2103.

May, R. M. 1976. Patterns in multi-species communities. In R. M. May, Ed., Theoretical Ecology: Principles and Applications. W. B. Saunders, Philadelphia, pp. 142-162.

McCart, P., P. Tsui, W. Grant, and R. Green. 1977. Baseline studies of aquatic environments in the Athabasca River near Lease 17. Environmental Res. Monogr., Syncrude Canada, Ltd., Edmonton. 205 pp.

McIntire, C. D. 1968. Structural characteristics of benthic algal communities in laboratory streams. Ecology 49: 520-537.

_____. 1973. Diatom associations in Yaquina estuary, Oregon: a multivariate analysis. J. Phycol. 9: 254-259.

McKee, B. 1972. Cascadia: the Glacial Evolution of the Pacific Northwest. McGraw-Hill, New York. 394 pp.

Moore, J. W. 1977a. Seasonal succession of algae in a eutrophic stream in southern England. Hydrobiologia 53: 181-192.

_____. 1977b. Seasonal succession of algae in rivers. 2. Examples from Highland Water, a small woodland stream. Arch. Hydrobiol. 80: 160-171.

_____. 1977c. Ecology of algae in a subarctic stream. Can. J. Bot. 55: 1838-1847.

Mori, M. 1975. Studies on the genus _Batrachospermum_ in Japan. Jpn. J. Bot. 20: 461-485.

Mueller-Dombois, D. 1965. Initial stages of secondary succession in the Coastal Douglas-fir and Western Hemlock Zones. Ecology of Western North America 1: 38-41.

_____ and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley, New York. 574 pp.

Müller, H. 1972. Wachstum und Phosphatbedarf von _Nitzschia actinastroides_ (Lemm.) V. Goor in Statischen und homokontinuierlicher Kultur unter Phosphatlimitierung. Arch. Hydrobiol. Suppl. 38: 399-484.

Mundie, J. H. 1974. Optimization of the salmonid nursery stream. J. Fish. Res. Board Can. 31: 1827-1837.

Munteanu, N. and E. J. Maly. 1978. Preferential distribution of diatom species colonizing submersed glass slides. Mimeograph Abstract, 41st Meet. Am. Soc. Limnol. Oceanogr., Victoria.

Northcote, T. G. and P. A. Larkin. 1963. Western Canada. In D. G. Frey, Ed., Limnology in North America. Univ. Wisconsin Press, Madison, pp. 451-485.

Orloci, L. 1965. The Coastal Western Hemlock Zone on the south-western British Columbia mainland. Ecology of Western North America 1: 18-34.

_____. 1966. Geometric models in ecology. I. The theory and application of some ordination methods. J. Ecol. 54: 193-215.

_____. 1975. Multivariate Methods in Vegetation Research. W. Junk B. V., The Hague. 276 pp.

Paine, R. T. 1966. Food web complexity and species diversity. Am. Nat. 100: 65-75.

Parke, M., J. W. G. Lund, and I. Manton. 1962. Observations on the biology and fine structure of the type species of Chrysochromulina (C. parva Lackey) in the English Lake District. Arch. Mikrobiol. 42: 333-352.

Parker, B. C., G. L. Samsel and G. W. Prescott. 1973. Comparison of microhabitats of microscopic subalpine stream algae. Am. Midl. Nat. 90: 143-153.

Pasicnyk, V. 1976. Aesthetic and engineering analysis of Alouette River crossing. M.For., Faculty of Forestry, Univ. British Columbia, Vancouver. 130 pp.

Patrick, R. 1967. The effect of invasion rate, species pool, and size of area on the structure of the diatom community. Proc. Nat. Acad. Sci. U.S.A. 58: 1335-1342.

_____. 1970. Benthic stream communities. A discussion of the factors that affect their structure and how they function. Am. Sci. 58: 546-549.

_____. 1975. Stream communities. In M. L. Cody and J. M. Diamonds, Eds., Ecology and Evolution of Communities. Harvard Univ. Press, Cambridge, pp. 445-459.

_____ and C. W. Reimer. 1966. The diatoms of the United States, exclusive of Alaska and Hawaii. Vol. I. Acad. Nat. Sci. Philadelphia, Monograph No. 13. 688 pp.

_____. 1975. The diatoms of the United States, exclusive of Alaska and Hawaii. Vol. II, Part 1. Acad. Nat. Sci. Philadelphia, Monograph No. 13. 213 pp.

Patrick, R., M. H. Hohn, and J. H. Wallace. 1954. A new method for determining the pattern of the diatom flora. Not. Nat. Acad. Nat. Sci. Philadelphia 259: 1-12.

Patrick, R., B. Crum, and J. Coles. 1969. Temperature and manganese as determining factors in the presence of diatom or blue-green algal floras in streams. Proc. Nat. Acad. Sci. U.S.A. 64: 472-478.

Prescott, G. W. 1962. Algae of the Western Great Lakes Area. rev. ed., Wm. C. Brown, Dubuque, Iowa. 977 pp.

Printz, H. 1964. Die Chaetophoralen der Binnengewässer (Eine systematische Übersicht). Hydrobiologia 23(1-3): 1-376.

Randhawa, M. S. 1959. Zygnemataceae. Academic Press, New York, and Indian Council Agricultural Research, New Delhi. 478 pp.

Reed, C. 1978. Species diversity in aquatic microecosystems. Ecology 59: 481-488.

Ricker, W.E. 1934. An ecological classification of certain Ontario streams. Univ. Toronto Stud. Biol. Ser. 37: 1-114.

Silva, P. C. 1962. Classification of algae. In R. A. Lewin, Ed., Physiology and Biochemistry of Algae. Academic Press, London, pp. 827-837.

Siver, P. A. 1977. Comparison of attached diatom communities on natural and artificial substrates. J. Phycol. 13: 402-406.

Skuja, H. 1935. Untersuchungen über die Rhodophyceen des Süsswassers. Beih. Botan. Centrabl. 52: 173-192.

Sládecková, A. 1962. Limnological investigation methods for the periphyton ("aufwuchs") community. Bot. Rev. 28: 286-350.

Sørensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content. K. Dansk. Vidensk. Selsk. Biol. Skr. 5(4): 1-34.

Slobodkin, L. B. and H. L. Sanders. 1969. On the contribution of environmental predictability to species diversity. Brookhaven Symp. Biol. 22: 82-95.

Smith, G. M. Phytoplankton of the inland waters of Wisconsin. Part II. Wisc. Geol. Nat. Hist. Surv. Bull. 57(2): 1-227.

Squires, L. E., S. R. Rushforth, and C. J. Endsley. 1973. An ecological survey of the algae of Huntington Canyon, Utah. Brigham Young Univ. Sci. Bull. Biol. Ser. 18(2): 1-87.

Stainton, M. P., M. J. Capel, and F. A. J. Armstrong. 1974. The chemical analysis of fresh water. Can. Dept. Environm., Freshwater Inst. Misc. Spec. Publ. 25. 120 pp.

Stanier, R. Y., W. R. Sistrom, T. A. Hansen, B. A. Whitton, R. W. Casteholz, N. Pfiennig, V. N. Gorlenko, E. N. Kondratiera, K. E. Eimhjellen, R. Whittenbury, R. L. Gherna, and H. G. Trupper. 1978. Proposal to place the nomenclature of the Cyanobacteria (Blue-green algae) under the rules of the International Code of Nomenclature of Bacteria. Int. J. Syst. Bacteriol. 28: 335-336.

Stein, J. R. 1975. Freshwater algae of British Columbia: the lower Fraser Valley. Syesis 8: 119-184.

_____ and J. F. Gerrath. 1968. Freshwater algae of British Columbia: desmids of bog lakes in Coast Mountain area. Syesis 1: 187-197.

_____ and C. A. Borden. 1979. Checklist of freshwater algae of British Columbia. Syesis (in press).

Stockner, J. G. and K. R. S. Shortreed. 1976. Autotrophic production in Carnation Creek, a coastal rainforest stream on Vancouver Island, British Columbia. J. Fish. Res. Board Can. 33: 1553-1563.

Stockner, J. G. and K. R. S. Shortreed. 1978. Enhancement of autotrophic production by nutrient addition in a coastal rainforest stream on Vancouver Island. J. Fish. Res. Board Can. 35: 28-34.

Strahler, A. N. 1964. Quantitative geomorphology of drainage basins and channel networks. In V. T. Chow, Ed., Handbook of Applied Hydrology. McGraw-Hill, New York, Section 4-11.

