VARIOUS ENVIRONMENTAL FACTORS GOVERNING
COMMUNITY STRUCTURE OF PERIPHYTON COLONIZING
SUBMERGED GLASS SLIDES

Norina Munteanu

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## ABSTRACT

## VARIOUS ENVIRONMENTAL FACTORS GOVERNING COMMUNITY STRUCTURE OF PERIPHYTON COLONIZING SUBMERGED GLASS SLIDES

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Glass slides were submerged for two to six week periods at selected sites in a small stream to test the effects of certain environmental factors on a diatom community. The primary factors were spatial succession, stream bottom type, and seasonal succession. Microdistribution of diatoms on slides was also investigated. The periphyton community of a mildly polluted stream was compared with that of the first stream.

Spatial succession, connected with changes in stream profiles, acts upon diatom communities by affecting species pool and settling efficiencies. Stream bottom affects species pool and settling rates. Higher numbers of diatoms migrate to slides located on heavily colonized rocks as compared to those located at muddy surfaces. Season influences differential growth rates of diatoms through settling and reproduction. Partial competitive exclusion by certain dominant diatoms, Cocconeis placentula in particular, takes place in the late summer, appreciably lowering the diversity. The antagonistic relationship between Cocconeis placentula and Achnanthes linearis and A. minutissima is attributed to different strategies by these two genera to current and to their differing growth rates.

Cocconeis placentula dominated the pristine stream; Achnanthes lanceolata dominated the polluted stream.

Preference of diatoms for edges of slides oriented parallel to the current is a result of physical factors: current and light.

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# INTRODUCTION

The communities which make up the ecosystem of a fresh water habitat consist of complex associations of populations which have evolved through the ages and presently co-exist through regular interactions. These associations are linked and interwoven to such an extent that changes in one species may be felt by the whole community. This property of inter-dependence extends beyond the community to all levels of organization within the ecosystem, encompassing every trophic level in the food web, and enables homeostatic mechanisms to maintain a dynamic equilibrium even in a highly stressed situation. However, this self-regulatory capacity can only be measured at the community level or higher. Therefore, when wishing to learn what repercussions might occur on the environment from various extraneous factors, the field ecologist must look at the level of the community.

This work concerns itself with one algal community and follows the development of periphyton (attached algae) on submerged glass slides placed in small creeks. Creeks, like the ones I study, are often sources of water for agricultural purposes and for use by small towns. These streams are also recipients of much of the pollution from non-point sources -- the most difficult to discover and control.

Periphyton was defined by a Russian hydrobiologist (Behning, 1924) as the biocoenosis[1] growing attached to artificial objects installed in the water by man. It is now commonly understood to mean all microorganisms which attach themselves to submerged surfaces. The epilithic, epi-

[1] Biocoenosis was described by Möbius (in "Natural Communities" by L.R. Dice, University of Michigan Press, Ann Arbor, 1952) as a more or less self-regulating unit or community.

phytic, epipelic, and epipsammic algae, which make up the floral components of the periphyton inhabiting rocks, macrophytes, mud surfaces, and mud depths respectively, occupy the lowest trophic level in the food chain. They are important primary producers in streams and therefore play a large role in the maintenance of higher life forms.

There is a dearth of literature on periphyton and much less exists on periphyton community structure (to be discussed later), as studies have changed from the general taxonomy of the past to those concerning growth and production. Periphyton generally comprise a small proportion of flora studies of aquatic systems. A great deal more literature is available on the phytoplankton. This is in part due to the focus of scientists, especially on this continent, on large rivers and lakes which contain a large and prominent phytoplankton community. In Europe, especially England, which contains many small rivers and streams in proximity to civilization, small waterways have been looked at more closely. These contain very little true phytoplankton and therefore the periphyton community is the important primary producer.

Biologists have already used the periphyton as biological indicators of pollution (Kolkwitz & Marsson, 1908; Butcher, 1949; Patrick, 1949, 1963; Margalef, 1955; Backhaus, 1968). Patrick (1974), whose work focuses on the diatom component of periphyton, states that diatoms can be very useful in monitoring pollution in lakes, rivers, and estuaries: "Because as a group they consist of many species that have populations composed of varying numbers of specimens, they are an excellent group to treat statistically in analyzing their reaction to varying ecological conditions."

Early in the investigation of periphyton difficulties, primarily involved with quantitative sampling of uneven and rough surfaces of natural substrata, have led biologists to use artificial substrates. Most common among those were wood, slate, clay, concrete, sheet metals, asbestos, eternite, celluloid, organic plastics, and glass (Sladeckova, 1962).

The advantages of using glass slides for investigation of periphyton are many. A few are summarized below:

1) Qualitative and quantitative investigation can be done accurately; production measurements are facilitated.

2) When low biomass permits, periphyton can be examined directly under the microscope in an undamaged state and in their natural positions.

3) Primary succession can be measured; different stages of an isolated organism or community can be studied and seasonal succession using similarly aged colonies can be examined.

4) Comparison studies are facilitated and <u>in situ</u> experiments are rendered more feasible.

5) Glass slides are easy to obtain, cheap, and easy to remove and carry in large quantities back to the laboratoy where controlled studies can be done.

6) This technique lends itself to many flexible modifications.

Since Hentschel first introduced the use of glass slides for the <u>in situ</u> qualitative and quantitative study of periphyton in 1917, this technique has gained popularity among periphyton ecologists: Geitler (1927) in Germany; Hurter (1928) in Switzerland; Butcher (1931) and Godward (1934) in England; Abdin (1950) in Palestine; Wysocka (1952) in Poland; Smyth (1955) in Scotland; Rodina (1956) and Sladecek & Sladeckova (1964) in the Soviet Union; Patrick (1949, 1949a, 1961, 1967), Welch (1948), Patrick et al. (1974), and Weber (1974) in the United States; Brown & Austin (1973) in Canada.

A number of review articles discuss the various techniques that have evolved according to the limnologist's particular needs, using artificial substrates to study periphyton (Cooke, 1956; Sladeckova, 1962; Castenholz, 1961; Wetzel, 1965). Several of the apparatus used for holding glass slides in the water resembled slide boxes with their ends open or modifications of the Bissonette sampler for invertebrates (1930) with slides oriented horizontally. Others, like Butcher's "printing frame", were simply anchored to the bottom of the stream or lake bed with slides laid flat. A notable version of the Bissonette sampler was devised by Patrick for the sampling of diatoms (1949). The Catherwood Diatometer used a slide chamber, orienting the slides vertically, edgewise to the current. The methods described above are in popular use at the present time. Most of the studies using artificial substrates were designed to elucidate basic ecological principals though several, notably the work of Patrick, focused on pollution-applied investigations.

The present work encompasses both genres of research by carrying out two major experiments: 1) a comparison study of two polluted streams to a pristine one; and 2) an ecological study using several sites along the pristine stream. In both cases periphyton community structure was used to evaluate the effects of the tested factors.

Generally, community structure can be analyzed and defined from three viewpoints: function; location; and biotic composition. I chose to examine species composition of periphyton communities to obtain a better understanding of how environmental contingencies influence periphyton communities. Aspects connected with species composition are: association of common species; species frequency; species per unit area; spatial distribution; numerical abundance; information content (Hairston, 1959). I have concentrated my attention on the first aspect mentioned, association of common species, given by relative abundance of prominent species and the specific hierarchy among them. However, spatial distribution of individuals, information theory for diversity, and numerical abundance of species as well as individuals are used to obtain an idea of the dynamics of the community.

As one can not assay the whole ecosystem, by focusing at the community level, the scientist can overcome the limited scope of an autecological study[2]. Autecological work is invaluable for harvesting information on life histories and physiological and behavioral mechanisms of an organism or species, but, by neglecting inter-specific (and in some cases intra-specific) interactions with and contributions of other components of the community, studies of this kind can provide little information about natural situations. The problems of autecological studies point logically to synecological studies at all levels, particularly that of the community. The use of community structure provides an efficacious and sensitive method of assessing the effects of environmental factors such as pollution on the biota of the ecosystem.

2 Autecology is the science of population ecology. It is the relation of a single individual or species population to its environment, as opposed to synecology which is the study of communities or groups of communities.

Two other approaches to measuring effects of pollution on biota have been used. These are: 1) Target species approach; and 2) "Saprobien System" approach[3].

Implicit in the target species approach, as pointed out by Cairns et al. (1972), is the parochial assumption that protection of the target species (usually herbivores or carnivores of direct value to man such as trout, salmon, and oysters) extends to the other components of the aquatic habitat occupying lower trophic levels which are directly or indirectly responsible for the viability of the "target species". These components usually exert a greater influence on the community as a whole. Patrick, Cairns and Scheier (1968) indicated that fish, invertebrates and diatoms evinced different sensitivities to various constituents of industrial wastes.

The use of the "Saprobien System", arising from the work of Kolkwitz and Marsson (1908) and primarily used in Europe, is based upon the niche concept (Hutchinson, 1957). They argue that the presence of certain indicator species alludes to a certain set of environmental conditions essential to their well being. The saprobic approach has limited applications. Because Kolkwitz & Marsson's model considered organic pollution arising mainly from domestic sewage, use of the model for other forms of pollution is not tenable. A particular species may show different tolerances to various toxicants and pollutants (Patrick, 1949; Hynes, 1960). Pollution tolerant organisms are also not necessarily confined to areas of existing pollution since in most cases their niches are broad. In practice, neither presence nor absence of an indicator species gives the

3 The "Saprobien System" describes gradations or zones of organic pollution and classifies organisms according to their tolerances.

investigator much information. The refined "Saprobien Method" rectifies some of the weaknesses associated with the original model (Gaufin, 1958; Fjerdinstad, 1962) though it remains limited by its autecological nature.

The "Saprobien System" is investigated in this study and rejected. I consider it far too simple and controversial to be useful to ecologists at the present time. The use of community structure to test the effects of variables on the biota was deemed the most useful.

Figure A shows a flow diagram of the two major experiments conducted on periphyton community structure. One was an ecological study and the other was a pollution study involving comparison.

Most comparative studies (polluted to unpolluted) involved assessing biomass, production or community structure. Those concerned with the last parameter most often used diversity to describe structure (Patrick, 1949, 1961; Patrick, Hohn and Wallace, 1954). In my comparison of polluted to unpolluted streams, the following parameters of community structure were used to assay the periphyton community: 1) dominance hierarchy (association of common species); 2) information theory for diversity; 3) total biomass (abundance of species and individuals).

In the ecological investigation the environmental factors influencing periphyton were chosen with respect to past work. The importance of current, light, temperature, nutrient concentration and certain pollutants to periphyton community structure is fairly well documented (Patrick, Hohn and Wallace, 1954; Patrick, 1968, 1969, 1971; Backhaus, 1968; McIntire, 1968). This study concerns itself with three lesser known factors that might affect periphyton community structure: 1) spatial suc-

FIGURE A: Flow diagram of the two major experiments on periphtyon community structure undertaken in this study. Several sites along one stream were used in the ecological study. The pollution study involved the comparison of three streams, one clean and two polluted.

## ECOLOGICAL STUDY

SLIDE COMMUNITY: parameters tested
- i) dominance hierarchy
- ii) species number
- iii) diversity
- iv) total biomass

I. Spatial Succession (Sites 1, 2, 3)

II. Substrate Differences (Subsites a, b)

III. Seasonal Succession (Series A to K)

IV. Maturity of Community (Subscripts 1 to 3)

V. Microdistribution on Slides (Transects)

VI. Surface Preference (Frosted/Smooth)

ROCK COMMUNITY: parameters tested
- i) species number
- ii) species composition

I. Epilithic algae

II. Grazers

## POLLUTION STUDY

SLIDE COMMUNITY: parameters tested
- i) dominance hierarchy
- ii) diversity
- iii) total biomass

I. Comparison of Streams (Bishop's Stream, L-1, L-2)

ROCK COMMUNITY: parameters tested
- i) dominance hierarchy
- ii) diversity
- iii) indicator species

I. Epilithic algae

II. Grazers

cession (location along stream length); 2) substrate differences (nature of stream bed under and in proximity to the apparatus with slides; 3) seasonal succession. The last two parameters have already been suggested as possible factors involved with differences in floral composition when looking at epipelic and epipsammic algae colonizing glass slides (Smyth, 1955). The same parameters of community structure were used to test differences in periphyton communities as were those used for the comparison of polluted to unpolluted streams. See Figure A.

I chose the first two factors, spatial succession and substrate type, to evaluate community structure in order to test the possibility that surveys along streams and rivers carried out to illustrate the changes in glass slide periphyton resulting from some kind of pollution (Butcher, 1947; Patrick, 1949, 1949a; Hansmann & Phinney, 1973; Weber, 1974) may be over-estimating or under-estimating the effects of pollution on the slide community. Spatial succession may be masked by introduced bias. Substrate, which may be indirectly related to the pollution source, may conceivably act as much if not more upon the periphyton community than the pollutant itself. Though most authors deliberately choose similar areas to place their apparatus, this similarity becomes progressively more difficult to achieve as one moves downstream. The effect of season on periphyton community structure was chosen because too little information is available on this factor in streams. The information is also conflicting (Blum, 1956).

Points IV through VI of Figure A (Maturity of community; microdistribution; and surface preference) are related directly or indirectly to the previous three factors and help to describe the events taking place.

The philosophy behind this work challenges the attitude of some workers who subjectively categorize species and assemblages with reference to pollution and simply assign tolerances. I feel the need for further caution in making value judgements about the effects concerning the effects of natural variables on the structure of periphyton. Environmental conditions other than pollution affect distribution of organisms (Needham, 1938). Patrick pointed out that "further studies are needed... to determine just what types of ecological variations are most significant." It is logical to elucidate the autochthonous variations (originating from within the system) influencing organisms before attempting to properly evaluate the allochthonous changes imposed on the receiving system. Smyth (1955) revealed the limitation of the present slide technique in assaying subtle environmental contamination. Patrick (1963) illustrated graphically how even in two similar sites located 500 yards apart, high variability could exist. Much more work similar to McIntire's laboratory study (1968), Patrick's semi-controlled studies (1968,1969), and the Cattaneo et al. (1975) in situ study must be carried out to measure the subtle effects of natural variables and to properly understand how the unique slide community reacts to these before apparatus such as the diatometer can be employed as an accurate gauge in pollution research.

The major problems I encountered in my study were uniquely associated with the field. The first and primary one was that of natural variability. Weather is an important variable, subject to change from day to day and its pattern from year to year. Unlike the controlled environment of the laboratory, it is next to impossible to find two places which are exactly alike in nature for accurate comparisons. And even if one is found today there is no assurance that it will be there tomorrow. One of the variables inherent in a study of nature, particularly one close to civilization, is that of human interference. Vandalism of more than half of the diatometers placed in the streams disrupted data collection upon occasions. In most cases tempering was not serious and the apparatus was recoverable. However, in 1977, both apparatus placed in the polluted stream were lost before any data was recovered from them. Makeshift apparatus were hastily constructed but these did not serve their purpose well. As a result, the comparison of polluted to unpolluted streams in 1977 yields inconclusive results and the limited comparison done in 1976, initially viewed as a preliminary study, is given more attention.