Strickland, J. D. H. and T. R. Parsons. 1972.. A practical handbook of seawater analysis. Fish. Res. Board Can. Bull. 167. 310 pp.

Technicon Industrial Systems. 1971a, b, c, d, 1973. Ammonia in sea water. Industr. Method AAII, no. 154-71W. 2 pp.; Chloride in water and waste water. Industr. Method AAII, no. 99-70W, 2 pp.; Phosphate (ortho) in water and waste water. Industr. Method AAII, no. 155-71W, 2 pp.; Sulphate in water and waste water. Industr. Method AAII, no. 118-71W, 2 pp.; Silicates in water and waste water. Industr. Method AAII, no. 105-71W. 2 pp.

Tett, P., C. Gallegos, M. G. Kelley, G. M. Hornberger, and B. J. Crosby. 1978. Relationships among substrate, flow, and benthic microalgal pigment density in the Mechums River, Virginia. Limnol. Oceanogr. 23: 785-797.

Tippet, R. 1970. Artificial surfaces as a method of studying populations of benthic micro-algae in fresh water. Br. Phycol. J. 5: 187-199.

Titman, D. 1976. Ecological competition between algae: experimental confirmation of resource-based competition theory. Science 192: 463-465.

Transeau, E. N. 1951. The Zygnemataceae. The Ohio State Univ. Press, Columbus. 244 pp.

Triska, F. J. and J. R. Sedell. 1976. Decomposition of four species of leaf litter in response to nitrate manipulation. Ecology 57: 783-793.

VanLandingham, S. L. 1969-1975. Catalogue of the fossil and recent genera and species of diatoms and their synonyms. Parts I-V. J. Cramer, Lehre. 2963 pp.

Vollenweider, R. A. 1969. A Manual on Methods for Measuring Primary Production in Aquatic Environments. I.B.P. Handbook No. 12. Blackwell Sci. Publ., Oxford. 213 pp.

Wali, M. K., G. K. Gruendling, and D. W. Blinn. 1972. Observations on the nutrient composition of a freshwater lake ecosystem. Arch. Hydrobiol. 69: 452-464.

Ward, J. H. 1963. Hierarchical grouping to optimize an objective function. J. Am. Stat. Assoc. 58: 236-244.

Weber, C. I. and R. L. Raschke. 1970. Use of a floating periphyton sampler for pollution surveillance. Analytical Qual. Contr. Lab. Rep. No. 20, Fed. Water Pollut. Contr. Admin., Cincinnati. 22 pp.

West, W. and G. S. West. 1904, 1905, 1908, 1912. A monograph of the British Desmidiaceae. I-IV. Ray Society, London. Vols. 82, 84, 88, 92.

West, W., G. S. West, and N. Carter. 1923. A monograph of the British Desmidiaceae. V. Ray Society, London. Vol. 108.

Wetzel, R. G. 1975. Limnology. W. B. Saunders, Philadelphia. 743 pp.

Whitford, L. A. and G. J. Schumacher. 1969. A manual of the freshwater algae in North Carolina. North Carolina Agric. Expt. Sta. Tech. Bull. No. 188. 313 pp.

Whittaker, R. H. 1969. Evolution of diversity in plant communities. Brookhaven Symp. Biol. 22: 178-196.

_____. 1970. Communities and Ecosystems. 2nd edition. MacMillan, New York. 385 pp.

Whitton, B. A., Ed. 1975. River Ecology. Blackwell Sci. Publ., Oxford. 725 pp.

Wilhm, J., J. Cooper, and H. Namminga. 1977. Species composition,diversity, biomass, and chlorophyll of periphyton in Greasy Creek, Red Rock Creek and the Arkansas River, Oklahoma. Hydrobiologia 57: 17-23.

Appendix A. Abundance of all algal taxa at Station 1 for 17
sampling dates, where abundance values range from 0 - 1 (see
Table 1 for species codes).

SPECIES	070677	210677	050777	190777	020877	160877	060977	270977	091077	270178	030378	310378	170478	040578	260578	080678	290678
CCO01																	
MIC01											0.0002	0.0002	0.0004				
GOC01																	
MPD01				0.0001									0.0002	0.0002			
XEN01														0.0005		0.0003	0.0002
CLS01	0.0004	0.0001	0.0004	0.0001	0.0002	0.0004	0.0005	0.0007	0.0002			0.0002	0.0002	0.0006	0.0005	0.0003	0.0005
CHM01	0.0027	0.0026	0.0063	0.0025	0.0016	0.0004	0.0005	0.0003		0.0003	0.0037	0.0020	0.0165	0.0054	0.0158	0.0278	0.0038
CHM02	0.0010	0.0026	0.0008	0.0007	0.0008	0.0006	0.0007				0.0005	0.0005	0.0015	0.0020	0.0019	0.0032	0.0019
CHM03	0.0007	0.0008	0.0004	0.0004	0.0002			0.0003			0.0002		0.0002	0.0005	0.0019		
CHM04	0.0009	0.0006	0.0002	0.0001	0.0002		0.0001			0.0002	0.0004	0.0002	0.0019	0.0044	0.0038	0.0016	
CHM05	0.0001			0.0002	0.0001			0.0005	0.0002								
CHM06	0.0002	0.0003	0.0007	0.0005	0.0006	0.0004	0.0003		0.0002	0.0002							0.0004
OSC01	0.0003	0.0003	0.0006	0.0004	0.0001	0.0001						0.0002		0.0004	0.0002		
OSC02	0.0004		0.0001					0.0002		0.0002				0.0002			
OSC03		0.0001															
PHB01	0.1139	0.2780	0.1779	0.2754	0.5169	0.5004	0.5013	0.0144	0.0062		0.0022	0.0005	0.0097	0.0044	0.0069	0.3354	0.3685
PHB02	0.0003	0.0005	0.0008	0.0010	0.0015	0.0008	0.0002	0.0003	0.0002		0.0002			0.0004		0.0003	0.0002
LYG01	0.0004						0.0001			0.0007							
LYG03	0.0008	0.0030	0.0007	0.0009	0.0006	0.0006	0.0005	0.0005	0.0004	0.0003	0.0004	0.0005		0.0010	0.0005	0.0033	0.0004
LYG04		0.0001	0.0001	0.0001										0.0004	0.0096		
LYG05		0.0001	0.0004	0.0001					0.0004					0.0004			
LYG06		0.0002	0.0013	0.0006	0.0007	0.0004	0.0003	0.0005	0.0008	0.0002	0.0004	0.0002	0.0004	0.0008		0.0002	0.0007
CSP01	0.0001		0.0004		0.0002		0.0002										
ANB01																	
ENC01		0.0010					0.0055	0.0003	0.0020	0.0017	0.0017	0.0229	0.0070	0.0003	0.0002		
CAL01			0.0001		0.0004	0.0003	0.0001	0.0005	0.0022	0.0080	0.0004	0.0002	0.0013	0.0006		0.0006	
CAL02	0.0001		0.0001	0.0001													
RVU01																	
HPL01																	
TXP01	0.0138	0.0910	0.0006	0.0005	0.0010	0.0001	0.0002	0.0028	0.0006	0.1432	0.0108	0.3335	0.1268	0.1787	0.0247	0.0237	0.0035
STG01	0.0138	0.2739	0.2660	0.0947	0.0115	0.0947	0.2001	0.2841	0.2000	0.1432	0.1667	0.1670	0.2502	0.0855	0.1684	0.1430	0.0184
CDY01														0.0003			
EOD01																	
TTR01					0.0009								0.0002	0.0002			
TTR02																	
AEC01																	
SHC01																	
COV01																	
COV02																	
GOL01																	
OST01																	
AKD01				0.0003	0.0002			0.0003						0.0002			
CRA01	0.0001		0.0001									0.0002	0.0002	0.0005		0.0032	
CRA02	0.0001		0.0001									0.0002					
SCD01																	
CML01																	
PDI01																	
UKL01	0.0242	0.1867	0.1015	0.4210	0.3610	0.4397	0.2331	0.0212	0.0008	0.0008	0.0055	0.0111	0.0619	0.3196	0.1810	0.2042	0.2005
UKL03	0.6382	0.1202	0.0204	0.1232	0.0135	0.0113	0.1331	0.5344	0.4111	0.7221	0.0070	0.3896	0.4343	0.1048	0.2531	0.0075	0.0037
MCP01	0.0021	0.0012	0.0003	0.0005	0.0001								0.0002				
CET01												0.0004	0.0017	0.0002	0.0004		
SGC01																	
DPR01																	
OED01					0.0002	0.5170	0.2447	0.2844	0.2022	0.0016	0.0004	0.0017	0.0004	0.0007	0.0020	0.0003	0.0004
OED02											0.0002			0.0007			