The problems of variability are related to the complex nature of of the environment. By opting to investigate a more realistic situation, II inherited the complexities attached. What the field biologists gain in realism, we lose in vagueness and generalities. Field studies, like mine, must then rely heavily upon circumstantial evidence and insightful interpretation. To make assumptions in this case would be dangerous and this, I fear, has been done in the past.

Variability is not the only problem limiting the glass slide _in situ_ method for studying periphyton and the effects of environmental contingencies on this specialized algal community. The question as to whether the slide community represents the natural community has arisen recently. Though it would seem reasonable to expect some kind of comparison to the representative community occurring on the natural substrata, very few studies actually report such comparisons (Douglas, 1958). However, some workers have devoted a major portion ot their work to this comparison and to the evaluation of the glass slide method for studying periphyton (Foerster & Schlichting, 1965; Smyth, 1955; Tippet, 1970; Cattaneo et al., 1975). Foerster & Schlichting's study indicated that the flora which developed on the slides was not representative of the natural flora. Tippet reiterated similar conclusions in his report, showing that diatoms colonizing slides differed in seasonal growth from those on natural substrates. However, Cattaneo et al. reported significant similarities between natural and artificial communities. The two studies by Tippet and by Foerster & Schlichting were done in lentic environments, while the study by Cattaneo et al. was carried out in a lotic one. Clearly, more comparisons such as the ones mentioned above must be made if ecologists will be able to separate responses to valid ecological occurrences from artifacts of the method.

When examining slide communities for comparison purposes as in the studies involving pollution, it has been assumed in the past, however dangerously, that the "artifacts" mentioned above are reduced in importance since they affect each test community in the comparison the same way. This assumption is yet to be proven. On the ~~other~~ hand, the studies by Tippet and others have not shown conclusively that such artifacts do exist. The issue is yet to be resolved. I attempt in my work to shed some light upon this matter.

It is hoped that this research will contribute to the general enlightenment of those involved in basic and applied periphyton ecology and to the eventual realization of the potential of the diatometer.

## STUDY SITES

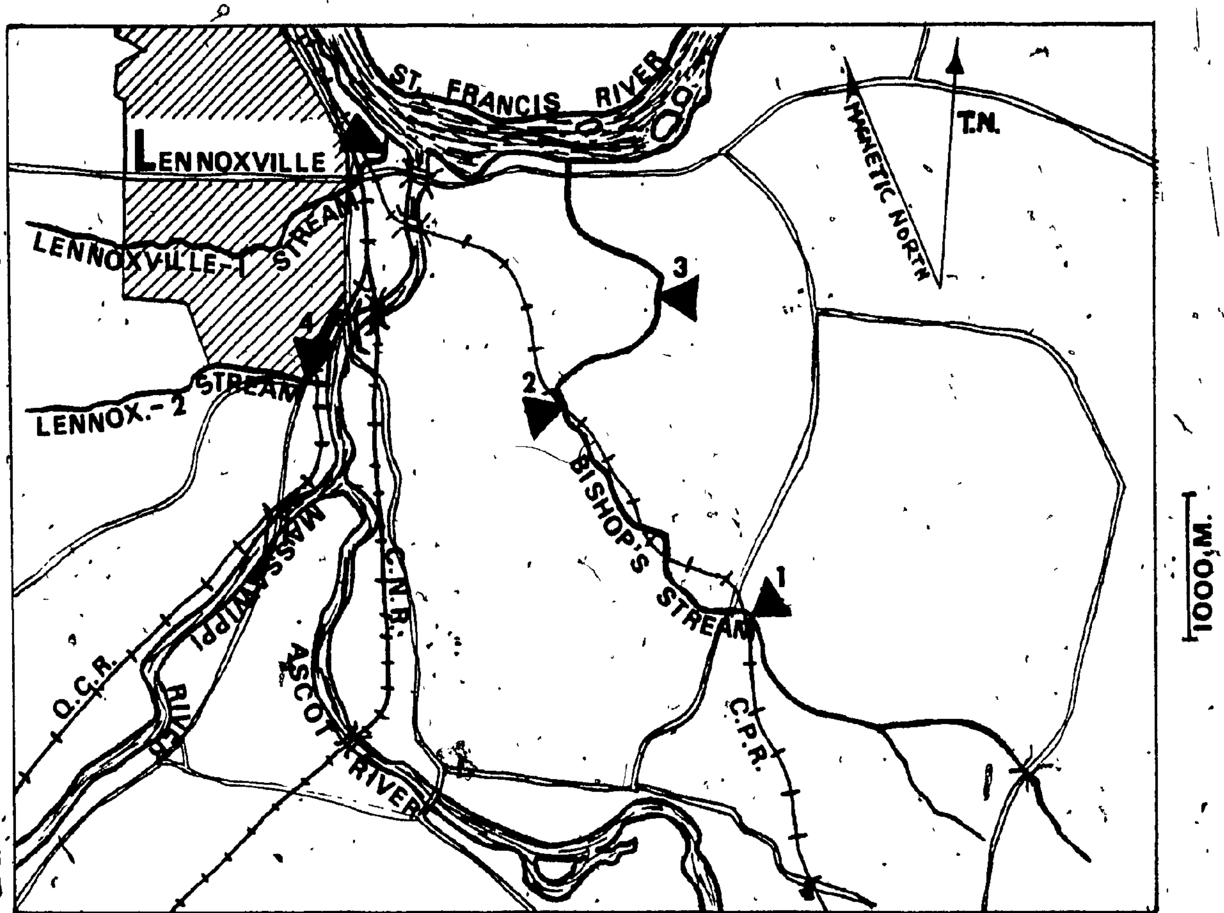
Three streams were examined between Spring 1976 and Fall 1978. These were small stony creeks located within proximity of one another in the Eastern Townships region of Québec near Lennoxville, a small town (Figure 1). Two of the streams flow through the town while the other bypasses it completely. The two streams which run through the town receive various extraneous material, (runoff, sewage, and other miscellaneous effluent), and were therefore considered mildly polluted. The third brook is considered pristine.

Since no names are given to these brooks, I have tentatively named them to avoid confusion: the two Lennoxville streams are simply L-1 and L-2; the third stream, which flows past Bishop's University is called Bishop's Stream. Bishop's Stream is longer than the others.

### a: Bishop's Stream

In its passage from source to mouth, Bishop's Stream flows 5.2 kilometers, originating 725 feet above sea level, before emptying into the Saint Francis River at 500 feet above sea level. The profile of Bishop's Stream can be interpreted from Figure 2. Arising from a natural spring, this turbulent creek averages a width of three meters and a depth of twenty centimeters, (not counting deep pools), in the summer. It is considerably more shallow in the winter. Bishop's Stream froze over completely the end of October of the year 1976 and melted in May of 1977; it froze in November of that year and melted in May, 1978. The brook commonly floods its banks in the spring, rising to more than three times its normal depth. During violent storms floods often occur.

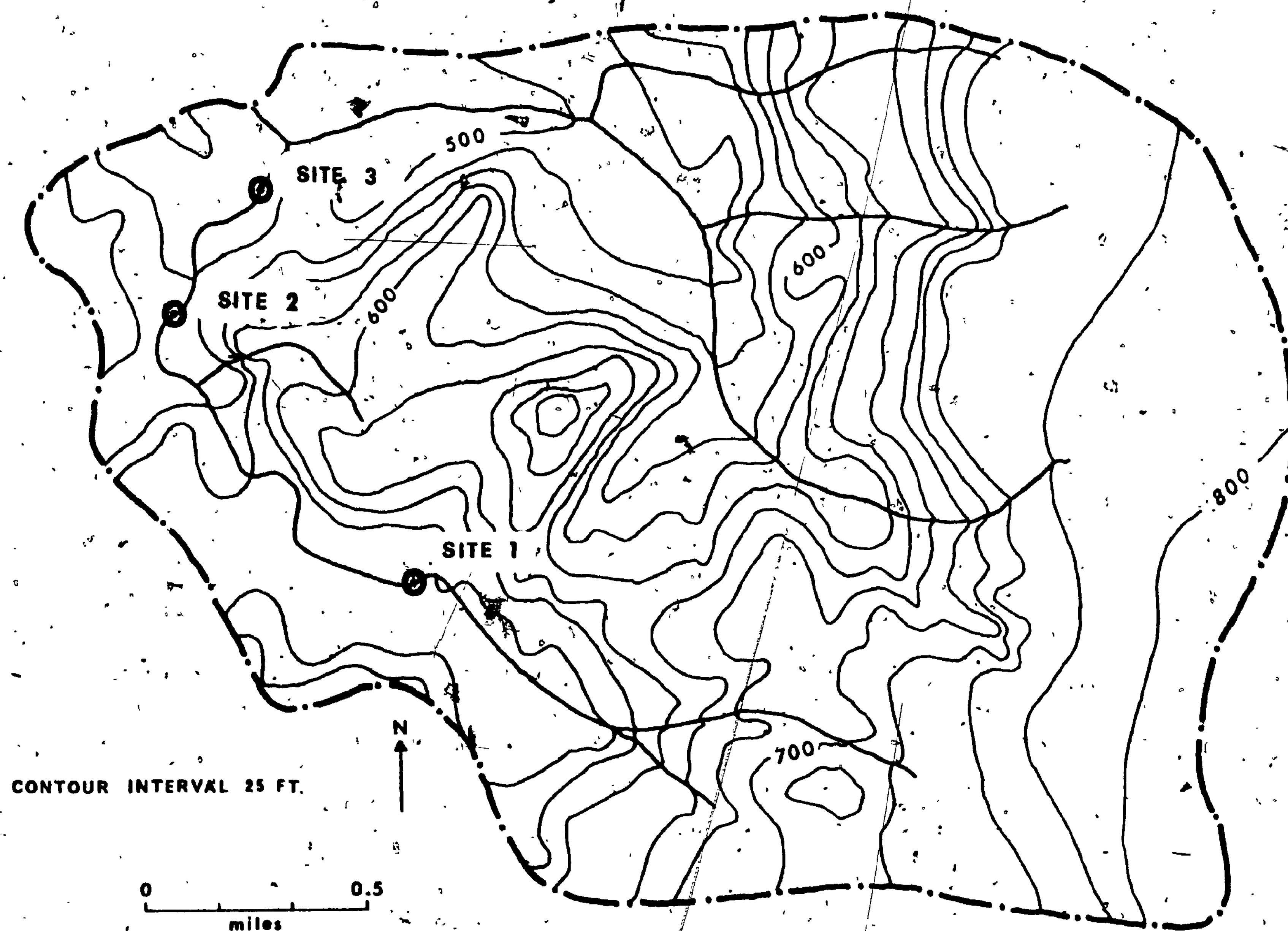
FIGURE 1: Map of the study region. Triangles mark positions of sampling stations.



ST. FRANCIS RIVER
LENNOXVILLE
LENNOXVILLE-1 STREAM
LENNOX.-2 STREAM
MAGNETIC NORTH
T.N.
3
2
1
BISHOP'S STREAM
MASSAWIPPI RIVER
Q.C.R.
C.N.R.
ASCOT RIVER
C.P.R.
1000 M.

FIGURE 2: Topographical map of the drainage basin of Bishop's Stream, showing the three major sampling stations.

# TOPOGRAPHY



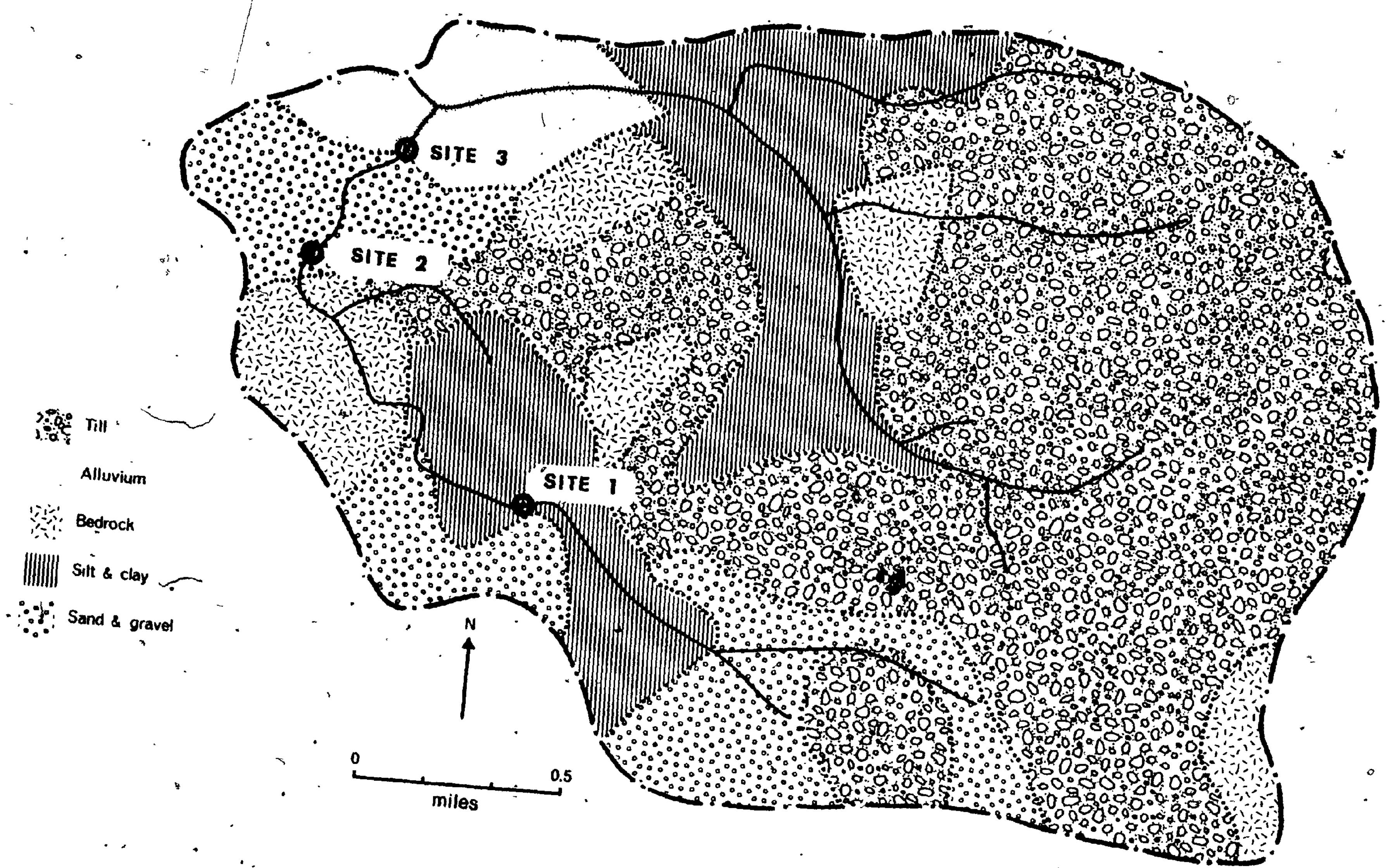
500
600
600
700
800
SITE 1
SITE 2
SITE 3
N
CONTOUR INTERVAL 25 FT.
0
0.5
miles

The rise in water level after heavy rainfall depends not only upon the amount of rain that falls but upon the frequency of rain. If a dry spell occurs prior to a storm much of the water is absorbed by the soil and virtually no difference in water level may be observed. Changes in water level in small streams can occur with rapidity so that in the course of a few hours it is possible that a stream may increase then decrease its flow. The importance of such changes in water level and current will be discussed later.