SPECIES	070677	210677	050777	190777	020877	160877	060977	270977	091077	270178	030378	310378	170478	040578	260578	080578	290678
BUL01					0.0002	0.0001	0.0001						0.0002	0.0002			
ZYG01	0.5157	0.6522	0.8493	0.6798	0.5478	0.1914	0.2229	0.0053	0.2042	0.1432	0.6670	0.5019	0.6446	0.6593	0.6896	0.8586	0.8335
ZYG02						0.0055											
SP101	0.0140	0.0222	0.1029	0.2785	0.5230	0.1353	0.1395	0.0053	0.0022	0.0002	0.0005	0.0094	0.0039	0.0200	0.1899	0.0265	0.0881
MOU01	0.0001	0.0001	0.0006	0.0067	0.0003	0.0002	0.0003	0.0005	0.2000	0.0003	0.0007	0.0020	0.0018	0.0021	0.0040	0.0047	0.0129
DSM01		0.0001	0.0002	0.0004	0.0004	0.0003	0.0001							0.0002			
DSM02	0.0001	0.0007	0.0005	0.0015	0.0005	0.0004							0.0002	0.0002	0.0004	0.0002	0.0020
DSM03	0.0002	0.0003		0.0001	0.0002	0.0003	0.0001	0.0005		0.0002			0.0002	0.0002	0.0003		
DSM04	0.0001		0.0001												0.0002		
DSM05		0.0001		0.0001		0.0002	0.0002	0.0003									
DSM06		0.0004	0.0001	0.0005	0.0006	0.0007	0.0003	0.0003	0.0002		0.0002	0.0002	0.0005	0.0006	0.0002	0.0002	0.0002
DSM07		0.0005	0.0005	0.0004	0.0004	0.0004	0.0003	0.0003			0.0002		0.0003	0.0007	0.0002	0.0003	0.0002
DSM08		0.0001				0.0003							0.0002	0.0004			
DSM09		0.0001	0.0003	0.0004	0.0003	0.0002	0.0002						0.0002				
DSM10		0.0001		0.0001									0.0002	0.0003	0.0002		
DSM11		0.0001		0.0001			0.0001										
DSM12		0.0001	0.0003	0.0004	0.0001		0.0001		0.0004			0.0002		0.0004	0.0002	0.0002	
DSM13	0.0002	0.0002	0.0003	0.0001	0.0002	0.0003	0.0005	0.0002								0.0002	
DSM14		0.0001	0.0001										0.0002				
DSM15			0.0001	0.0003	0.0001								0.0002				
DSM16			0.0006			0.0001		0.0003							0.0002		
DSM18				0.0002											0.0002	0.0002	
DSM19	0.0001			0.0001	0.0003			0.0005	0.0004	0.0002	0.0002		0.0002	0.0004	0.0004		0.0002
DSM20				0.0001													
DSM21				0.0001	0.0003								0.0002	0.0003			
DSM22				0.0001	0.0001						0.0002						
DSM23				0.0001									0.0002	0.0002			
DSM24					0.0002	0.0003						0.0002	0.0002	0.0004	0.0004		
DSM25					0.0001												
DSM26					0.0001												
DSM27						0.0001		0.0003									
DSM28								0.0003	0.0002				0.0002				
DSM29									0.0002								
DSM30									0.0002								
DSM31													0.0002				
DSM32												0.0002					
DSM34												0.0002					
DSM35													0.0003				
DSM36													0.0002				
DSM37													0.0002				
DSM38															0.0002	0.0002	
DSM39															0.0002	0.0002	
DSM40															0.0002	0.0002	
DSM41																0.0002	
DSM42																	
DSM43																	
DSM44						0.0001											
DSM45																	
DSM46																	
DSM47																	
DSM48																	
DSM49																	
DSM50																	
DSM51																0.0002	
DSM52																	

Appendix A. Continued.

SPECIES	070677	210677	050777	190777	020877	160877	060977	270977	091077	270178	030378	310378	170478	040578	260578	080678	290678
DSM53																	
DSM54																	
DSM55																	
DSM56																	
DSM57																	
EGL01																	
CIP01																	
OCR01											0.0002	0.0005	0.0005	0.0006			
MAL01											0.0002	0.0002					
MAL02												0.0002					
SBN01																	
CXP01																	
DNB01					0.0001	0.0002		0.0002									
DNB02																	
CRY01													0.0005	0.0005	0.0004	0.0002	
SDC01	0.0004	0.0010	0.0001														
CYC01	0.0001	0.0002	0.0001	0.0001	0.0002		0.0006	0.0003			0.0002	0.0002	0.0003	0.0007	0.0005	0.0003	0.0004
CYC02	0.0006	0.0002	0.0001						0.0006								
MEL01	0.0006	0.0004	0.0002	0.0001		0.0001				0.0002							
MEL02					0.0003	0.0001	0.0005	0.0004	0.0002			0.0002	0.0004	0.0010	0.0007	0.0003	0.0002
COS01		0.0002															
COS02			0.0001	0.0001				0.0006		0.0002							0.0002
THA01		0.0001															
TAB01	0.0127	0.0124	0.0122	0.0070	0.0085	0.0115	0.0100	0.0212	0.0100	0.0088	0.0293	0.0085	0.0100	0.0100	0.0100	0.0151	0.0085
TAB02	0.0001	0.0005	0.0001														
DAT01	0.0006	0.0004	0.0007	0.0005	0.0006	0.0005	0.0009	0.0007	0.0010	0.0008	0.0007	0.0007	0.0010	0.0010	0.0008	0.0008	0.0004
DAT02	0.0001						0.0001							0.0002			
MDN01	0.0002	0.0005	0.0002	0.0004	0.0004	0.0003	0.0004	0.0005			0.0004	0.0004	0.0004	0.0010	0.0004	0.0002	0.0002
TCY01																	
FGL01	0.0003	0.0005	0.0002	0.0003	0.0002	0.0004	0.0002			0.0002							
FGL02											0.0002						
FGL03																	
FGL04																	
FGL05																	
AST01		0.0001	0.0004	0.0003													
SYN01	0.0028	0.0050	0.0032	0.0040	0.0024	0.0032	0.0027	0.0055	0.0064	0.0062	0.0055	0.0023	0.0065	0.0066	0.0085	0.0060	0.0010
SYN02	0.0005	0.0005	0.0004	0.0004	0.0004	0.0005	0.0014	0.0035	0.0008	0.0007	0.0007	0.0005	0.0010	0.0010	0.0007	0.0010	0.0004
SYN03		0.0005			0.0001						0.0002						
SYN04	0.0002			0.0001	0.0001												
SYN05																	
SYN06			0.0010	0.0013	0.0024	0.0001					0.0002	0.0002				0.0002	
SYN07			0.0001	0.0001	0.0002										0.0003	0.0002	
PER01	0.0001												0.0002	0.0002		0.0002	
HAN01	0.0004	0.0003	0.0001	0.0003	0.0005	0.0009	0.0004	0.0005	0.0006			0.0002	0.0004	0.0010	0.0002	0.0007	0.0022
HAN02		0.0001		0.0002									0.0003				0.0002
SMB01																	
EUN01	0.0037	0.0124	0.0017	0.0025	0.0040	0.0032	0.0046	0.0032	0.0028	0.0033	0.0144	0.0097	0.0007	0.0021	0.0038	0.0021	0.0114
EUN02	0.0001																
EUN03	0.0010	0.0043	0.0055	0.0047	0.0025	0.0032	0.0016	0.0030	0.0026	0.0033	0.0005	0.0022	0.0055	0.0044	0.0010	0.0010	0.0008
EUN04	0.0004	0.0005	0.0005	0.0013	0.0004	0.0004	0.0002	0.0005	0.0006		0.0004	0.0007	0.0010	0.0010	0.0007	0.0006	
EUN05	0.0005	0.0007	0.0006	0.0008	0.0005	0.0005	0.0008	0.0007	0.0008	0.0008	0.0007	0.0008	0.0007	0.0008	0.0008	0.0010	0.0007
EUN06						0.0001							0.0002				
EUN07	0.0003		0.0001		0.0002	0.0001		0.0004	0.0002			0.0002	0.0002	0.0002		0.0002	0.0002
EUN08	0.0001	0.0005	0.0002	0.0001			0.0005	0.0006	0.0002	0.0004	0.0004			0.0008	0.0004	0.0003	0.0004
EUN10			0.0002														

Appendix A. Continued.