The drainage area of Bishop's Stream and its tributaries is about sixty-four square kilometers. Its surficial geology consists of a variety of materials (Figure 3). Bishop's Stream originates on a sand and gravel surface, passing over glacial till, silt and clay, bedrock, and finally emptying over alluvium. The glacial till, silt and clay, and sand and gravel were all deposited in the late Pleistocene epoch during the last two glacial phases in the Wisconsin age. The surface till found throughout southeastern Québec is called Lennoxville Till, the youngest deposit, and formed by the Lennoxville Glacier during the late Wisconsin. General properties of Lennoxville Till in the Saint Francis River basin are discussed in detail in the paper by McDonald and Shilts (1970). The silt and clay, sand and gravel deposits are part of the Gayhurst Formation, glacial-lake sediments deposited in Glacial Lake Gayhurst, occupying the upper parts of the Chaudière and St. Francis Rivers, during the time interval between the Chaudière and Lennoxville glacial phases. It represents older deposits of more than 20,000 $C^{14}$ - years B.P. The alluvium, connected with the St. Francis River, is a post-glacial development. It is the youngest of the surficial geology (McDonald & Shilts, 1970; J.D. Booth, personal communication).

FIGURE 3: Map of drainage basin of Bishop's Stream showing surficial geology. Sites 1 to 3 refer to the three major sampling stations.

# SURFICIAL GEOLOGY



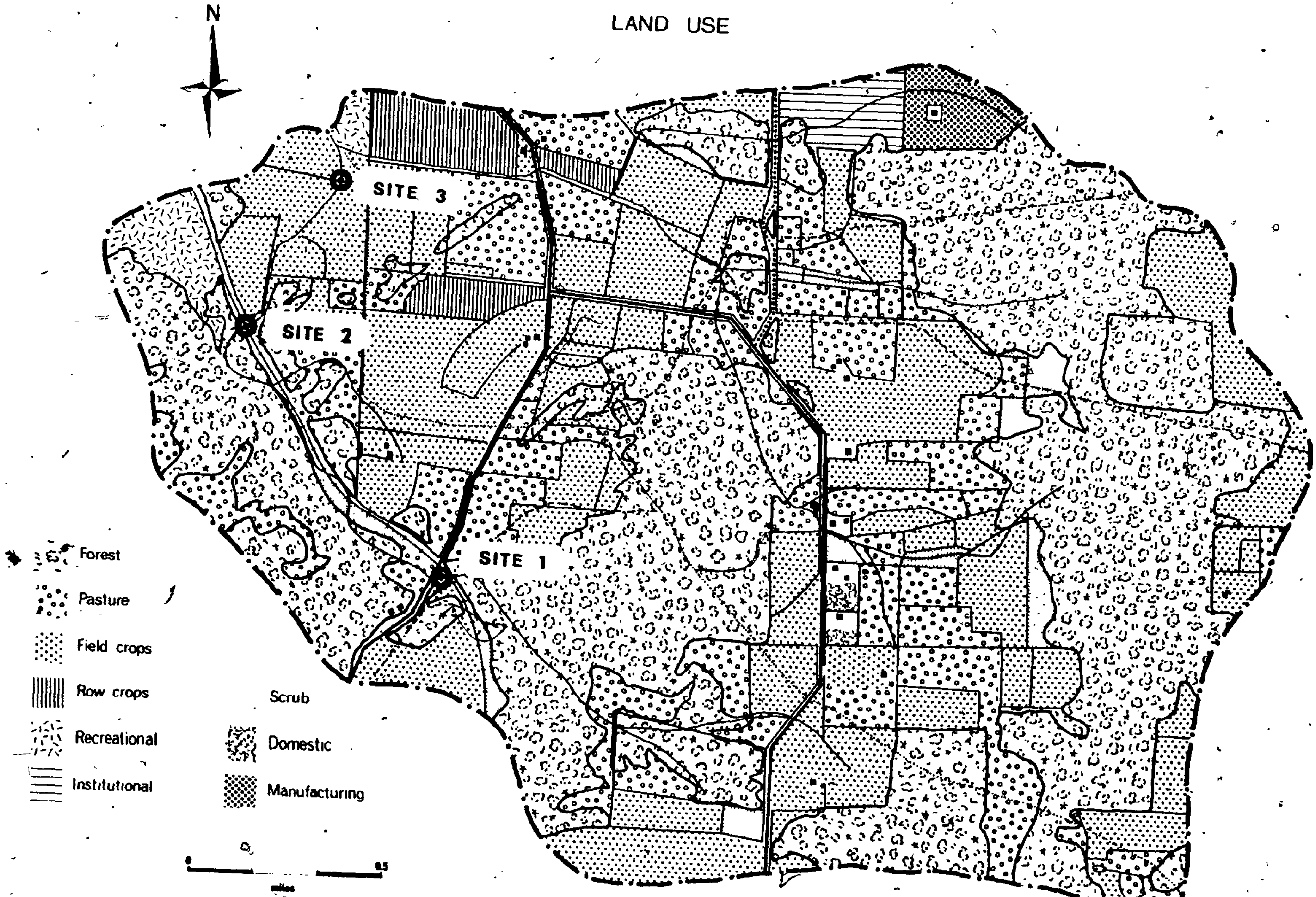
The Bishop's Stream watershed, as well as those of the other two streams, is located in a large region of podzolic soil type (J.D. Booth, personal communication). Podzolization is the principal soil process in climates cold enough to inhibit bacterial action and having sufficient moisture for plants to live easily (Strahler, 1969). Such a climate exists in the whole of eastern Canada. Associated with the growth of conifers which do not make use of calcium, magnesium or potassium ions, podzols are slightly acidic because of the leached out ions. The clay micelles of the podzol have a preponderance of exchangeable $H^-$ ions adsorbed to their surfaces as well as cations Ca, Mg, Na, K. The bound cations are released into the underground water and into streams. Calcium (or magnesium) binds with carbonate from dissociation of carbonic acid to form complexes like $CaCO_3$, increasing the pH accordingly (Reid, 1961; Devlin, 1975).

Figure 4 illustrates land use of the Bishop's Stream watershed from a survey done by J.D. Booth of the geology department at the University of Bishop's in 1973. Figures 2 and 3 are also taken from that survey. Much of the area is not in use and left as forest or scrubland. The stream passes through a considerable amount of forest, representing more than 60% of the area through which Bishop's Stream flows. According to the 1973 survey, the brook's tributaries originate in land used for field crops and forest; they join about a kilometer upstream of Station 1 and pass through pastureland, a great deal of forest, and some scrub and marshy areas; a little downstream of Station 2 the stream enters an area used for field crops. Only minor changes in land use (row crops, field crops and pasture are cycled) occurs from year to year.

Three major sampling stations were selected along the course of the

FIGURE 4: Land use map of Bishop's Stream watershed for 1973.

# LAND USE


N
SITE 3
SITE 2
SITE 1
Forest
Pasture
Field crops
Row crops
Recreational
Institutional
Scrub
Domestic
Manufacturing
0
0.5
miles

brook. Each sampling site consisted of two minor ones, a and b: (a) being a spot in the stream with stony/gravel bottom; and (b) consisting of a clay/silt bed. Subsites a and b of each major sampling station were placed as close to one another as possible. The three major sites were numbered from 1 to 3. Station 1 was closest to the source of the stream; Station 3 was situated nearest the mouth. The order of the sites downstream was: 1a; 1b; 2b; 2a; 3a; 3b.

The first site was placed two kilometers downstream from the source. Subsite a was just downstream of a railway culvert and a relatively large pool, located at the bottom of a steep slope on the north side; a flat meadow around ten meters wide lies between the stream and the slope. The south side of the stream is flat and consists of a scrubby wooded area made up of _Prunus_, _Populus tremuloides_, and _Ulmus_ which serve to shade the stream in the late afternoon. On the immediate banks of the brook grow various herbs and grasses, following a successional pattern as the season progresses. Figure 5 shows the surrounding herbaceous vegetation of Subsite 1a and the five other subsites.

Subsite 1b was located about twenty meters downstream from Subsite 1a. The apparatus holding the glass slides rested on a clay stream bed at the bottom of a steep bank leading to a road.

About 1.5 kilometers further down, the second station was placed just above (2b) and below (2a) a culvert for the Canadian Pacific Railway. Between Site 1 and 2 the brook parallels the railway track, flanked by mixed coniferous forest, after flowing through a swampy area just downstream of Site 1. The second site was situated at the periphery of the forest in an area of grass, bushes and _Ulmus_ trees.

The creek at Subsite 2b is flanked on one side by a steep incline,

FIGURE 5: Prominent bank vegetation lining the stream sites during the growing season of 1977. The dotted lines show the extent of growth for each individual plant.

Site    April    May    June    July    August    September

1a

.......................... grasses ......................................
... Caltha palustris .....
.. Thalictrum dioicum ....
..... Veratrum viride .....
.................. Spiraea latifolia ........
.................... Rubus idaeus ..........
................. Eupatorium maculatum ........
.................... Oenothera biennis ........
....... Impatiens capensis .......
....... Clematis virginiana ......
......Hypericum pyramidatum ......
......... Solidago sp. ...........

1b

.......................... grasses ......................................
... Caltha palustris .....
..... Veratrum viride .....
..... Typha latifolia .....
.... Potentilla recta .....
... Viola papilionacea ...
....... Impatiens capensis .......
....... Clematis virginiana ......
..... Hypericum pyramidatum ......
.......... Solidago sp. .........
.... Thalictrum polygamum ........
.... Sagittaria latifolia ........

2a

.......................... grasses ......................................
..... Zizia aurea ........
... Thalictrum dioicum ...
.......................... Oxalis europaea ...............................
............. Equisetum arvense .................................
.... Veratrum viride ......
............. Rubus allegheniensis .......................
............... Solanum dulcamara .........................
.......... Vicia cracea ..............
.... Apocynum medium .......
....... Eupatorium maculatum .....
.......... Galium alprellum .......
........ Impatiens capensis ......
........ Clematis virginiana .....
............ Solidago sp. ........

.......................... grasses ......................................
....... Eupatorium maculatum .....
........ Impatiens capensis ......
........ Clematis virginiana .....
...... Thalictrum polygamum ......
........... Solidago sp. .........

FIGURE 5: Continued.

April May June July August September

.............................. grasses ..................................

.................... Vicia craacas ........................

............. Rubus idaeus .....................

............. Cirsum sp. ......................

.. Geum virginianum ..

........ Impatiens capensis ......

.............................. grasses ..................................

............. Apocynum medium .................

....... Eupatorium maculatum .....

....... Galium asperellum ........

.......... Solidago sp. ..........

thick with grasses and briars. Close by, the entrance to a ground hog burrow opens over the stream. The other side of the stream consists of forest: Picea; Abies balsamea; Populus; and Acer. Immediate to the bank grows an Alnus rugosa and some Prunus bushes. This subsite is well shaded most of the day by the steep bank and overhanging shrubs. Herbs lining the banks are given in Figure 5.

Subsite 2a was situated below the culvert after a deep pool which was created in the fall of 1976 by a large scouring flood. In many respects this subsite is very similar to Subsite 1a. Both banks at Subsite 2a are rather steep and made up chiefly of grasses and herbs. A few Prunus shrubs and a hawthorn stand on the summit of the northern slope.

Just below Subsite 2a a fence is drawn across the stream, forming the border line between the C.P.R. property and farmland. Here, just meters downstream of the site, cows occasionally graze and drink the water.

The third station was placed a kilometer further downstream. Between Site 2 and Site 3, the brook runs through grassy fields harvested for hay in August by the Experimental Farm run by Environment Canada. A section of this field was used in 1977 for a large crop of corn.

The banks on either side of the brook are quite steep all along the stream from Site 2 onward. As in all the other sites, with the exception of Subsite 2b, the third station received direct sunlight until mid to late afternoon when the banks themselves shaded the stream.

Subsite 3a, like 2a and 1a before it, was located downstream from a culvert. Subsite 3a was situated a few meters from the culvert at the entrance to a large deep pool. On the eastern bank of the stream bolders and ground hog homes abound. The fields house many burrows of small rodents: voles; weasels; field mice; chipmunks; ground hogs; and shrews. The west bank of the stream where Subsite 3a was located is covered with brambles and other shrubery.

Several meters below Subsite 3a, Subsite 3b was chosen for a clay surface. The banks at the muddy subsite are mostly mud and grass, but some herbaceous vegetation grows a little further back.

Though each site was carefully chosen to appear as similar to the other sites as possible, some disparity was unavoidable.

b: Lennoxville Streams, L-1 and L-2

I began my study in 1976 using only two sites (due to equipment loss); one site was located near the mouth of L-1 (see Figure 1) and the other site was situated in Bishop's Stream just upstream of 2a where now a deep pool about a meter deep has existed since August 1976. Subsequent to that date, the apparatus was placed exactly where 2a is presently located. The 1976-77 study was strictly a comparison of periphyton communities between two streams, one organically enriched (L-1), and the other pristine (Bishop's Stream). It was conceived as a preliminary study to be later augmented by more complex ecological research.

Before a new sewage construction plan changed the course of L-1, it originated from a spring in mixed coniferous forest and passed through the outskirts of the city, flowing in backwood areas behind houses where it received some sewage from neighbouring septic tanks during heavy rainfall and flooding (Mr. Gervais, City Planning, City Hall, Lennoxville). When the stream reached a residential street in a densely populated region, it went underground. It emerged after passing through and receiving effluent from an electric plating factory, Union Screen Plate, to run along the C.N.R. and C.P.R. tracks, past the gas station, before entering a fifty meter long culvert. Upon emerging, it flowed along some houses then beneath a main road and behind more houses until it finally emptied into the St. Francis River. Occasionally oil, gasoline and tar from the gas station, Union Screen Plate, and the railroad yard formed an irridescent film on the surface of the water. Tar from the latter source collected at the bottom, covering rocks with a resinous coating and mixing with the silt and clay to form a sticky sludge. Organic loading from non-point sources such as leaf fall, runoff from the roads and miscellaneous dumping from the private sector was considerable at times.

Though the main outflow of Union Screen Plate was diverted into the primitive sewage system of Lennoxville, which empties into the Massawippi and St. Francis Rivers, some effluent was dumped periodically into the creek meant only for surface drainage (Mr. Gervais, City Hall) in the form of phosphoric acid (45% by volume) and sulfuric acid (41% by volume), totalling an annual average of 100 gallons (Mr. Oill, General manager/ Excecutive Vice President of U.S.P., personal communication). This dumping accounts for the low pH (6.0) found intermittantly during chemical testing. Evidence of further dumping was found and it was assumed that traces of heavy metal ions, lubricants, and the acids used in the plating may have entered the stream at that time.

The site selected for study in early May of 1976 was just downstream of a culvert under the main road on a gravel/silt bed. Light was greatly diminished by Ulmus and Acer negundo and other vegetation. In mid July another site was found upstream of the culvert. Though access to it was greatly hindered, light conditions were closer to those found at the Bishop's Stream site. The bottom surface was similar (stony/gravel) to the bottom surface of Bishop's Stream, though the L-1 site was littered with garbage: rusted cans; broken tools; and similar household and general jetsam.

In Spring 1977 the first stage of the new sewage system of Lennoxville was implemented. It involved diverting L-1 at the Union Screen Plate factory to flow into an underground culvert straight to the Massawippi River at the site of the old sewage outlet. The old system had been taking surface and sanitary waters with the same pipes, canalizing these waters to the two rivers passing through the town by the use of eight main pipes and numerous small creeks whose dubious contents could be called anything but wholesome. Ultimately, the purpose of all surface and sanitary canalization is to build a water treatment plant (Côté, Lemieux, Carignan & Royer, 1964; Mr. Gervais, personal communication).

Plans for an extensive comparison study including above and below the Union Screen Plate outflow were discontinued and another polluted stream was found.

L-2 is located at the south side of Lennoxville, close to where a new housing development has begun. L-2 flows approximately one kilometer (Figure 1). It originates in mixed coniferous forest and flows a considerable distance through it before seeing signs of civilization. Reaching the outskirts of Lennoxville, the creek follows a dirt road and is eventually diverted into the gully along the road. It passes a utility and welding shop before reaching a culvert to the main south-bound highway. It exits from the culvert into a deep ravine where two pipes for sanitary and surface runoff were laid. The outlets empty some eighty meters downstream of the highway culvert just upstream of the Quebec Railway tracks. The first site was located several meters upstream of of the outlets. The second site was located just downstream of the culvert for the Quebec Railway track before the stream empties into the Massawippi. Presumably, some backwash from the river, especially during flooding in storm weather, affected the slide community there by diluting the effluent from the pipes of L-2 or by introducing organisms and other materials from the river.

L-2 is a stony creek, averaging a width of six meters with a highly variable depth. Both sites were located in open areas and received close to the maximum sunlight.

The site above the sewage outlets, coded 4a, was situated on a stony bottom. Bank vegetation at the site is given in Figure 5. Site 4b, located below the outlets, was on a gravelly surface. The banks of the stream at 4b are of stone and mud. Grass grows much further back. The entire portion of the stream below the culvert to the highway is heavily littered with various discarded articles from bricks to parts of cars. A great deal of garbage from domestic origin settled on the apparatus at both sites, particularly the one located at Site 4b.

## METHODS

### a: Sampling Methods

Sampling using artificial substrate: A plexiglass apparatus was designed to hold glass slides which served as the artificial substrate for colonizing algae. In many respects the device resembles Patrick's diatometer (Patrick, Hohn and Wallace, 1954). See Figure 6A.

Slides were held in a vertical position, edgewise to the current, to minimize settling of various abiotic material brought in by the current. Horizontal substrata collect a great deal of seston such as decaying plankton, detritus, stirred up mud and other debris (Sladeckova, 1962). Newcombe (1949) discovered that the accumulation of organic matter on horizontally placed slides was 6.6 times greater than on vertical ones. Harper and Harper (1967) found that stationary diatoms adhered more strongly to vertical slides than to horizontal ones. This suggests that, although a smaller periphyton population will attach to vertical slides, the community will not consist of pseudo-periphyton, plankton and excess tripton.

The slide chamber was constructed of transparent material to reduce light extinction. Each apparatus also contained a nylon screening, mesh size of 1.5 mm., ten centimeters in front of the slide chamber to deflect most of the large detrital material and to allow the current to pass freely.

The apparatus was laid directly on the bottom of the stream and secured with chains and foot-long nails driven into the muddy or gravel bed. Piping 1 cm. in diameter and 1.5 meters long extended from the device and weights were placed over or tied to the ends as added ballast.

FIGURE 6: Plexiglass apparatus with slide chamber designed to hold slides edge-wise to the current. A is the apparatus used in the 1977-1978 experiments; B is the device used in the 1976-1977 experiments.

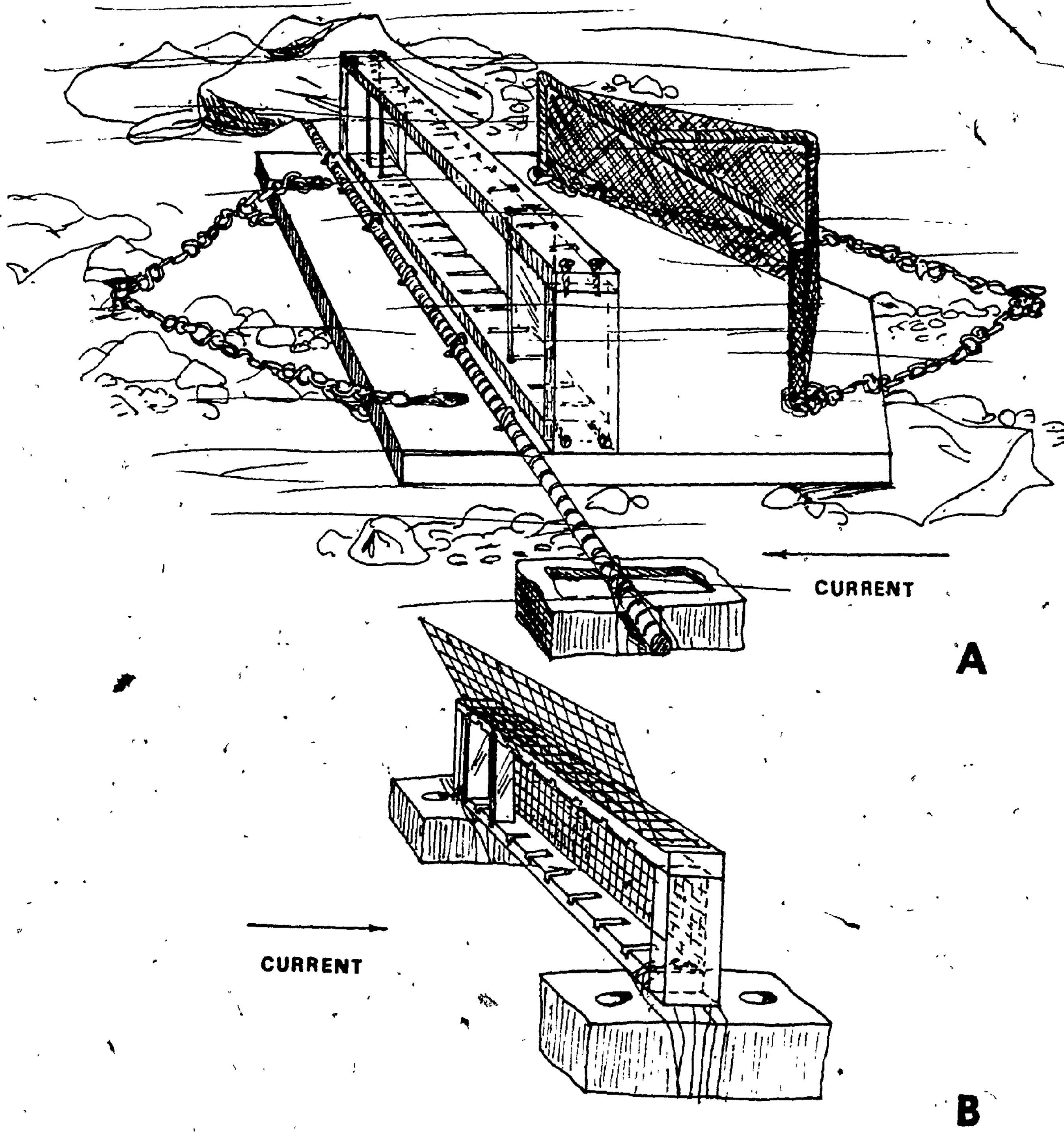

CURRENT
A
CURRENT
B

Figure 6B shows the device used in 1976, resembling Bissonette's original slide rack (1930). This apparatus was found unsuitable for the rapid creeks.

Slides were immersed in 1976 for 1, 2, 3, and 4 week intervals and in 1977 for 2, 4, and 6 weeks; intervals followed a staggered time sequence like that of Brown & Austin (1973) and Cattaneo et al. (1975). This procedure was followed for two reasons: to enable one to look at various stages of colonization at any one time and to better evaluate short term effects; and to separate changes caused by envirnmental contingencies from those elicited by seasonal succession. Table 1 gives the schedule of the 1976 and 1977 experiments. Slides were coded according to Figure 7.

Winter samples were taken every month whenever possible.

From each major sampling site ( of which there were two in 1976 and four in 1977) slides were collected, a minimum of 4 each time in 1976 and 6 (3 per subsite) in 1977, every week (1976) or two weeks (1977), placed into individual coplin jars to keep grazers of one slide away from other slides, and carried in their natural water back to the laboratory which was from 15 to 60 minutes away.

In 1977 a separate collection day was designated for each station. Sampling of the four sites, though not carried out on the same day, was made at the same time of day. The schedule remained consistent; that is, Tuesday would always be a collection day for Site 3, Wednesday for Site 2, and so on. As stated before, in 1977 each site consisted of two subsites with three series in progress at any one time, therefore a total of 6 slides was collected from each station on a sampling day (Table 1).

On several occasions throughout the 1977 season extra slides were

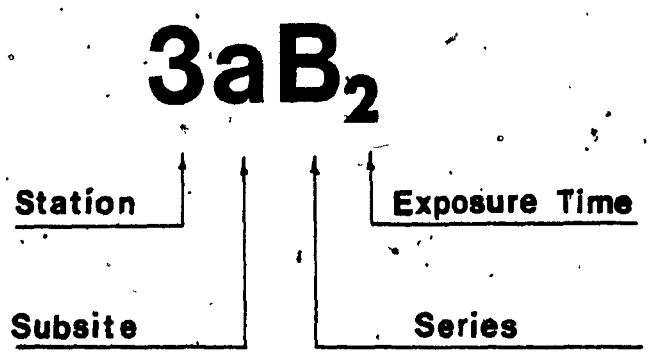
TABLE 1a: Schedule of the 1977 experiment for Station 2. Initiation and collection dates for Station 1 and Station 3 are precisely a day after and a day before those shown for Station 2 respectively. Initiation and collection dates for Station 4 were precisely two days after the dates for Station 2. The capital letters refer to the series (when the slides were initiated); the numerical subscripts give the three lengths of time each slide was submerged (refer to Figure 7).

| Date of Collection | Date when slide was placed in stream | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 03/05 | 19/05 | 02/06 | 16/06 | 30/06 | 14/07 | 28/07 | 11/08 | 25/08 | 08/09 | 01/10 | 29/10 |
| 19/05 | $A_1$ | | | | | | | | | | | |
| 02/06 | $A_2$ | $B_1$ | | | | | | | | | | |
| 16/06 | $A_3$ | $B_2$ | $C_1$ | | | | | | | | | |
| 30/06 | | $B_3$ | $C_2$ | $D_1$ | | | | | | | | |
| 14/07 | | | $C_3$ | $D_2$ | $E_1$ | | | | | | | |
| 28/07 | | | | $D_3$ | $E_2$ | $F_1$ | | | | | | |
| 11/08 | | | | | $E_3$ | $F_2$ | $G_1$ | | | | | |
| 25/08 | | | | | | $F_3$ | $G_2$ | $H_1$ | | | | |
| 08/09 | | | | | | | | - | - | | | |
| 01/10 | | | | | | | | - | - | $I_2$ | | |
| 29/10 | | | | | | | | | - | | $J_2$ | |
| 03/12 | | | | | | | | | | | | $K_2$ |

TABLE 1b: Schedule of 1976 experiment using Bishop's Stream and L-1. Slides from each stream were sampled on the same day. Capital letters refer to the series (when the slides were immersed); the numerical subscripts indicate the number of weeks each slide was submerged.

| Date of Collection | Date of Immersion | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 25/05 | 01/06 | 08/06 | 15/06 | 18/06 | 29/06 | 06/07 | 13/07 | 20/07 | 27/07 | 03/08 |
| 01/06 | $A_1$ | | | | | | | | | | |
| 08/06 | $A_2$ | $B_1$ | | | | | | | | | |
| 15/06 | $A_3$ | $B_2$ | $C_1$ | | | | | | | | |
| 18/06 | $A_4$ | $B_3$ | $C_2$ | $D_1$ | | | | | | | |
| 29/06 | | $B_4$ | $C_3$ | $D_2$ | $E_1$ | | | | | | |
| 06/07 | | | $C_4$ | $D_3$ | $E_2$ | $F_1$ | | | | | |
| 13/07 | | | | $D_4$ | $E_3$ | $F_2$ | $G_1$ | | | | |
| 20/07 | | | | | $E_4$ | $F_3$ | $G_2$ | $H_1$ | | | |
| 27/07 | | | | | | $F_4$ | $G_3$ | $H_2$ | $I_1$ | | |
| 03/08 | | | | | | | $F_4$ | $H_3$ | $I_2$ | $J_1$ | |
| 10/08 | | | | | | | | $H_4$ | $I_3$ | $J_2$ | $K_1$ |

FIGURE 7: In 1977 each slide was coded according to major sampling station (1, 2, or 3); subsite (a -- rocky, or b -- muddy); series (initiation time); and length of time submerged (1=2 weeks; 2=4 weeks; 3=6 weeks). In 1976 slides were coded according to Stream; series; and colonization time (1, 2, 3, and 4 weeks).