SPECIES	070677	210677	050777	190777	020877	160877	060977	270977	091077	270178	030378	310378	170478	040578	260578	080678	290678
EUN11			0.0002	0.0002	0.0002	0.0002						0.0002			0.0002		
EUN12		0.0002						0.0004					0.0002	0.0006	0.0002		
EUN13	0.0001		0.0001	0.0002	0.0001				0.0006	0.0003	0.0004	0.0002	0.0003	0.0003	0.0002		0.0002
EUN14																	
EUN15							0.0002	0.0011	0.0003		0.0002						
EUN16	0.0001	0.0011	0.0003	0.0004	0.0001	0.0008	0.0006	0.0005		0.0004	0.0007			0.0005	0.0002		0.0002
EUN17		0.0001		0.0001	0.0001					0.0004	0.0002	0.0002	0.0002	0.0003	0.0005	0.0002	
EUN18	0.0002	0.0005	0.0002	0.0004	0.0001						0.0002	0.0004		0.0007	0.0002	0.0004	0.0002
EUN19	0.0001												0.0002	0.0005	0.0002		
EUN20																	
EUN21														0.0002			
ATN01				0.0001										0.0002			
ACN01	0.0019	0.0034	0.0047	0.0055	0.0040	0.0167	0.0180	0.0166	0.0082	0.0075	0.0040	0.0100	0.0066	0.0032	0.0040	0.0036	0.0085
ACN03	0.0001		0.0002												0.0003		
ACN04		0.0002					0.0002						0.0002	0.0002			
ACN05	0.0001	0.0003	0.0001			0.0001		0.0004			0.0005	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
CNS01														0.0003		0.0002	
FRU01	0.0009	0.0007	0.0008	0.0009	0.0007	0.0010	0.0010	0.0007	0.0028	0.0007	0.0007	0.0008	0.0021	0.0010	0.0010	0.0020	0.0025
FRU02	0.0002	0.0001	0.0001	0.0001	0.0001												
FRU03	0.0003	0.0004	0.0001	0.0002	0.0001		0.0002	0.0003	0.0004		0.0004	0.0002	0.0004	0.0010	0.0004	0.0003	0.0007
NVA17																	
NVA23												0.0002		0.0005	0.0002		
SNS01	0.0001									0.0002			0.0002	0.0003			0.0002
SNS02														0.0002			
NVA04	0.0003	0.0004	0.0004	0.0004	0.0002	0.0006	0.0005	0.0007	0.0008	0.0003	0.0005	0.0007	0.0006	0.0010	0.0007	0.0006	0.0005
NVA08	0.0003	0.0005	0.0009	0.0016	0.0017	0.0025	0.0017	0.0030	0.0008	0.0007	0.0007	0.0005	0.0006	0.0010	0.0008	0.0010	0.0025
NVA15													0.0003	0.0003			
NVA29																	
NEI01	0.0001									0.0002			0.0002	0.0002			
NEI02													0.0002				
NEI03																	
DPN01				0.0001													
DPN02																	
NVA01												0.0002					
NVA05	0.0001							0.0003									
NVA07																	
NVA09	0.0002	0.0003	0.0004	0.0003	0.0007	0.0009	0.0010	0.0005	0.0010	0.0006	0.0010	0.0008	0.0008	0.0010	0.0010	0.0007	0.0007
NVA10				0.0004													
NVA11				0.0001													
NVA13					0.0002												
NVA16					0.0001	0.0001			0.0004				0.0003	0.0003			
NVA19						0.0001	0.0002						0.0002	0.0002		0.0002	
NVA20										0.0003	0.0002			0.0002	0.0002		
NVA21												0.0002	0.0002	0.0003	0.0002		
NVA22													0.0002				0.0002
NVA24													0.0003				
NVA25		0.0001											0.0004				
NVA26													0.0004				
NVA27		0.0001	0.0004	0.0002			0.0002			0.0002		0.0002	0.0004	0.0010	0.0007	0.0006	0.0004
NVA28													0.0002				0.0002
NVA30																	
NVA31															0.0002	0.0002	0.0005
NVA32																0.0002	
NVA35																	
NVA36			0.0001														

DATE (DAY/MONTH/YEAR)

SPECIES	070677	210677	050777	190777	020877	160877	060977	270977	091077	270178	030378	310378	170478	040578	260578	080678	290678
NVA06	0.0001	0.0005	0.0001	0.0003	0.0003	0.0001	0.0001	0.0003	0.0004	0.0002	0.0002	0.0004	0.0004	0.0007	0.0008	0.0002	0.0002
NVA12		0.0001		0.0001		0.0001							0.0002	0.0002			0.0002
NVA14					0.0001								0.0002	0.0002			
NVA18						0.0001		0.0003				0.0002	0.0002	0.0004	0.0004	0.0002	
NVA33																	
NVA34																	
GPN01	0.0016	0.0026	0.0024	0.0040	0.0025	0.0004				0.0003	0.0038	0.0010	0.0008	0.0055	0.0025	0.0049	0.0025
GPN02			0.0004														
GPN03			0.0002	0.0002	0.0002	0.0016	0.0010	0.0007	0.0006	0.0004	0.0007		0.0004	0.0010	0.0005	0.0007	0.0008
GPN04		0.0001	0.0001	0.0004	0.0003	0.0085	0.0019	0.0010	0.0006	0.0007	0.0008	0.0002	0.0006	0.0005			
GPN05					0.0001												
GPN06							0.0002							0.0004			0.0002
GPN07																	
GPN08																	
CYM02	0.0007	0.0008	0.0006	0.0003	0.0003						0.0003						0.0010
CYM03		0.0001	0.0002	0.0002		0.0002					0.0002	0.0004		0.0002			
CYM04	0.0009	0.0007	0.0007	0.0007	0.0005	0.0008	0.0007	0.0003	0.0004	0.0002	0.0004	0.0002	0.0005	0.0008	0.0005	0.0003	0.0004
CYM05	0.0004	0.0006	0.0016	0.0009	0.0017	0.0017	0.0009	0.0010	0.0010	0.0006	0.0005	0.0010	0.0007	0.0010	0.0010	0.0010	0.0010
CYM06			0.0001														
CYM07			0.0002	0.0003		0.0007	0.0004	0.0005	0.0006	0.0002	0.0004	0.0002	0.0002	0.0005	0.0002		
CYM08	0.0002		0.0001			0.0001		0.0004				0.0002					
CYM09		0.0001	0.0002	0.0001										0.0002			
CYM10																	
CYM11																	
CYM12													0.0004	0.0006	0.0002	0.0002	0.0002
CYM13																	
APH01											0.0002			0.0002		0.0002	
APH02														0.0002			
EPM01			0.0001		0.0001												
EPM02																	
NZA02	0.0001	0.0001	0.0001	0.0002		0.0002											
NZA03		0.0001															
NZA04		0.0002		0.0004	0.0003	0.0007	0.0004	0.0003				0.0002		0.0005	0.0002	0.0006	0.0002
NZA05		0.0001				0.0002	0.0001						0.0003	0.0002	0.0002		
NZA06			0.0001	0.0001	0.0001	0.0004	0.0004	0.0030	0.0006	0.0002	0.0002			0.0010	0.0005	0.0002	0.0002
NZA07																0.0003	
SUR01		0.0001				0.0001											
SUR02																	
SUR03																	0.0002
NZA01	0.0001	0.0001	0.0002	0.0002	0.0001			0.0003			0.0002	0.0002	0.0003	0.0005		0.0002	
BAT01			0.0001	0.0047	0.0092	0.1001		0.0028	0.0293	0.0002	0.1667	0.0246	0.0004	0.0016	0.0091	0.0156	0.0228
BAT02																	
BAT03																	
AUD01	0.0001	0.0013							0.0015				0.0004	0.0003			
CPT01													0.0003			0.0003	
GLD01													0.0002				
PDN01																	

Appendix B. Abundance of all algal taxa at alternate collecting stations (2-7) for four dates (day/month/year), where values range from 0 - 1 (see Table 1 for species codes).