$3aB_2$
Station
Subsite
Series
Exposure Time

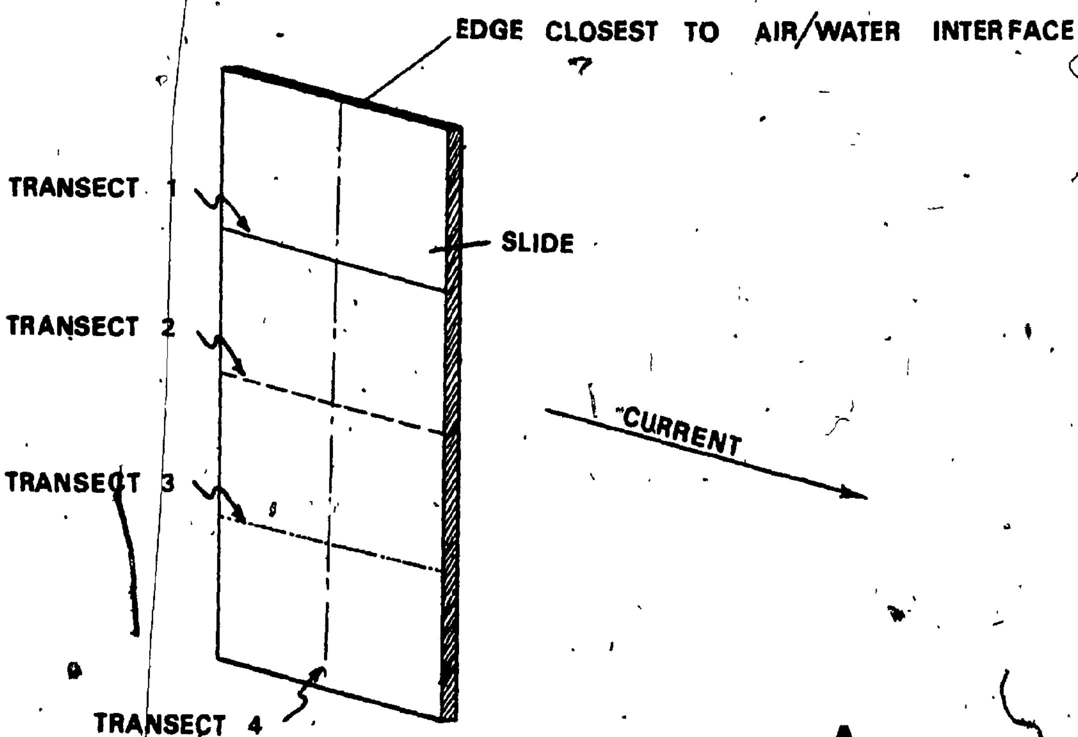
collected from various locations in the slide chamber (eg. edge of the chamber vs. middle) and the community composition was assessed to measure variability within the same apparatus. Random replication was also carried out. Partially frosted slides were used in a separate experiment to ascertain any partiality to surface type.

In the fall of 1978 two experiments were done using apparatus at Subsite 2b of Bishop's Stream to assess the affects of current on spatial micro-distribution of the diatom community settling on the slides. The slides were oriented edgewise and normal to the current. Using the prepared slides of Bishop's Stream from the 1977 and 1978 experiments, four transects were chosen systematically (see Figure 8a); each transect contained nine designated fields from one edge of the slide to the other. The first three transects were through the width of the slide; the fourth transect was taken along the length.

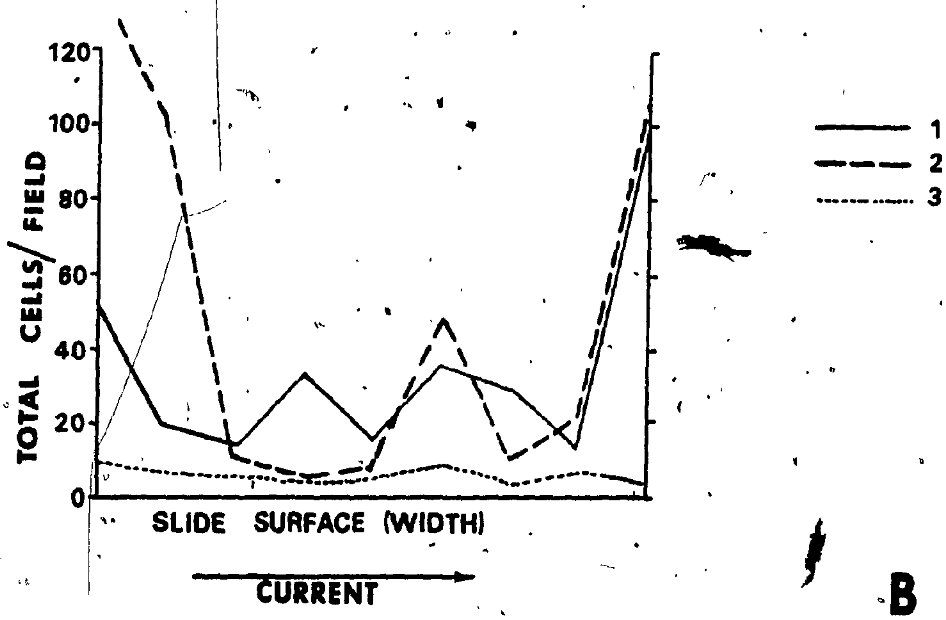
Data from Transects 1 to 3 were not pooled due to the high variation among them. It was found that trends could more easily be seen when the transects were looked at individually. Graphs such as the one in Figure 8b are used to show diatom micro-distribution patterns across the width of the slide. Since, with the exception of the slide facing the current in the 1978 experiment, all the slides were oriented edgewise to the current, the origin of the abscissa represents the upstream edge of the slide. The downstream edge is on the far right of the graph. The nine discrete counts along each transect are joined to show trend.

Sampling of stones and rocks: Along with the slide collection, scrapings from stones were taken for epilithic algae, because the periphyton of these watercourses was represented mainly by such algae.

FIGURE 8: Illustration of the slide showing A -- how the four transects are taken on the slide; and B -- how the three transects across the width of the slide are graphically portrayed.


EDGE CLOSEST TO AIR/WATER INTERFACE
TRANSECT 1
SLIDE
TRANSECT 2
TRANSECT 3
CURRENT
TRANSECT 4

A


120
100
80
60
40
20
0
TOTAL CELLS/FIELD
SLIDE SURFACE (WIDTH)
CURRENT
1
2
3

B

Sampling locations were determined by throwing a shiny object into the brook and sampling the stone on or beside which it rested. Algae were scraped off using a razer blade and put into 4-dram vials, along with the water from the stream.

Fauna were also collected monthly in 1976 and bi-weekly in 1977. Five rocks of varying sizes (10 to 30 cm. in diameter) were checked, organisms noted, counted, and representatives collected in their natural water in 6-dram vials. All samples were brought back to the laboratory unpreserved and alive. These were preserved in 70% ethanol pending further identification.

Information on the fauna representative of different areas of Bishop's Stream was also provided by a report submitted in 1978 by Ben Corey, research assistant to Dr. Hilton, Entomologist at Bishop's University.

Each time the sampling stations were visited, a general observation was made. Clumped blooms of green and blue-green algae were especially noted and samples were taken back to the laboratory. Any obvious changes relevant to the stream site such as dumping, a fallen tree or a change in the stream bed from a scouring flood, were recorded.

### b: Counting and Identification

Slides from apparatus: In the laboratory slides were removed from the coplin jars and first examined under a dissecting microscope. Large objects such as fauna and large filamentous algae were noted. The slides were then examined under a Leitz compound microscope and smaller objects were scanned. Fresh counts of algae were done at 400x magnification using an occular Whipple grid. Identification of the Chlorophyta, Cyanophyta and some of the Chrysophyta was facilitated by a number of keys, the important ones being: Prescott (1962); Smith (1950); Drouet (1968).

Because 80 to 99% of the biomass of the periphyton on the slides consisted of the Bacillariophyceae (diatoms), additional procedures were necessary to prepare for identification and counting purposes. A combination of two methods was employed to clean the frustules so they could be identified to species.

An improvised version of the acid treatment outlined in Patrick & Reimer (1966) was used for the initial stage of cleaning. Frustules were cleaned without being scraped off the slide.

Water with a few drops of nitric acid concentrate was warmed and the ethanol-treated slides were placed in the beakers containing the heated solution. Potassium di-chromate which dissolves organic matter was added. The slides were left in the cleaning mixture for several hours until the layer of frustules turned completely white and most of the organic residue was gone. The slides were rinsed through two changes of distilled water, then one of absolute alcohol and dried on a hot plate.

The second stage involved complete removal of organic debris and dries the slide further. The slide was passed over a hot flame until the frustules and debris turned black then white as the remaining organic residue was burned away, leaving only the silicious frustules. The end result was a slide with sharp and clean diatom cells of high resolution (H.L. Smith, in Van Heurck, 1896).

Once the flaming was done, the slides were allowed to cool and were mounted in Hyrax using #1.0 thickness coverslips 55 x 22 mm.

Fifty random counts at x640 on a Zeiss photomicroscope were made.

The fresh counts done earlier revealed that live frustules represented 90 to 100% of the population on the slide. Presumably dead frustules sloughed off the slide in the current. Identification of diatroms was made to species at x1600 magnification. Useful keys were Hustedt (1930); Patrick & Reimer (vol. I, 1966; vol. II, 1972); Van Cleve-Euler (1951); and Van Heurck (1896). Some of the identifications were supervised by A. Cattaneo, periphyton ecologist at McGill University.

Rock samples: These were analyzed qualitatively. Collected periphyton scraped from the rocks was analyzed; both algae and fauna were recorded. In 1977 a subsample of the mixture which included diatoms, larger algae, fauna and much organic debris was taken and treated in the following way to separate the diatoms from the remaining mixture:

The subsample was placed in a small vial. Three or four milliters of distilled water and a few drops of 95% ethanol were added. The vial was shaken vigorously then swirled and left standing, allowing the heavier particles to settle. This left a filmy suspension mainly of diatoms. The suspension was pipetted out by a dropper and put into another vial. The diatoms were allowed to settle overnight, the supernatant decanted and the almost pure batch of diatoms placed on a slide, incinerated and mounted in Hyrax using #0.0 thickness coverslips. This procedure produced an almost pure collection of diatoms with little extraneous material except for those samples taken from muddy subsites where the smaller sand particles could not be filtered out without losing a major portion of the diatom population. Loss of diatoms during the course of the treatment was checked and found to be insignificant.

Diatoms were identified on the Zeiss photomicroscope at magnification x1600 and compared qualitatively to the slide communities.

Fauna collected from the rocks as well as the grazers from the slides were identified usually to the genus. Ephemeroptera were identified using Leonard (1961); Plecoptera with Chu (1949); Trichoptera with Wiggens (1977); Diptera using Johannsen (1933); and other miscellaneous invertebrates with Ward & Whipple (1958) and Pennak (1953).

### c: Chemical Analysis

Analysis of the chemistry of the water was performed weekly in 1976 and every two weeks, precisely a week between the fauna and flora sampling weeks, in 1977. The same schedule for testing sites was used as that for sampling the biota. Most of the tests were done in situ, using LaMotte chemical kits #AM-22 and AM-23. For other tests, done in the laboratory, samples of the water were taken back in small glass jars. Tests were performed from 30 to 60 minutes following the removal of the water from the stream. The following chemical factors were assessed:

Dissolved oxygen — using Winkler's titration method.

Nitrate -- by colorimetric estimation using diphenylamine in concentrated sulphuric acid.

Sulphide — by colorimetric estimation using a reaction of sulphide in the presence of hydrochloric acid and oxidizing agent, ferric chloride, with p-aminodimethylaniline hydrochloride to produce the dye methylene blue.

Sulphate — based on the precipitation of benzidrine sulphate followed by the titration of the washed precipitate with standard sodium hydroxide using phenolphthalein as the indicator.

Alkalinity (bicarbonate, normal carbonate and hydroxide) — by titration with indicators, phenolphthalein and Bromcresol Green-Methyl Red, and titrator, 0.02N sulphuric acid.

Free carbon dioxide — by titration with standard sodium hydroxide in the presence of phenophthalein.

Chloride — by titrating potassium chromate indicator with silver nitrate.

Fluoride — by colorimetric estimation using acid zirconium-alizarin and aluminum salt.

Total hardness -- by titration using a standard solution of EDTA in the presence of Eriochrome Black T and Borate Buffer.

Calcium hardness -- by titration with EDTA, using sodium hydroxide as buffer and Murexide indicator.

Ammonia — by colorimetric determination using Nessler's Reagent (a solution of potassium mercuri-iodide in excess of potassium hydroxide) and a stabilizer, Rochelle salt (sodium potassium tartrate), which prevents the precipitation of residual calcium and magnesium ions in the alkaline Nessler's Reagent.

Phosphate — by colorimetric determination through a reaction of ammonium vanadate-molybdate in sulphuric acid solution with stannous chloride.

Silica — by colorimetric estimation using hydrochloric acid; ammonium molybdate,which reacts with both silica and phosphate to form molybdophosphoric acid and molybdosicilic acid; oxalic acid to selectively destroy the molybdophosphoric acid; and reducing agent stannous chloride.

pH — by colorimetric determination using wide range indicator solution: phenolphthalein; bromthymol blue; methyl red; and dinitrophenol. A pH meter was also used.

Manganese -- by colorimetric determination following a reaction initiated by phosphoric acid, silver nitrate, mercuric sulphate, nitric acid solution and ammonium persulphate.

d: Other Environmental Factors

During the time that chemical tests were performed a number of physical factors were assessed:

Turbidity -- by visual comparison using turbidity tubes and standard suspension of Fuller's Earth equal to 500 Jackson Turbidity Units (jtu) which are arbitrary units fixed in relation to a standard Jackson candle turbimeter.

Color -- by visual comparison using color tubes and platinum cobalt solution. The color is expressed in terms of the Hazen standard unit which is the color given by one ppm of cobaltous chloride hexahydrate.

Temperature -- with a mercury thermometer.

Stream velocity -- by using a calibrated line with a float attached to one end. Small floating objects were placed in the water at the upstream end of the line, held by the author, and allowed to drift down till the end of the calibrated line was reached, then the time was logged. A current meter was also used on several occasions.

Stream depth and width -- using a calibrated line and a meter stick.

Light -- was not qualitatively measured. Only subjective observations were made. The length of direct sunlight received by each site was assessed.

Weather conditions -- with the aid of daily summaries made by the meteorological department of Environment Canada. The weather assessments were done at the Experimental Farm located within five kilometers of the farthest site. I made separate temperature readings during visits to the sites.

## e. Statistical Analysis

The data from the 1977 and 1978 experiments was subjected to parametric and nonparametric statistical tests.

Diversity and total numbers of sampled populations from each slide were evaluated and analysis of variance was carried out. However, because the distribution of the populations were negatively binomial with an average k-value of 2, normalization by log conversion was carried out on the data to produce a normal distribution so that parametric statistics could be performed (Elliott, 1971).

Nonparametric statistics such as the Wilcoxon Signed Ranks Test and the Spearman Correlation Analysis (Conover, 1971) were used on the twenty prominent diatoms to test similarities of populations on the slides.

The Wilcoxon test pairs two sets of observations to see if they have the same median by matching the same species from the two sets of data and by using ranks.

The Spearman Correlation coefficient is used here as a test statistic for independance. The alternative hypothesis of the one-tailed test for positive correlation is that there is a tendancy for the larger values of X to be paired with the larger values of Y (in this case the same species). While the Wilcoxon test provides information on the differences between each matched pair of the same species, the Spearman Rho examines the degree of similarity between each species within one community as contrasted with differences between the two matched communities.

# RESULTS AND ANALYSIS

## a: Chemical and Physical Characteristics of the Streams

Seasonal and yearly variation:

Monthly figures for total sunshine, rainfall, and average temperature recorded by Environment Canada for the 1976 and 1977 seasons are given in Appendix I, Table 1. These figures are compared to the standard numbers calculated by Environment Canada for the immediate region.