SPECIES	ST2 100977	ST2 021578	ST2 051878	ST2 062378	ST3 080977	ST3 021578	ST3 051878	ST3 062378	ST4 080977	ST4 021578	ST4 051878	ST4 062378	ST5 080977	ST5 021578	ST5 051878	ST5 062378
CCO01										0.0005						
MIC01							0.0005	0.0010			0.0037	0.0010				
GOC01										0.0005						
MPD01					0.0010	0.0003	0.0005	0.0005	0.0005		0.0007	0.0010				
XEN01							0.0005	0.0005			0.0004	0.0005				
CLS01			0.0005	0.0010	0.0005										0.0010	0.0005
CHM01	0.0100	0.0055	0.0323	0.0323		0.0005							0.0010	0.0050	0.0273	0.0050
CHM02		0.0005	0.0005		0.0005											
CHM03		0.0005	0.0010											0.0005		
CHM04		0.0005	0.0005	0.0010				0.0010						0.0010		
CHM05																
CHM06																
OSC01								0.0005	0.0005		0.0007	0.0100	0.0010	0.0005	0.0005	
OSC02												0.0050				
OSC03																
PHR01	0.0100	0.0050	1.0000	0.5682			0.0100	0.0323						0.0055		0.0050
PHR02				0.0050		0.0003	0.0005				0.0037		0.0010			
LYG01		0.0050								0.0005						
LYG03			0.0005	0.0010	0.0010		0.0005								0.0005	
LYG04			0.0005						0.0005		0.0007		0.0010			
LYG05																
LYG06	0.0010		0.0010	0.0005		0.0003	0.0005						0.0005	0.0005	0.0005	
CSP01										0.0005						
ANB01							0.0005		0.0010							
ENC01		0.0005	0.0005													
CAL01			0.0005		0.0010	0.0003	0.0005				0.0004	0.0050		0.0005		0.0055
CAL02	0.0010					0.0137			0.0005							
RVU01						0.0025	0.0278	0.0010							0.0687	0.0055
HPL01											0.0004					
TXP01		0.0278	0.0273	0.0005				0.0005	0.5000							0.0005
STG01	0.0010		0.0273	0.0050	1.0000	0.5366	0.5050	0.5682			0.0034	0.0050			0.5000	0.0273
CDY01						0.0003					0.0007	0.0005	0.0010		0.0005	
EOD01									0.0005							
TTR01																
TTR02					0.0546	0.0025										
AEC01											0.0004	0.0010				
SHC01																0.0273
COV01					0.1364		0.0273	0.0273								0.0005
COV02							0.5000	0.5000			0.0004	0.0050				0.0005
GOL01																
OST01									0.0005	0.0004						
AKD01										0.0004			0.0010			0.0005
CBA01													0.0010			
CRA02																
SCD01					0.0010				0.0005				0.0010			
CML01									0.0005							
PDI01									0.0005							
UKL01	1.0000	0.0010	0.0005							0.0004			1.0000	0.5682	0.0278	0.5682
UKL03	0.0100	0.0323	0.0955	0.0323			0.2891	0.5005	0.0005	0.3337	0.0005			0.0955	0.0732	
MCP01										0.0005						
CET01						0.0003	0.0005		0.0005		0.0004					0.0005
SGC01						0.0025										
DPR01																
OED01	0.0010		0.0005	0.0005				0.0005	0.0050						0.0050	0.0010
OED02											0.0004	0.0546				

SPECIES	*DATES FOR STATION 2* 100977	021578	051878	062378	*DATES FOR STATION 3* 080977	021578	051878	062378	*DATES FOR STATION 4* 080977	021578	051878	062378	*DATES FOR STATION 5* 080977	021578	051878	062378
BUL01	0.0100				1.0000	0.2841	0.0278	0.0687	0.0005		0.0004	0.0050			0.0010	0.0100
ZYG01	1.0000	1.0000	1.0000	1.0000	0.0546		0.0273	0.5000	0.0005				0.0546	0.5000	0.5000	0.5682
ZYG02										0.0004						
SPE01									0.0050		0.0034	0.0278	0.0546		0.0273	0.5273
MOU01	0.0010	0.0010	0.0055	0.0010	0.0010	0.0137	0.0010	0.0050	0.0955	0.5000	0.6667	0.5050	0.0100		0.0010	0.0278
DSM01								0.0005	0.0050		0.0004	0.0005	0.0010			
DSM02					0.0010		0.0010	0.0005	0.0050				0.0010			0.0010
DSM03			0.0005		0.0010	0.0003	0.0010	0.0005	0.0050		0.0070	0.0010			0.0010	0.0005
DSM04																
DSM05												0.0005				
DSM06					0.0010		0.0005				0.0004		0.0010			0.0005
DSM07					0.0010		0.0005		0.0050		0.0004	0.0005	0.0010		0.0005	0.0005
DSM08							0.0005	0.0005								
DSM09								0.0005								
DSM10					0.0010							0.0005				
DSM11							0.0005						0.0010			
DSM12	0.0010								0.0050		0.0004		0.0010			
DSM13					0.0010											
DSM14											0.0004					
DSM15																
DSM16																
DSM18						0.0003				0.0005	0.0004					0.0005
DSM19		0.0005					0.0010				0.0004	0.0005				
DSM20																
DSM21						0.0003		0.0010	0.0050		0.0004	0.0278				
DSM22					0.0010							0.0005				
DSM23									0.0050	0.0005	0.0004	0.0005	0.0010			
DSM24					0.0010		0.0010		0.0005		0.0007	0.0005				0.0005
DSM25																
DSM26																
DSM27							0.0005				0.0004	0.0005				
DSM28						0.0003						0.0010				
DSM29																
DSM30																0.0005
DSM31	0.0010				0.0010			0.0005								
DSM32							0.0005	0.0005				0.0010				
DSM34																
DSM35						0.0003		0.0005								0.0005
DSM36																
DSM37										0.0005		0.0005				
DSM38								0.0005			0.0037	0.0005				
DSM39											0.0004		0.0010			
DSM40							0.0005	0.0005			0.0010	0.0010				
DSM41									0.0005		0.0004	0.0010				
DSM42							0.0005				0.0007	0.0010				
DSM43							0.0005									
DSM44									0.0005		0.0004	0.0005				
DSM45												0.0010				
DSM46										0.0050		0.0005				
DSM47									0.0005			0.0005				
DSM48											0.0004	0.0005				
DSM49												0.0010				
DSM50												0.0005				
DSM51								0.0005								
DSM52									0.0005							