Comparison of 1976 and 1977 with the normal figures reveals that rainfall in 1976 exceeded normal rainfall by close to double; 1977 received much less than the average rainfall. With the exception of May, 1977 did not receive more sunshine than usual. Temperature for both years were similar and closely approximated the normal values.

Scouring floods were recorded on the following days in 1976: May 18; June 4; 8; 16; 21*; 25*; 26*; 30; July 1*; 2; 7*; 8; 27*; 31; August 1*; 2; 10*; 11*; 13; 15*; 16. Scouring floods were recorded on these days in 1977: June 21; July 14; 31; August 10; 14. Between September 1976 and April 1977 no record was kept of water dynamics. Dates marked with an asterisk represent particularly violent storms. The floods recorded in 1977 were small and short lived and did not affect stream bottom to a great extent. However, their effect on stream biota can not be ignored.

Tables 2 to 16 (Appendix I) present the results of chemical and physical tests performed weekly on water from Bishop's Stream (Site 2a) and Lennoxville-One Stream (L-1) in 1976 and biweekly on water from Bishop's Stream and L-2 in 1977.

Tables 2 and 3 from Appendix I show the average and standard deviation of each tested parameter for 1976 and 1977. Most of the chemical characteristics remain consistent throughout each season. Physical parameters varied considerably as did certain chemical factors directly associated with the physics of the water.

Inter-Stream Variation:

I. Comparison of Bishop's Stream with L-1 (1976) --

Tables 4 through 8 of Appendix I present weekly data on the chemical and physical characteristics of the water at Site 2a of Bishop's Stream and L-1 for 1976. Of the parameters tested only a few differ markedly between Bishop's Stream and L-1. Free carbon dioxide in L-1 exceeds that found in Bishop's Stream, though a high variation exists. Total hardness is consistently higher in L-1. In both streams total hardness usually exceeds values for total alkalinity, indicating the presence of noncarbonate sources of hardness such as chloride or sulphate ions. I consider L-1 a hard-water stream and classify Bishop's Stream as slightly hard (Klein, 1959). Both streams are spring runoffs on a sedimentary geological region. Calcium content of L-1 approximates that found in a spring issuing from limestone (Reid, 1961), though the high carbonate hardness may be due to organic pollution.

Chloride content is far higher in L-1, varying from two to five times that found in Bishop's Stream. The chloride content in L-1 approximates that for deep well water and that found in weak sewage (Klein, 1959).

Bishop's Stream contains too little phosphate to be measurable by the method used (sensitivity of 0.1 mg./1). The phosphate in the water of L-1 reads consistently near the limit and upon a few occasions at 1.0 and 1.5 mg./1. Nitrate also shows readings close to 0.1 mg./1 (the limit of the measuring kit) throughout the season in L-1, while no trace is found in Bishop's Stream at any time.

Weekly records indicate that L-1 and Bishop's Stream have similar temperatures throughout the year. However, during periodic visits to the streams, I discovered that, while Bishop's Stream remained with ice cover throughout the winter (with the exception of a partial January melt), L-1 was often without ice cover, steamy, turbid and oily. Whether this condition reflects a thermal change or a chemical change (from salt run-off) in the water of L-1, dumping of some kind is evident.

Turbidity is slightly higher in L-1. Alkalinity, despite the high variation, shows slightly higher values in L-1 than Bishop's Stream. The pH, which hovers on the alkaline side of neutral, varies much more in L-1 (see Table 2, Appendix I).

II. Comparison of Stations in Bishop's Stream and L-2 (1977) --

Table 3 and Tables 9 to 16 in Appendix I show that variation from station to station of Bishop's Stream water is slight, and most parameters indicate the stream to be rather uniform along the reach tested.

Silica declines consistently from source to mouth while turbidity and color increase. The increase of turbidity and color is an obvious result of silt-loading from the banks and accumulation of suspended particles along the length of the stream.

Carbon dioxide is consistently higher at muddy (b) subsites. Current is generally slower at muddy subsites, though Station 2 evinces identical velocities for both subsites.

The variation in water chemistry and physics from station to station in Bishop's Stream is less than that shown for the same station during two consecutive years. This may be seen by comparing Site 2a of Table 3 from Appendix I to Bishop's Stream (same site) of Table 2 from the same Appendix. Except for alkalinity and hardness figures, the between year variation is significantly greater than within year variation. The distinction between years can best be explained by the excessive differences in yearly rainfall.

Despite the high variation from year to year, chloride and calcium hardness show a consistent relationship between Bishop's Stream and the two Lennoxville streams. The chemical characteristics of L-2 are remarkably similar to those of L-1 when compared to Bishop's Stream: relative amounts of $CO_2$, chloride, total hardness and calcium hardness are similar.

## b: Ecological Study

In the first of two major experiments, an ecological study of the periphyton community of Bishop's Stream was carried out in 1977 using 3 sampling stations located along the length of the stream. The glass slide community and the natural community of the stream were looked at and the community structure investigated. An attempt was made to measure the reliability of the glass slide method in ecological studies.

### Glass slide community:

The effects of the following factors on community structure of periphyton which colonize glass slides were tested: spatial succession; substrate differences (nature of stream bed); seasonal succession; maturity of community; microdistribution on slides; and surface preference. (See Figure A in the Introduction). The last two factors mentioned will be considered in Section d as they were incidental to the primary work.

Only the diatom community, comprising from 85 to 99% of the glass slide periphyton, is quantitatively analyzed, though some attention is given to the other algae settling on the glass slides. A list of the diatom species found on the glass slides and rocks in Bishop's Stream (all stations) as well as L-1 and L-2 is presented in Table 1 of Appendix II. Other algae inhabiting slides and rocks in the three streams are enumerated in Table 2, Appendix II. Twenty of the most prominent diatoms found on the slides immersed in Bishop's Stream were chosen to graphically represent relative abundances and to carry out statistical analysis. These diatoms are presented along with ecological descriptions in Table 3, Appendix II.

The criteria for choosing these particular twenty out of the 124 species found on the slides are: 1) persistence (seasonal longevity); and 2) abundance at any given time. If a species was rare but persisted throughout the season, or if a species was very abundant though for only a short period of time, it was considered an important member of the community. Most species were both rare and ephemeral. A few (Species 1 to 6 in Table 3, Appendix II) were fairly abundant throughout the whole sampling time. The twenty species enumerated in Table 3 (Appendix II) represented in all cases more than 90% and in mature (6 weeks) communities 98 to 99% of the total numbers of the sampled community.

Though the following data are based in most part upon non-replicated slides, some random replication was done, showing that the variation from slide to slide and from sets of random counts done on the same slide was slight (see Table 1, Appendix III). The results indicate that the technique is reliable.

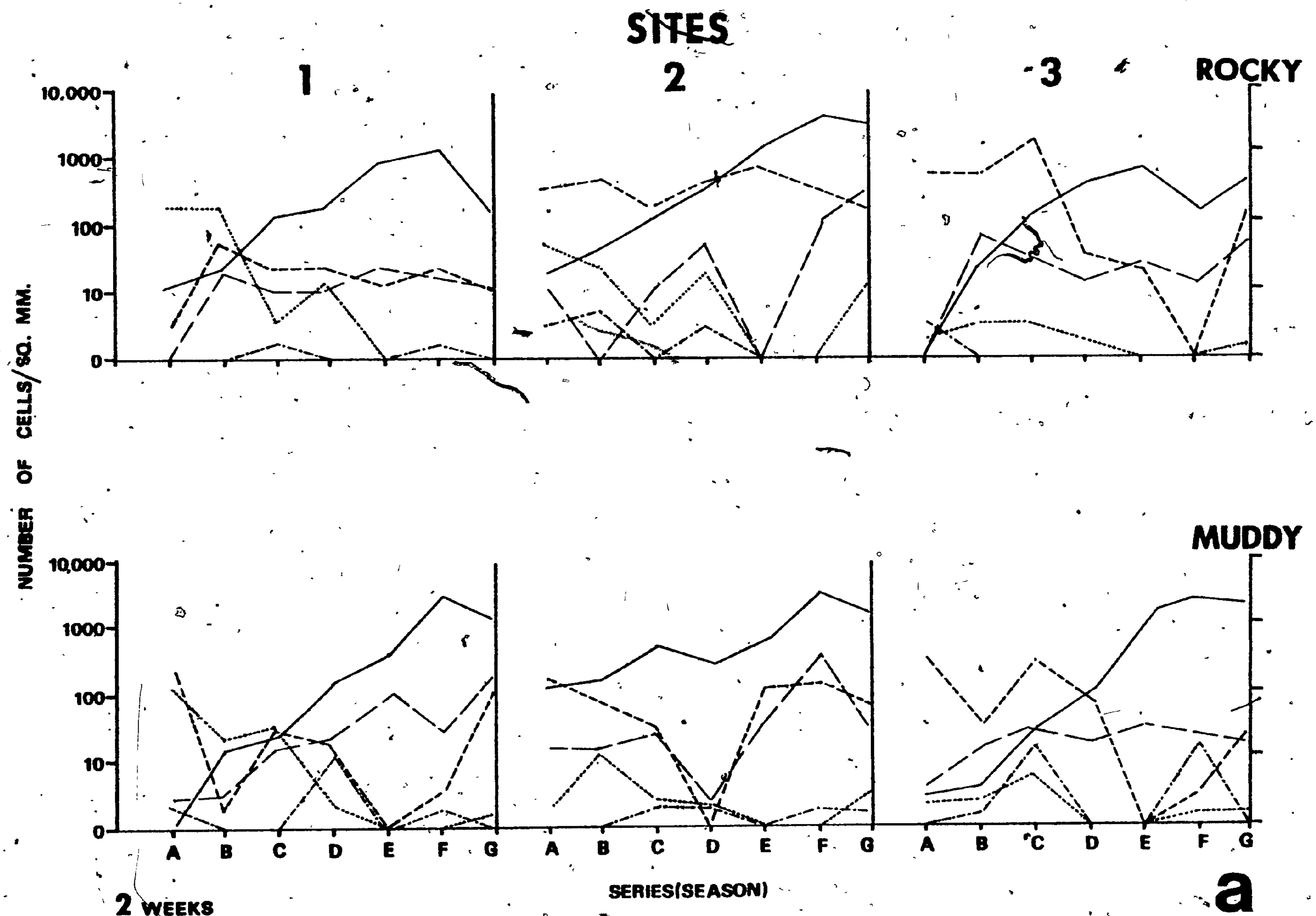
The environmental factors I chose to test on the slide community (points I to IV in Figure A) do not operate discretely but interact in the environment to produce complex results. I therefore considered all factors when dealing with each one separately. The effects of these on community structure was evaluated according to the following parameters: i) dominance hierarchy; ii) species number; iii) diversity and iv) total biomass.

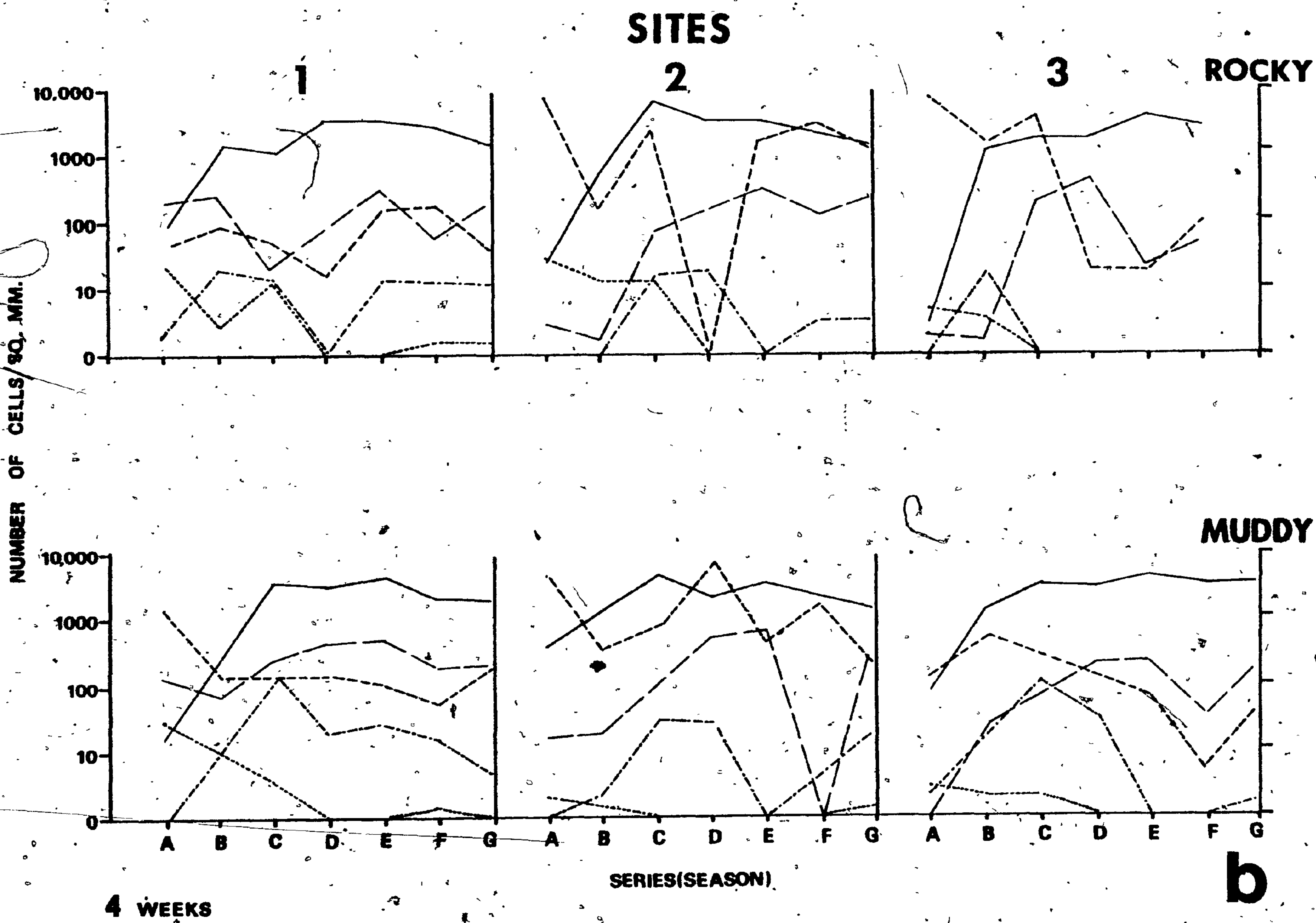
I. Spatial Succession (Major Stations) --

i) Dominance hierarchy: The histograms of Appendix II (Figures 1 to 48) compare the relative abundance of the twenty dominant diatoms on slides at the three stations at all colonization lengths throughout the sampling season of 1977. In some cases a fourth station is included. This station is situated in L-2 (see Figure 1). Slides from early May (A-series) to December (K-series) are compared. For an explanation of the coded slides see Figure 7 and Table 1a from the Methods Section. The histograms do not show ostensible differences between slides of major sampling stations. However, slides at Station 1 (solid bar) have smaller communities at early and middle ages (2 and 4 weeks respectively). Slides at Station 2 (striped bar) often have the largest numbers of the first six species (Table 3, Appendix II), though this is not a general rule.