SPECIES	STA2 100977	STA2 021578	STA2 051878	STA2 062378	STA3 080977	STA3 021578	STA3 051878	STA3 062378	STA4 080977	STA4 021578	STA4 051878	STA4 062378	STA5 080977	STA5 021578	STA5 051878	STA5 062378
DSM53					0.0010				0.0005							
DSM54									0.0005							
DSM55					0.0010				0.0005							
DSM56					0.0010				0.0005							
DSM57					0.0010				0.0005							
EGL01									0.0050		0.0007					
CIP01						0.0003				0.0005						
OCR01	0.0005															
MAL01																
MAL02													0.0010			
SRN01								0.0005	0.0005							
CXP01									0.0005							
DNB01									0.0005				0.0010			
DNB02												0.5000				
CRY01		0.0005					0.0010	0.0055			0.0185	0.0278				0.0005
SDC01									0.0010							
CYC01	0.0005	0.0005			0.0010	0.0003	0.0005	0.0010	0.0278	0.0005	0.0037	0.0010				
CYC02								0.0005			0.0004					
MEL01			0.0005			0.0003			0.0005	0.0005		0.0005				
MEL02	0.0010	0.0005	0.0005	0.0005	0.0010	0.0005	0.0010	0.0010	0.0010	0.5005	0.3340	0.5050			0.0005	0.0005
COS01																
COS02			0.0005					0.0005								
THA01																
TAB01	0.0546	0.0100	0.0100	0.0100	0.0546	0.0614	0.0278	0.0055	0.0010	0.0005	0.0007	0.0010	0.0546	0.0055	0.0100	0.0323
TAB02								0.0010	0.0055	0.0055	0.0070	0.0323	0.0010			
DAT01	0.0010	0.0055	0.0055	0.0055			0.0005				0.0004		0.0010		0.0010	0.0005
DAT02						0.0003		0.0005	0.0005						0.0005	0.0005
MDN01	0.0010	0.0005	0.0010	0.0010		0.0003	0.0005								0.0005	0.0005
TCY01								0.0005								
FGL01						0.0003			0.0005							
FGL02											0.0004	0.0005				
FGL03								0.0005				0.0005				
FGL04								0.0005								
FGL05										0.0005						
AST01		0.0005						0.0005	0.0050							
SYN01	0.0010	0.0055	0.0055	0.0055	0.0010	0.0007	0.0010				0.0004		0.0010	0.0010	0.0010	0.0010
SYN02	0.0010	0.0010	0.0010	0.0010		0.0005										
SYN03												0.0005				
SYN04																
SYN05																
SYN06																
SYN07		0.0005	0.0005													
PER01						0.0007	0.0005	0.0005				0.0005				0.0005
HAN01		0.0005	0.0055	0.0010		0.0003	0.0005	0.0005								
HAN02		0.0005														
SMB01					0.0010			0.0005		0.0005	0.0004	0.0005				
EUN01	0.0010	0.0005	0.0010	0.0055	0.0010	0.0010	0.0010	0.0100	0.0005	0.0005	0.0007	0.0055	0.0010	0.0010	0.0005	0.0050
EUN02											0.0004					
EUN03	0.0010	0.0010	0.0010	0.0010		0.0007	0.0005		0.0005		0.0004	0.0005	0.0010	0.0005	0.0010	0.0010
EUN04	0.0010	0.0005	0.0010		0.0010	0.0005	0.0005				0.0055	0.0067		0.0005	0.0050	0.0010
EUN05	0.0010	0.0005	0.0010	0.0010		0.0005				0.0005		0.0005	0.0010		0.0005	0.0005
EUN06		0.0005				0.0003	0.0005	0.0010		0.0005	0.0004	0.0005	0.0010			
EUN07	0.0010	0.0005	0.0005			0.0005	0.0010	0.0005	0.0055	0.0010	0.0004	0.0010	0.0010			
EUN08			0.0005	0.0005		0.0007	0.0005	0.0010	0.0005	0.0010	0.0037	0.0055	0.0010	0.0005	0.0010	
EUN10																

SPECIES	STATION 2 100977	021578	051878	062378	STATION 3 080977	021578	051878	062378	STATION 4 080977	021578	051878	062378	STATION 5 030977	021578	051878	062378
EUN11																
EUN12			0.0005		0.0010	0.0005	0.0010	0.0005			0.0007	0.0055			0.0005	0.0005
EUN13		0.0005			0.0010	0.0003	0.0005	0.0010	0.0005	0.0010	0.0007	0.0010	0.0010			
EUN14					0.0010						0.0004					
EUN15					0.0010		0.0005	0.0005		0.0005		0.0010			0.0005	
EUN16		0.0010	0.0005							0.0005				0.0005		
EUN17	0.0010					0.0003										
EUN18				0.0005			0.0050	0.0010				0.0050	0.0010	0.0005	0.0278	0.0005
EUN19			0.0005				0.0005	0.0005	0.0005	0.0010	0.0005		0.0010		0.0005	0.0010
EUN20		0.0005								0.0005						
EUN21										0.0005		0.0005				
ATN01							0.0005	0.0010	0.0005	0.0005	0.0004	0.0010				
ACN01	0.0100	0.0010	0.0010	0.0100	0.0010	0.0053	0.0010	0.0005			0.0004	0.0005	0.0100	0.0100	0.0100	0.0055
ACN03									0.0005							
ACN04			0.0005					0.0005								
ACN05		0.0005	0.0005			0.0003										
CNS01						0.0025										
FBU01	0.0100	0.0010	0.0005	0.0010	0.0546	0.0505	0.0323	0.0546	0.0955	0.5682	0.3822	0.5050	0.0010	0.0278	0.0055	0.0055
FBU02																
FRU03		0.0010	0.0005			0.0005	0.0010	0.0010	0.0005	0.0055	0.0185	0.0055	0.0010	0.0005		0.0005
NVA17						0.0003			0.0010	0.0055		0.0010				
NVA23								0.0005			0.0004	0.0005				
SNS01							0.0005	0.0005			0.0037	0.0010				
SNS02							0.0005				0.0004					
NVA04	0.0010	0.0005	0.0005	0.0005	0.0100	0.0007	0.0278	0.0055	0.0055	0.0100	0.0491	0.0273	0.0010	0.0050	0.0010	
NVA08	0.0010	0.0010	0.0005	0.0010	0.0010	0.0030	0.0323	0.0100	0.0055	0.0278	0.0040	0.0732	0.0010	0.0055	0.0010	0.0055
NVA15									0.0010	0.0005		0.0010				
NVA29								0.0005	0.0005	0.0005	0.0004	0.0055			0.0005	
NEI01	0.0010	0.0005					0.0010	0.0010	0.0005	0.0010	0.0037	0.0010				0.0005
NEI02										0.0005	0.0007	0.0010				
NEI03											0.0004					
DPN01													0.0010			
DFN02						0.0003						0.0005				
NVA01											0.0004					
NVA05																
NVA07									0.0005							
NVA09	0.0010	0.0005	0.0010	0.0010		0.0030	0.0055	0.0055	0.0005	0.0005	0.0040	0.0278	0.0010	0.0005	0.0010	0.0010
NVA10								0.0005	0.0010	0.0005						
NVA11																
NVA13							0.0005	0.0005		0.0010	0.0004	0.0005		0.0005		
NVA16					0.0010		0.0005	0.0005	0.0010			0.0050				
NVA19											0.0004	0.0005				
NVA20								0.0005			0.0004					0.0005
NVA21						0.0003	0.0005				0.0004					
NVA22							0.0005			0.0005	0.0004	0.0050				0.0005
NVA24																
NVA25		0.0005						0.0005	0.0005			0.0005	0.0010			
NVA26								0.0005				0.0005				
NVA27			0.0010	0.0010		0.0030	0.0010	0.0055		0.0005	0.0004	0.0055	0.0100	0.0005	0.0010	0.0010
NVA28																
NVA30								0.0005							0.0005	
NVA31												0.0005				0.0005
NVA32												0.0005				
NVA35												0.0005				
NVA36																

SPECIES	DATES FOR STATION 2				DATES FOR STATION 3				DATES FOR STATION 4				DATES FOR STATION 5			
	100977	021578	051878	062378	080977	021578	051878	062378	080977	021578	051878	062378	080977	021578	051878	062378
NVA06	0.0010		0.0010		0.0010		0.0005		0.0010	0.0005	0.0004	0.0005			0.0005	0.0005
NVA12				0.0005			0.0005			0.0005	0.0004	0.0005				
NVA14			0.0005				0.0005	0.0010		0.0005	0.0037				0.0005	
NVA18			0.0005		0.0010	0.0003		0.0010		0.0055	0.0034				0.0005	
NVA33										0.0005		0.0010				
NVA34												0.0055				
GPN01			0.0010	0.0005			0.0005		0.0005				0.0010	0.0005	0.0010	0.0010
GPN02																
GPN03	0.0010		0.0005				0.0003		0.0010			0.0005				
GEN04	0.0010	0.0010					0.0005	0.0005	0.0005			0.0005				0.0005
GPN05																
GPN06							0.0003	0.0005		0.0005	0.0004					0.0005
GPN07											0.0004	0.0005				
GPN08															0.0005	
CYM02							0.0003		0.0005		0.0004	0.0005	0.0010			
CYM03					0.0010				0.0010		0.0004					
CYM04	0.0010		0.0010	0.0010	0.0010	0.0003	0.0010		0.0005				0.0010	0.0010	0.0010	0.0010
CYM05	0.0010	0.0005	0.0005	0.0005	0.0010	0.0166	0.0055	0.0323	0.0100	0.0010	0.0188	0.0323		0.0005	0.0005	0.0050
CYM06																
CYM07	0.0010	0.0005	0.0005											0.0005	0.0005	0.0005
CYM08							0.0003									
CYM09								0.0005				0.0005				0.0005
CYM10										0.0005	0.0034					
CYM11																
CYM12								0.0005			0.0037					
CYM13										0.0005		0.0005				
APH01						0.0003	0.0005						0.0010			
APH02							0.0005									
EPM01									0.0687							
EPM02												0.0005				
NZA02									0.0050							
NZA03																
NZA04						0.0003	0.0005	0.0005	0.0005		0.0004					0.0005
NZA05						0.0005	0.0005			0.0005	0.0004					
NZA06	0.0010					0.0003	0.0005	0.0005		0.0005		0.0010				
NZA07									0.0005							
SUR01						0.0005			0.0005	0.0005	0.0004					
SUR02								0.0005				0.0005				
SUR03										0.0005		0.0010				
NZA01		0.0005	0.0005		0.0010	0.0003	0.0055	0.0010	0.0278	0.0055	0.0040	0.0055	0.0010		0.0005	0.0005
BAT01								0.0050							0.0005	0.5000
BAT02															0.0005	0.0005
BAT03																0.0005
AUD01			0.0050	0.0005												
CPT01			0.0005					0.0005		0.0005	0.0007	0.0005				0.0010
GLD01								0.0005			0.0010	0.0010				
PDN01										0.0005						