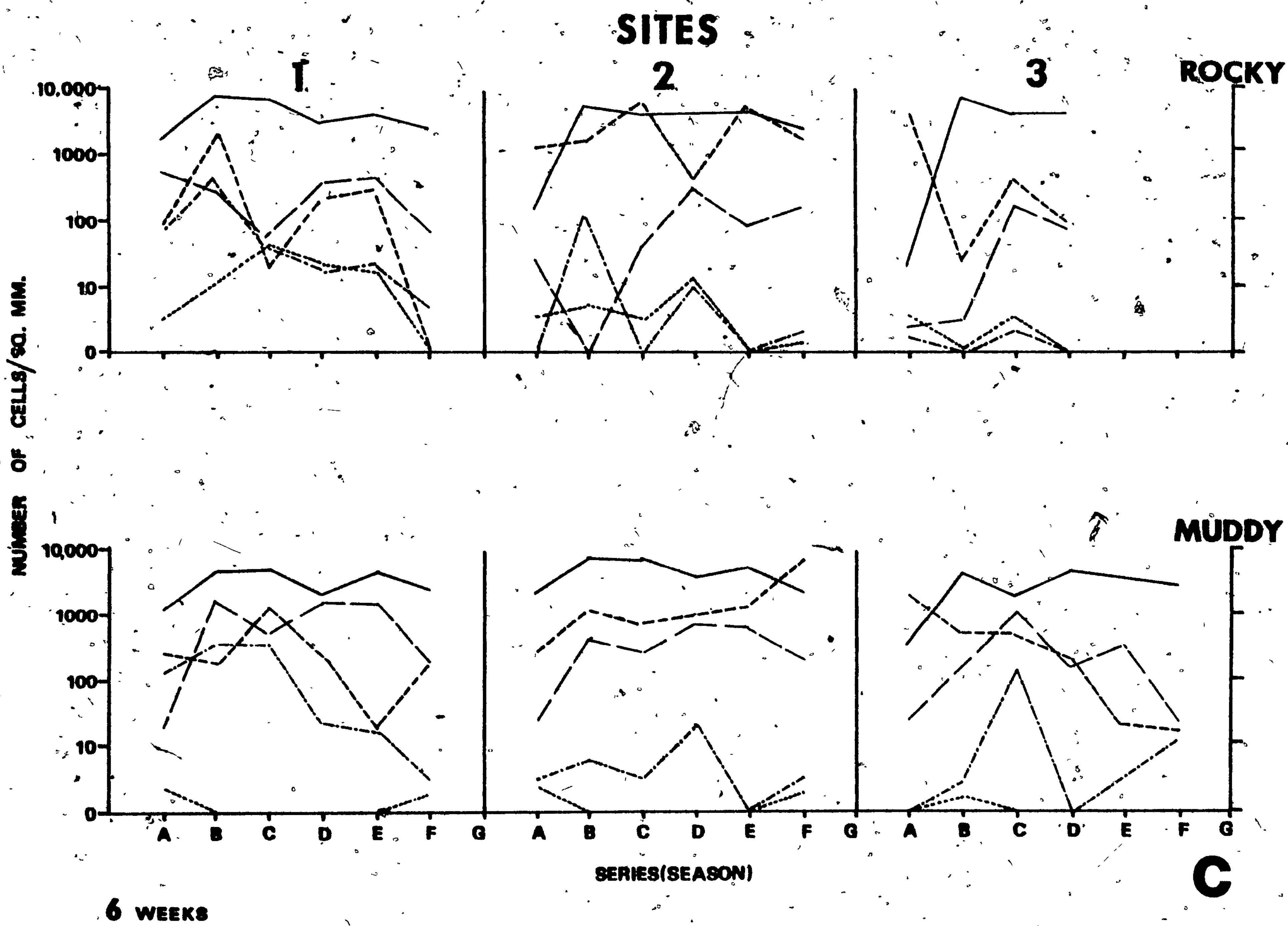
Figures 9a to c present the seasonal changes of five prominent diatoms for each of the three colonization ages of slide communities at the three stations for 1977. These figures show that variability from site to site is very high. However, the communities of the 2 week slides from the same station but different subsite tend to resemble one another (see especially Site 3a and 3b of Figure 9a) more than do communities from the same stream bottom type (a or b) of different stations. The reverse is true of 4 week slide communities. Looking at individual species, Surirella ovata and Eunotia pectinalis v. minor are generally better represented at Site 1, closest to the source and least represent-

FIGURE 9: Seasonal changes of five dominant diatoms: Cocconeis placentula ——; Achnanthes lanceolata — —; Achnanthes linearis ----; Eunotia pectinalis v. minor ---; and Surirella ovata ·········, in 1977. Figure a corresponds to 2 week old communities, Figure b to 4 week, and Figure c to 6 week old communities.


SITES
1
2
3
ROCKY
MUDDY
NUMBER OF CELLS/SQ. MM.
10,000
1000
100
10
0
A
B
C
D
E
F
G
SERIES(SEASON)
2 WEEKS
a



SITES
1
2
3
ROCKY
MUDDY
10,000
1000
100
10
0
NUMBER OF CELLS/SQ. MM.
A B C D E F G
SERIES(SEASON)
4 WEEKS
b


SITES
1
2
3
ROCKY
MUDDY
NUMBER OF CELLS/SQ. MM.
10,000
1000
100
10
0
A B C D E F G
SERIES(SEASON)
C
6 WEEKS

ed at Site 3. The remaining species show insignificant differences between sites.

Table 2 of Appendix III tabulates results of the Wilcoxon Signed Ranks Test and shows the relationship of the slide populations between the major stations for Series A to K. This test, as I explained previously, was used to determine, by matching pairs of the same species, whether one slide population was larger than the other for the twenty prominent diatoms. The null hypothesis of the Wilcoxon Test is that two samples come from identical populations (or that the means are the same). The probability that the differences in populations on the slides is a chance occurrence appears to the right of each sign associated with it. Slides at Station 2 show a higher number for each diatom species than slides at Station 1. This is especially evident in the two week old slides. Slides at Station 2 generally possess higher numbers of individuals for each of the twenty diatoms represented than slides at Station 3, though by insignificant amounts.

The Spearman Rho Correlation which tests for independance was carried out on the twenty diatoms of variously paired slides. The populations of the slides are not mutually independent; dominance hierarchy is similar for all sites throughout the sampling season. Perusal of the slide histograms of Appendix II confirms that a particular species that is dominant at one site is also dominant to the same degree at the other sites. In 157 of 175 tests performed, the Rho coefficient shows significance at the 0.05 confidence level. The exceptions are the following pairs: $1aA_1/2aA_1$; $1aA_1/3aA_1$; $1aA_2/3aA_2$; $2aA_1/3aA_1$; $1bA_1/2bA_1$; $2bA_1/3bA_1$; $1aB_2/2aB_2$; $1bD_1/2bD_1$; $2aD_2/3aD_2$; $2aE_1/3aE_1$; $2aE_2/3aE_2$; $2aF_1/3aF_1$; $2bG_2/3bG_2$; $1aJ_2/2aJ_2$; $1bJ_2/3bJ_2$; $1aK_2/2aK_2$; $2aK_2/3aK_2$; $1bK_2/2bK_2$.

These exceptions demonstrate the high variability and instability of the younger slide populations. Mutually independant slide populations between sites are represented mainly by two week old communities (subscript-l) early in the year when growth rate is high and by four week old communities (subscript-w) later in the season (Series G to K) when growth rate is low. Stable periphyton communities (4 and 6 weeks depending upon the season) which establish themselves on slides show a distinct hierarchy which is very similar for all sites (see histograms of Appendix II).

ii) Species number: The total number of counted species for each slide community appears on the top right hand corner of the histograms of Appendix II which graph only the twenty major species. Comparison of Stations reveals that fewer numbers of species exist closer to the source of the stream (Station 1). Species richness increases downstream.

iii) Diversity: The diversity of slide communities, calculated by the formula of Shannon and Weaver (1949), is presented in Table 2. Two-way analysis of variance was performed on the data and confirms that diversity does not differ from station to station with the possible exception of rocky subsites where significantly higher values were recorded at Station 2 for older colonies (see Table 3 of Appendix III).

iv) Total biomass: The total numbers of individuals counted on each slide are shown in Table 3. The data were then subjected to analysis of variance after log-transformation. Table 4 of Appendix III shows that higher numbers exists on slides at Station 2, though not at significant levels. Variation between sites of slide populations declines at rocky subsites and increases at muddy subsites with maturity of community.

TABLE 2: Diversity (Shannon & Weaver, 1949) of glass slide diatom communities at the three stations of Bishop's Stream and Station 4 of L-2 in 1977.

| SLIDE | STATIONS 1a | 1b | 2a | 2b | 3a | 3b | 4a |
|---|---|---|---|---|---|---|---|
| $A_1$ | 2.05 | 2.54 | 2.24 | 1.79 | 2.26 | 2.19 | — |
| $A_2$ | 1.96 | 1.43 | 1.39 | — | 1.84 | 2.37 | 2.13 |
| $A_3$ | 0.96 | 0.95 | 1.11 | 0.68 | 0.99 | 1.26 | — |
| $B_1$ | 2.54 | 2.43 | 2.30 | 1.35 | 2.31 | 2.28 | 2.23 |
| $B_2$ | 1.08 | 1.47 | 1.73 | 0.87 | 1.28 | 1.37 | — |
| $B_3$ | 1.04 | 1.06 | 1.27 | 1.32 | 0.08 | 0.66 | — |
| $C_1$ | 2.14 | 3.32 | 2.78 | 1.06 | 2.68 | 2.37 | 2.39 |
| $C_2$ | 0.55 | 0.76 | 1.29 | 0.84 | 1.17 | 0.69 | — |
| $C_3$ | 0.16 | 1.11 | 1.08 | 0.88 | 0.57 | 1.22 | — |
| $D_1$ | 1.64 | 1.33 | 1.33 | 2.14 | 2.48 | 1.42 | — |
| $D_2$ | 0.28 | 0.56 | 0.37 | 0.84 | 1.03 | 0.67 | — |
| $D_3$ | 0.85 | 1.01 | 1.23 | 1.16 | 0.43 | 0.39 | — |
| $E_1$ | 0.56 | 1.49 | 1.16 | 1.75 | 1.62 | 0.34 | — |
| $E_2$ | 0.60 | 0.51 | 1.06 | 1.14 | 0.16 | 0.45 | — |
| $E_3$ | 0.78 | 0.85 | 1.44 | 1.36 | — | 0.42 | — |
| $F_1$ | 0.27 | 0.32 | — | 0.82 | 1.78 | 0.46 | 0.56 |
| $F_2$ | 0.45 | 0.44 | 1.25 | 1.38 | 0.32 | 0.10 | 0.03 |
| $F_3$ | 0.17 | 0.41 | 0.99 | 1.17 | — | 0.19 | — |
| $G_1$ | 1.26 | 1.29 | 1.59 | 1.26 | 1.64 | 0.21 | 0.34 |
| $G_2$ | 0.98 | 1.13 | 1.93 | 1.51 | — | 0.04 | 0.10 |
| $H_1$ | 2.44 | — | 2.93 | 2.07 | — | 1.19 | 0.95 |
| $I_2$ | 2.22 | — | — | 1.78 | — | 0.84 | — |
| $J_2$ | 2.89 | 1.79 | 2.72 | 1.86 | 1.86 | 2.76 | — |
| $K_2$ | 1.59 | 2.46 | 2.75 | 2.19 | — | 2.88 | — |
| $L_2$ | 2.20 | — | — | — | — | — | — |

TABLE 3: Total number of diatoms counted in 50 random fields at x400 magnification of slides at the three stations of Bishop's Stream and Station 4 of L-2 in 1977.

| SLIDE | STATIONS 1a | 1b | 2a | 2b | 3a | 3b | 4a |
|---|---|---|---|---|---|---|---|
| $A_1$ | 288 | 550 | 1004 | 226 | 680 | 388 | - |
| $A_2$ | 254 | 1005 | 1339 | 3663 | 2179 | 297 | 162 |
| $A_3$ | 2048 | 1412 | 1958 | 1848 | 3383 | 1367 | - |
| $B_1$ | 235 | 215 | 793 | 1632 | 857 | 620 | 124 |
| $B_2$ | 1107 | 439 | 520 | 1224 | 2456 | 1548 | - |
| $B_3$ | 6977 | 4597 | 5005 | 6143 | 3253 | 3785 | - |
| $C_1$ | 220 | 150 | 515 | 340 | 1795 | 399 | 256 |
| $C_2$ | 1264 | 2647 | 6707 | 4918 | 4974 | 3153 | - |
| $C_3$ | 5204 | 5594 | 9010 | 4516 | 2610 | 2783 | - |
| $D_1$ | 170 | 143 | 1772 | 725 | 91 | 152 | - |
| $D_2$ | 2270 | 2714 | 5496 | 5381 | 1819 | 2180 | - |
| $D_3$ | 2887 | 3135 | 5853 | 3740 | 2604 | 3455 | - |
| $E_1$ | 642 | 365 | 1561 | 569 | 472 | 1339 | - |
| $E_2$ | 2742 | 3097 | 4496 | 3337 | 2794 | 3283 | - |
| $E_3$ | 3297 | 3968 | 7127 | 5770 | - | 3050 | - |
| $F_1$ | 1303 | 2336 | 2602 | 2040 | 132 | 1628 | 142 |
| $F_2$ | 3034 | 2748 | 6574 | 4484 | 2632 | 3221 | 4225 |
| $F_3$ | 2848 | 3161 | 4298 | 10486 | - | 2731 | - |
| $G_1$ | 217 | 1208 | 1741 | 1287 | 645 | 1817 | 2271 |
| $G_2$ | 1585 | 2865 | 2690 | 2562 | - | 3668 | 4992 |
| $H_1$ | 177 | 455 | 655 | - | - | 585 | 2141 |
| $I_2$ | 250 | - | - | - | - | - | - |
| $J_2$ | 204 | 82 | 520 | 1107 | 1066 | 132 | - |
| $K_2$ | 204 | 67 | 509 | 126 | - | 167 | - |
| $L_2$ | 14 | - | - | - | - | - | - |

II. Substrate Differences (Subsites) --

i) Dominance hierarchy: Differences in relative abundance of the dominant diatoms between muddy and rocky subsites is shown in the histograms of Appendix II. Fewer of the dominant species (and fewer species in general) are represented on the slides at the muddy (b) subsites. This phenomenon becomes less apparent in older communities. Table 5 of Appendix III shows that numbers of individuals per dominant species is generally higher on slides placed at the rocky subsites than those at muddy subsites (Wilcoxon Signed Ranks Test). This phenomenon is consistent though not always significant at Station 2, and is clearly evinced by young colonization stages early in the season. Similarly, young slide populations at Station 3 demonstrate a preference for the rocky subsite. While older slide populations show no such distinction. The slide communities of Station 1 are an exception to this generalization as their numbers are higher at the muddy subsite.