SPECIES	DATES FOR STATION 6				DATES FOR STATION 7		
	080977	021578	051878	062378	021578	051878	062378
CCO01							
HIC01							
GOC01							
NPD01							
XEN01							
CLS01		0.0005		0.0005		0.0005	0.0005
CHM01	0.0010	0.0050	0.0278	0.0055	0.0007	0.0273	0.0050
CHM02	0.0010		0.0005	0.0050		0.0005	0.0005
CHM03			0.0005				
CHM04			0.0010			0.0278	
CHM05							
CHM06	0.0010						
OSC01			0.0005		0.0007		
OSC02							
OSC03							
PHR01	0.0010	0.0050	0.0546	0.0055	0.0037	0.5050	0.5682
PHR02	0.0010						
LYG01							
LYG03	0.0010			0.0010			0.0005
LYG04		0.0005					
LYG05							
LYG06		0.0010	0.0055				
CSP01	0.0010		0.0005				
ANB01							
ENC01					0.0034	0.0005	
CAL01	0.0100	0.0005	0.0055	0.0050		0.0005	
CAL02	0.0010						
RVU01			0.0273	0.0005			
HPL01							
TXP01	0.0100	0.0323	0.0682	0.0050	0.0004		0.0005
STG01	0.0010	0.0955	0.5000	0.0005			
CDY01							
EOD01							
TTR01							
TTR02							
AEC01							
SHC01				0.0050			
COV01							
COV02							
GOL01							
OST01							
AKD01							
CBA01							
CRA02							
SCD01							
CML01							
PDI01							
UKL01	1.0000	0.5682	0.5682	0.5682	0.0034	0.1364	0.5682
UKL03		0.5682	0.0323	0.0100	0.3788	0.0010	0.0055
MCP01							
CET01							
SGC01							
DPR01					0.0182		0.0005
OED01				0.0055			0.0050
OED02							

SPECIES	DATES FOR STATION 6				DATES FOR STATION 7		
	080977	021578	051878	062378	021578	051878	062378
BUL01		0.0050	0.0005	0.0005	0.0182		0.0005
ZYG01	0.0100	0.0273	0.5050	0.5273	0.0034	0.5050	0.5000
ZYG02							
SPI01	0.0010		0.0323	0.5273		0.5273	0.5050
MOU01		0.0546	0.0273	0.0055	0.0034	0.0005	0.0005
DSM01					0.0004		
DSM02	0.0010		0.0005	0.0005		0.0005	0.0005
DSM03	0.0010			0.0005			
DSM04							
DSM05							
DSM06	0.0010			0.0005			
DSM07	0.0010			0.0005	0.0005		
DSM08							
DSM09							
DSM10							
DSM11							
DSM12							
DSM13	0.0010						
DSM14							
DSM15							
DSM16							
DSM18							
DSM19				0.0005			
DSM20							
DSM21							
DSM22							
DSM23							
DSM24							
DSM25							
DSM26							
DSM27							
DSM28							
DSM29							
DSM30							
DSM31							
DSM32							0.0005
DSM34							
DSM35				0.0010			0.0005
DSM36							
DSM37							
DSM38							
DSM39							
DSM40							
DSM41							
DSM42							
DSM43							
DSM44							
DSM45							
DSM46							
DSM47							
DSM48							
DSM49							
DSM50							
DSM51							
DSM52							

SPECIES	DATES FOR STATION 6				DATES FOR STATION 7		
	080977	021578	051878	062378	021578	051878	062378
DSM53							
DSM54							
DSM55							
DSM56							
DSM57							
EGL01							
CIP01							
OCB01							
MAL01							
MAL02							
SBN01							
CXP01							
DNB01							
DNB02							
CRY01							
SDC01							
CYC01							
CYC02							
MEL01							
MEL02							0.0010
COS01							
COS02							
THA01							
TAB01	0.0546	0.0100	0.0546	0.0323	0.0397	0.0100	0.0100
TAB02							
DAT01	0.0010	0.0010	0.0010	0.0005	0.0040	0.0010	0.0005
DAT02							
MDN01		0.0010	0.0005		0.0010	0.0005	0.0005
TCY01							
FGL01							
FGL02							
FGL03							
FGL04							
FGL05							
AST01							
SYN01	0.0100	0.0100	0.0323	0.0278	0.0007	0.0055	0.0100
SYN02		0.0005			0.0004	0.0055	
SYN03							
SYN04							
SYN05							
SYN06					0.0007		
SYN07							
PER01							
HAN01					0.0004	0.0005	0.0010
HAN02							
SMB01							
EUN01	0.0010	0.0010	0.0323	0.0055	0.0010	0.0010	0.0010
EUN02							
EUN03	0.0010	0.0010	0.0055	0.0055	0.0070	0.0010	0.0005
EUN04		0.0010	0.0010	0.0005	0.0004		
EUN05		0.0005	0.0010	0.0005	0.0007		0.0005
EUN06							
EUN07	0.0010	0.0005					
EUN08			0.0010	0.0010	0.0010		
EUN10							

SPECIES	DATES FOR STATION 6 080977	021578	051878	062378	DATES FOR STATION 7 021578	051878	062378
EUN11							
EUN12							0.0005
EUN13		0.0010			0.0005		
EUN14							
EUN15							
EUN16					0.0004		
EUN17			0.0005				
EUN18	0.0010		0.0010				0.0005
EUN19							
EUN20							
EUN21							
ATN01							
ACN01	0.0100	0.0055	0.0546	0.0055	0.0219	0.0055	0.0100
ACN03							
ACN04							
ACN05		0.0005					
CNS01							
FBU01	0.0010	0.0005	0.0010	0.0010	0.0007	0.0010	0.0005
FRU02							
FBU03							
NVA17							
NVA23							
SNS01							
SNS02							
NVA04		0.0005	0.0010	0.0005	0.0005		
NVA08	0.0010	0.0010	0.0010	0.0010		0.0010	0.0010
NVA15							
NVA29							
NEI01							
NEI02							
NEI03							
DPN01							
DEN02							
NVA01							
NVA05							
NVA07							
NVA09		0.0005	0.0010	0.0010	0.0004	0.0005	0.0010
NVA10							
NVA11							
NVA13		0.0005					
NVA16							
NVA19							
NVA20							
NVA21							
NVA22							
NVA24							
NVA25							
NVA26							
NVA27		0.0005	0.0005	0.0010			0.0005
NVA28							
NVA30							
NVA31							
NVA32							
NVA35							
NVA36							

Appendix B. Continued.

SPECIES	DATES FOR STATION 6				DATES FOR STATION 7		
	080977	021578	051878	062378	021578	051878	062378
NVA06					0.0004	0.0005	
NVA12			0.0005				
NVA14							
NVA18							
NVA33							
NVA34							
GPN01	0.0010		0.0055	0.0055	0.0040	0.0055	0.0055
GPN02							
GPN03					0.0004		0.0005
GPN04		0.0010			0.0004		
GPN05			0.0005				
GEN06			0.0005				
GPN07							
GEN08							
CYM02	0.0010	0.0005	0.0005				
CYM03							
CYM04	0.0010		0.0100	0.0010	0.0004	0.0010	0.0010
CYM05	0.0010	0.0005	0.0010	0.0005	0.0004	0.0010	0.0010
CYM06							
CYM07	0.0010	0.0010	0.0010	0.0005	0.0004		0.0005
CYM08					0.0004		
CYM09							
CYM10					0.0004		
CYM11					0.0007	0.0005	0.0005
CYM12	0.0010						
CYM13							
APH01							
APH02							
EPM01							
EPM02							
NZA02							
NZA03							
NZA04				0.0010			
NZA05						0.0005	
NZA06			0.0005				0.0005
NZA07							
SUR01							
SUR02							
SUR03							
NZA01							
BAT01				0.0273	0.0004	0.5000	0.0682
BAT02							
BAT03							
AUD01					0.3367	0.0682	0.0273
CPT01							
GLD01			0.0005				
PDN01							

APPENDIX C. Presence of all algal taxa from Jacob's Lake (Station 4) in drift and attached habits to downstream stations (see Table 1 for species codes; PPL = phytoplankton, EPE = epipelic, EPH = epiphytic, EPL = epilithic, MET = metaphytonic).

SPECIES CODE	PREDOMINANT LAKE HABIT	PRESENCE IN STREAM (+)	COLONIZED (+) OR DRIFT ONLY (−)	DOMINANT STREAM HABIT IF ATTACHED
CCØ01	PPL			
XEN01	PPL	+	−	
GØC01	EPH			
MPD01	PPL	+	−	
MIC01	PPL	+	−	
ANB01	PPL			
CAL02	EPH	+	+	EPH
CAL01	EPH	+	+	EPH
LYG01	MET	+	−	
LYG04	MET	+	−	
ØSC01	MET	+	−	
PHR02	EPH	+	+	EPH
CSP01	MET	+	−	
TXP01	EPH	+	+	EPL
STG01	EPH	+	+	EPL
CDY01	PPL	+	−	
EØD01	PPL			
UKL01	MET	+	+	EPL
UKL03	EPH	+	+	EPL
MCP01	EPH	+	+	EPL
CET01	PPL	+	+	EPH
AKD01	PPL	+	−	
AEC01	PPL			
CØV02	EPE	+	+	EPL
CML01	PPL			
ØST01	PPL			
PDI01	PPL			
SCD01	PPL	+	−	
BUL01	EPH	+	+	EPL
ØED01	EPH	+	+	EPL
ØED02	EPH	+	+	EPL
DSM46	PPL			
DSM03	MET	+	−	
DSM12	MET	+	−	
DSM23	PPL	+	−	
DSM02	PPL	+	−	
DSM28	PPL	+	−	
DSM38	PPL	+	−	
DSM32	MET	+	−	

APPENDIX C. Continued.

SPECIES CODE	PREDOMINANT LAKE HABIT	PRESENCE IN STREAM (+)	COLONIZED (+) OR DRIFT ONLY (−)	DOMINANT STREAM HABIT IF ATTACHED
DSM18	PPL	+	−	
DSM14	PPL	+	−	
DSM22	MET	+	−	
DSM01	EPE	+	−	
DSM56	MET			
DSM05	MET	+	−	
DSM27	MET	+	−	
DSM57	PPL	+	−	
DSM07	PPL	+	+	EPH
DSM19	MET	+	−	
DSM47	PPL			
DSM24	EPH	+	−	
DSM50	EPH			
DSM10	MET	+	−	
DSM42	PPL	+	−	
DSM44	PPL	+	−	
DSM37	PPL	+	−	
DSM45	PPL			
DSM54	PPL			
DSM48	PPL			
DSM53	PPL	+	−	
DSM49	EPH			
DSM40	MET	+	−	
DSM06	PPL	+	−	
DSM39	EPE	+	−	
DSM41	PPL	+	−	
DSM21	PPL	+	−	
DSM52	PPL			
DSM55	PPL	+	−	
MØU01	EPH	+	+	EPL
SPI01	EPH	+	+	EPL
ZYG01	MET	+	+	EPL
ZYG02	EPH	+	−	
CIP01	PPL	+	−	
CXP01	EPH			
DNB01	PPL	+	−	
DNB02	PPL			
MAL01	PPL	+	−	
MAL02	PPL	+	−	
ØCR01	PPL	+	−	
SRN01	PPL			
CRY01	PPL	+	+	EPH
CYC02	MET	+	−	
CYC01	PPL	+	−	
MEL02	EPH	+	−	
MEL01	PPL	+	−	
SDC01	PPL	+	−	

APPENDIX C. Continued.

SPECIES CODE	PREDOMINANT LAKE HABIT	PRESENCE IN STREAM (+)	COLONIZED (+) OR DRIFT ONLY (−)	DOMINANT STREAM HABIT IF ATTACHED
AST01	PPL	+	−	
DAT02	PPL	+	+	EPH
FGL02	EPE	+	−	
FGL03	PPL	+	−	
FGL05	PPL			
FGL01	PPL	+	−	
SMB01	EPE	+	−	
SYN03	PPL	+	+	EPH
SYN01	EPE	+	+	EPL
TAB02	PPL	+	−	
TAB01	PPL	+	+	EPH
ATN01	EPE	+	−	
EUN21	EPE	+	−	
EUN08	EPE	+	+	EPH
EUN12	EPE			
EUN13	EPE	+	+	EPH
EUN07	EPH	+	+	EPH
EUN02	MET	+	−	
EUN19	EPE	+	−	
EUN04	EPH	+	+	EPH
EUN01	EPH	+	+	EPH
EUN05	EPE	+	+	EPH
EUN14	EPE	+	−	
EUN20	EPE			
EUN06	EPE	+	−	
EUN16	MET	+	+	EPH
EUN17	EPE	+	−	
EUN03	MET	+	+	EPH
EUN15	MET	+	−	
PER01	EPE	+	−	
ACN01	MET	+	+	EPL
ACN03	PPL	+	−	
NVA15	EPE	+	−	
NVA29	EPE	+	−	
NVA04	EPE	+	+	EPH
NVA08	EPE	+	+	EPH
CYM03	EPE	+	−	
CYM02	EPE	+	+	EPH
CYM05	EPH	+	+	EPH
CYM13	EPH			
DAT01	PPL	+	+	EPL
CYM10	EPE	+	−	
CYM04	MET	+	+	EPL
CYM09	MET	+	−	
CYM12	EPE	+	−	
DPN01	EPE	+	−	
DPN02	EPE	+	−	

APPENDIX C. Continued.

SPECIES CODE	PREDOMINANT LAKE HABIT	PRESENCE IN STREAM (+)	COLONIZED (+) OR DRIFT ONLY	DOMINANT STREAM HABIT IF ATTACHED
EPM02	EPE			
EPM01	PPL	+	−	
FRU03	EPE	+	+	EPH
FRU01	EPH	+	+	EPH
FRU02	EPE	+	−	
GPN06	EPH	+	+	EPL
GPN07	EPE			
GPN01	MET	+	+	EPL
GPN03	EPH	+	+	EPH
GPN04	MET	+	+	EPL
NVA01	EPH	+	−	
NVA32	EPE	+	−	
NVA13	PPL	+	−	
NVA27	EPH	+	+	EPH
NVA10	EPH	+	−	
NVA35	EPE			
NVA26	EPE	+	−	
NVA16	MET	+	−	
NVA19	EPH	+	−	
NVA25	EPE	+	−	
NVA09	EPE	+	+	EPH
NVA22	EPE	+	−	
NVA07	PPL			
NVA37	EPE	+	−	
NVA21	EPH	+	−	
NVA20	PPL	+	−	
NEI01	EPE	+	−	
NEI02	EPE	+	−	
NEI03	EPE			
NVA34	EPE			
NVA06	MET	+	+	EPH
NVA33	EPE			
NVA18	EPE	+	+	EPH
NVA12	EPE	+	−	
NVA14	EPE	+	−	
SNS02	MET	+	−	
NVA23	EPE	+	−	
NVA17	EPE	+	−	
SNS01	EPE	+	−	
NZA02	PPL	+	−	
NZA05	PPL	+	−	
NZA07	PPL	+	−	
NZA04	EPE	+	+	EPH
NZA06	EPE	+	+	EPH
NZA01	EPE	+	+	EPH

APPENDIX C. Continued.

SPECIES CODE	PREDOMINANT LAKE HABIT	PRESENCE IN STREAM (+)	COLONIZED (+) OR DRIFT ONLY	DOMINANT STREAM HABIT IF ATTACHED
SUR01	EPE	+	−	
SUR03	EPH	+	−	
SUR02	PPL	+	−	
EGL01	PPL			
GLD01	PPL	+	−	
PDN01	PPL			
CPT01	PPL	+	−	