The Spearman Rho Correlation Test demonstrates that the dominance hierarchy is similar for the muddy and rocky slides at the 0.05 significance level.

ii) Species number: Fewer numbers of species colonize slides placed at muddy subsites (see histograms of Appendix II).

iii) Diversity: Table 2 shows that diversity was not significantly different between slide communities of rocky and muddy subsites.

iv) Total biomass: Table 3 shows no clear relationship between total numbers counted on slides and subsite (rocky or muddy). However, one may venture to observe that early in the season diatom numbers on slides at the rocky subsites are higher than numbers at muddy subsites; as the season progresses, this relationship reverses.

III. Season (Series) --

The data already presented demonstrates how season interacts with spatial succession and substrate bottom on glass slide periphyton.

i) Dominance hierarchy: The histograms of Appendix II indicate that as the season progresses from May to December of 1977, represented by Series A to K, Species 1 to 6 (Table 3, Appendix II) undergo hierarchical changes. Figures 9a to c which present seasonal changes of Species 1 to 6, excluding *Achnanthes minutissima*, show that *Cocconeis placentula* rises from a spring low to a maximum in late July and early August (Series E and F) and then declines. *Surirella ovata* and *Achnanthes linearis*, which have a spring maximum, become less numerous in mid summer and their numbers rise again in the fall. The highly erratic seasonality shown by all the slide populations, even six week old slides which presumably contain stable communities, suggests that the algae are growing in a highly volatile environment.

ii) Species number: Histograms 1 to 48 of Appendix II show that species number does not change significantly during the season though there is a general trend for larger numbers in the spring and fall and fewer numbers in the late summer (July-August).

iii) Diversity: The histograms of Appendix II show that as the season progresses from May to December of 1977 (Series A to K), diversity decreases, as Species 1 to 6 (Table 3, Appendix II) become more dominant, alluding to partial competitive exclusion; diversity reaches a minimum in the late summer (Series E and F). Diversity increases again in the fall and winter (Series G to K) as a result of heterogeneity in numbers and fewer total numbers in general.

Results from an analysis of variance confirm this observation. Seasonal influence on diversity of periphyton is exerted to a greater degree (or simply seen more clearly) on slides placed at rocky subsites than on those placed at muddy subsites; seasonal influence diminishes with maturity of the slide community (Table 3, Appendix III).

iv) Total biomass: Tables 2 and 3 show that the changing diversity values throughout the season are directly related to the numerical biomass of the periphyton on the slides and not to the number of species represented which does not change overly during the sampling season (Histograms 1 to 48 of Appendix II). The lowest recorded values of diversity of the slide community in July and early August (Series E and F) correspond to the highest recorded total numbers. Since total species number was not significantly different, lower diversity in late summer is attributed to a shift in the major component of the total numbers into a few species (1 to 6). Seasonal variation of numerical biomass was higher at muddy subsites (Table 4, Appendix III).

IV. Maturity of Community (Subscripts) --

i) Dominance hierarchy: The hierarchy or relative abundance of Species 1 to 20 of Table 3, Appendix II, changes with maturity of the periphyton community (Histograms 1 to 48, Appendix II). Species 1 to 6 become dominant with age of community, often to the near exclusion of all other organisms.

ii) Species number: The trend shown by Species 1 to 20 reflects an overall trend by the periphyton community on glass slides: species number and age of community are inversely related.

iii) Diversity: The diversity decreases with increasing age of the slide community (Table 2). This decrease is a function of low species number and high total number. Analysis of variance of diversity (Table 6,

Appendix III) at the three slide community ages suggests that season affects colonization rates.

iv) Total biomass: Table 3, which tabulates the total number of counted individuals per slide, shows that total numbers of diatoms increase with maturity of the community, with the greatest increment occurring between the two and four week old slide communities of the same series. It is very likely that optimum, though not necessarily maximum, numbers of diatoms on slides is reached by four weeks of exposure. Beyond this point a supra-optimal biomass is created by further settling and reproduction, and heavy competition for space takes place. Depressed numbers evinced by some six week old slide communities may be a result of impinging environmental contingencies such as current, light, turbidity, and grazing which act upon the unstable and stressed community as regulators.

Table 7, Appendix III, presents analysis of variance done on total numbers at the three community ages during the season. Results of this test confirm those carried out on diversity data: season affects colonization rates. Figures 9a to c demonstrate this phenomenon. By choosing one of the species, for example Cocconeis placentula, and super-imposing the figures over one another, colonization rate is graphically shown to increase to a maximum in August (Series E and F) then decline.

Mature communities and those established in late summer evince similar characteristics: high dominance by Species 1 to 7; low species number; low diversity; high number of individuals.

Rock Community:

I. Epilithic algae --

Every two weeks in 1977 the algae on rocks were sampled and compared qualitatively with the glass slide community sampled at the same time. In a majority of cases the two communities were quite similar. Table 1, Appendix II, enumerates species of diatoms found on the slides and rocks of Bishop's Stream. I was unable to compare relative abundances of the slide and rock communities except for a few rare occasions when blooms of diatoms on the rocks at various times of the year (eg. Cymbella tumida, Surirella ovata, Nitzchia linearis, Meridion circulare, Melosira varians) correspond to higher numbers on slides. The relative increase of Surirella ovata on slides at Station 1 in the spring (slides $A_1$, $A_2$, $B_1$) can be directly correlated to a bloom of this species on the nearby rocks at the same time.

II. Grazers --

A large and diverse population of fauna was found on the glass slides. These were recorded to investigate the possibility that grazers could affect periphyton community structure. Table 4 of Appendix II lists the fauna found on the rocks at the three stations of Bishop's Stream and the other two streams. The customary diets of the animals is included. Fauna that were actually seen on the slides are distinguished with an asterisk. The remainder can not be excluded from the investigation as their mobility enabled them to encounter the submerged glass slides even though they were never found on them.

Fauna did not vary greatly from station to station of Bishop's Stream. However, some distinciton between the subsites was observed and is given here: dragonfly nymphs were only encountered in the muddy subsite of Station 1; muddy subsites in general contained fewer large gill breathing animals such as the bigger mayflies, the stoneflies, crayfish and fish. Subsite 2b, however, supported a fair sized and constant population of shiners as did 2a. Fewer blackflies and caddisflies were seen in the muddy environments, most probably due to the lower current and the lack of suitable substrate.

I was unable to make any correlations between grazers and the glass slide periphyton for the three stations. Any affect of the grazers was too subtle to ascertain from the data. Grazers are discussed again in the following section.

c: Pollution Study

In 1976 Bishop's Stream (Site 2a) was compared with L-1 in a preliminary study to ascertain their specific characteristics. This was done by testing water chemistry, looking at algae and fauna on rocks, and by using a diatometer to monitor the community that settled on glass slides. These three methods were compared for efficiency and ease of experimentation. In 1977 Bishop's Stream was compared with L-2 using similar methods.

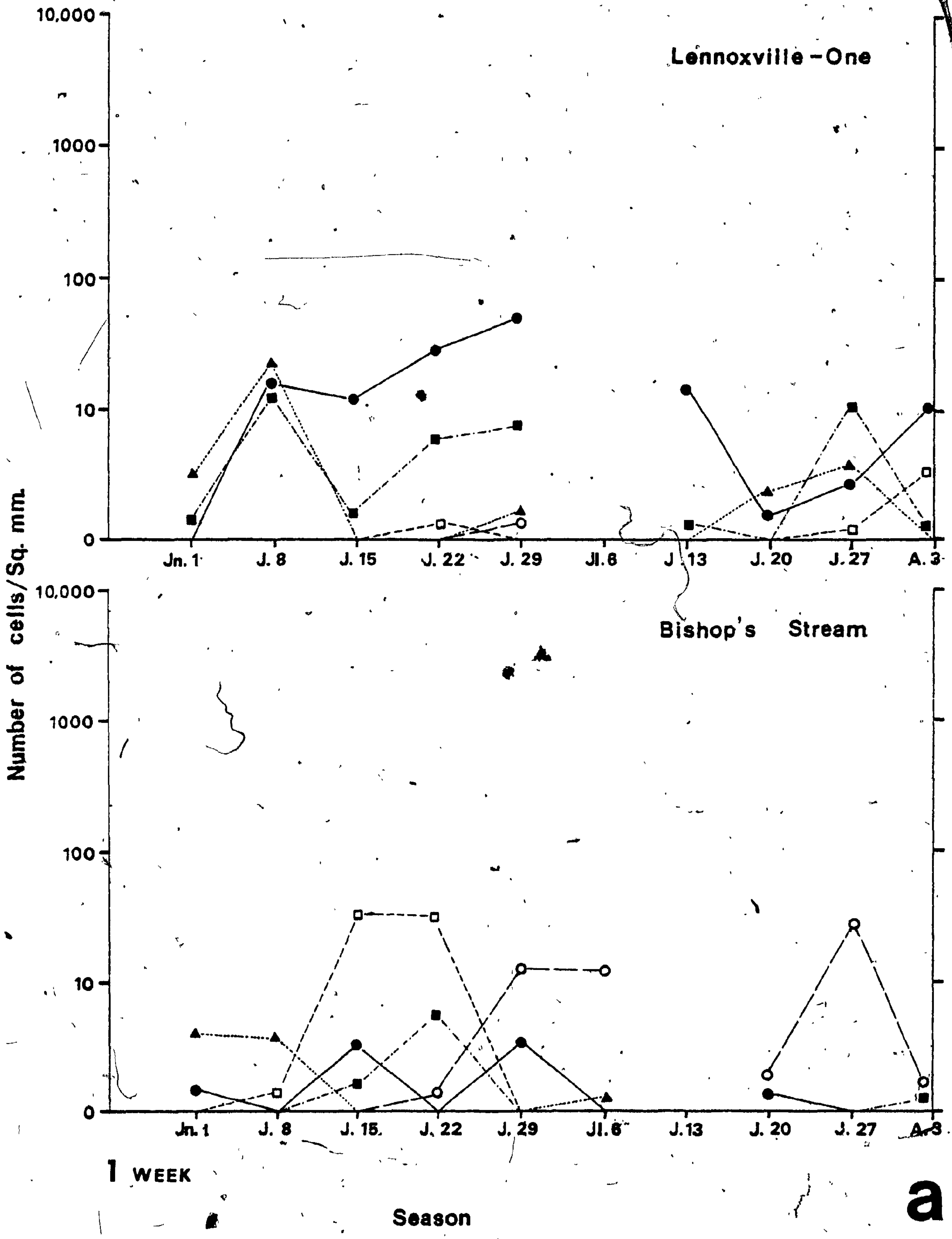
Factors I to IV of the ecological study (Figure A) were taken into account in the comparison.

Glass Slide Community:

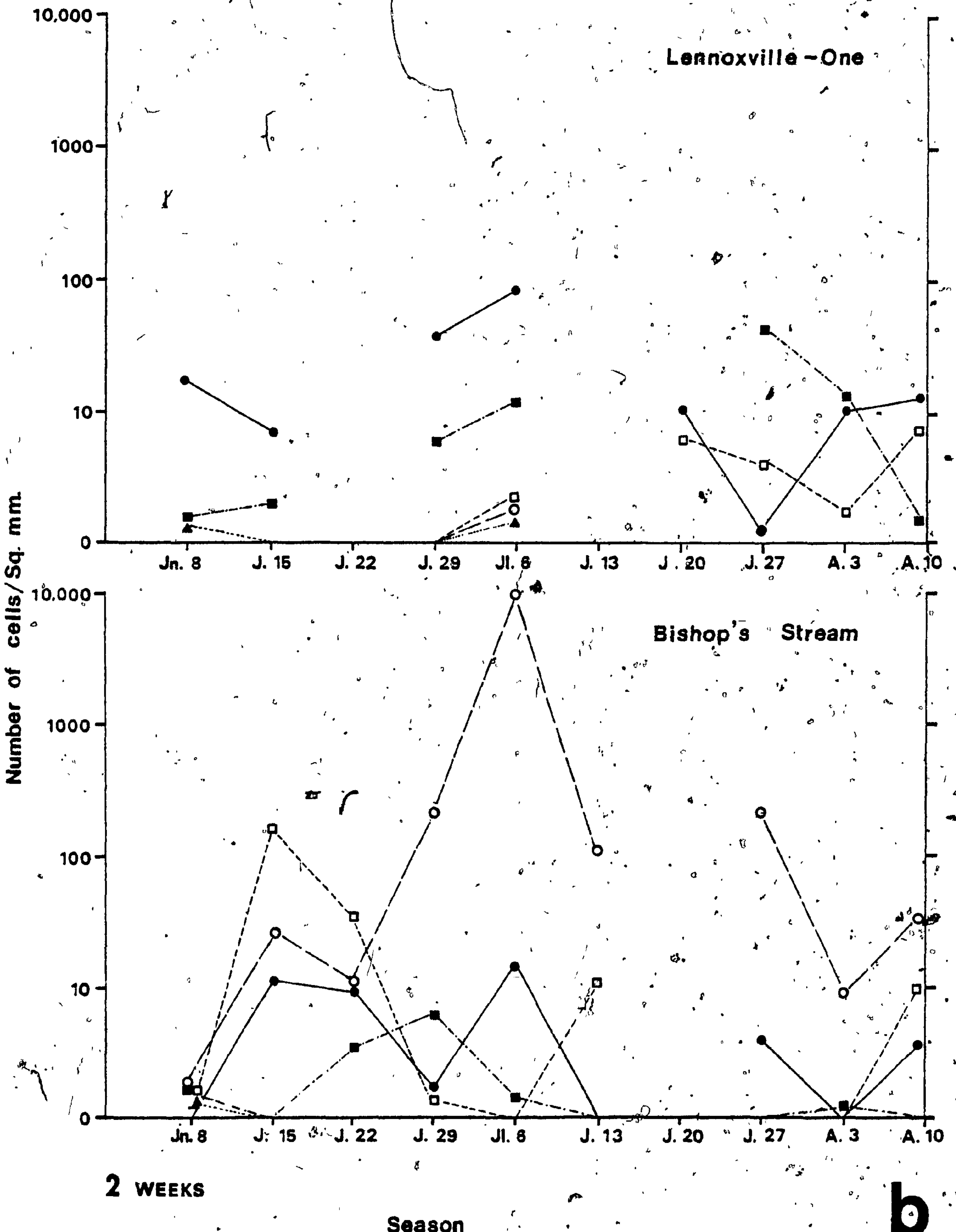
A considerable overlap of diatom species colonizing submerged glass slides and rocks exists between Bishop's Stream and L-1 and L-2 with only a few organisms being restricted to one or other of the streams (Table 1, Appendix II).

i) Dominance hierarchy: Figures 10a to d show the seasonal changes of the five most common diatoms of Bishop's Stream and L-1 for one to four week old slides respectively.

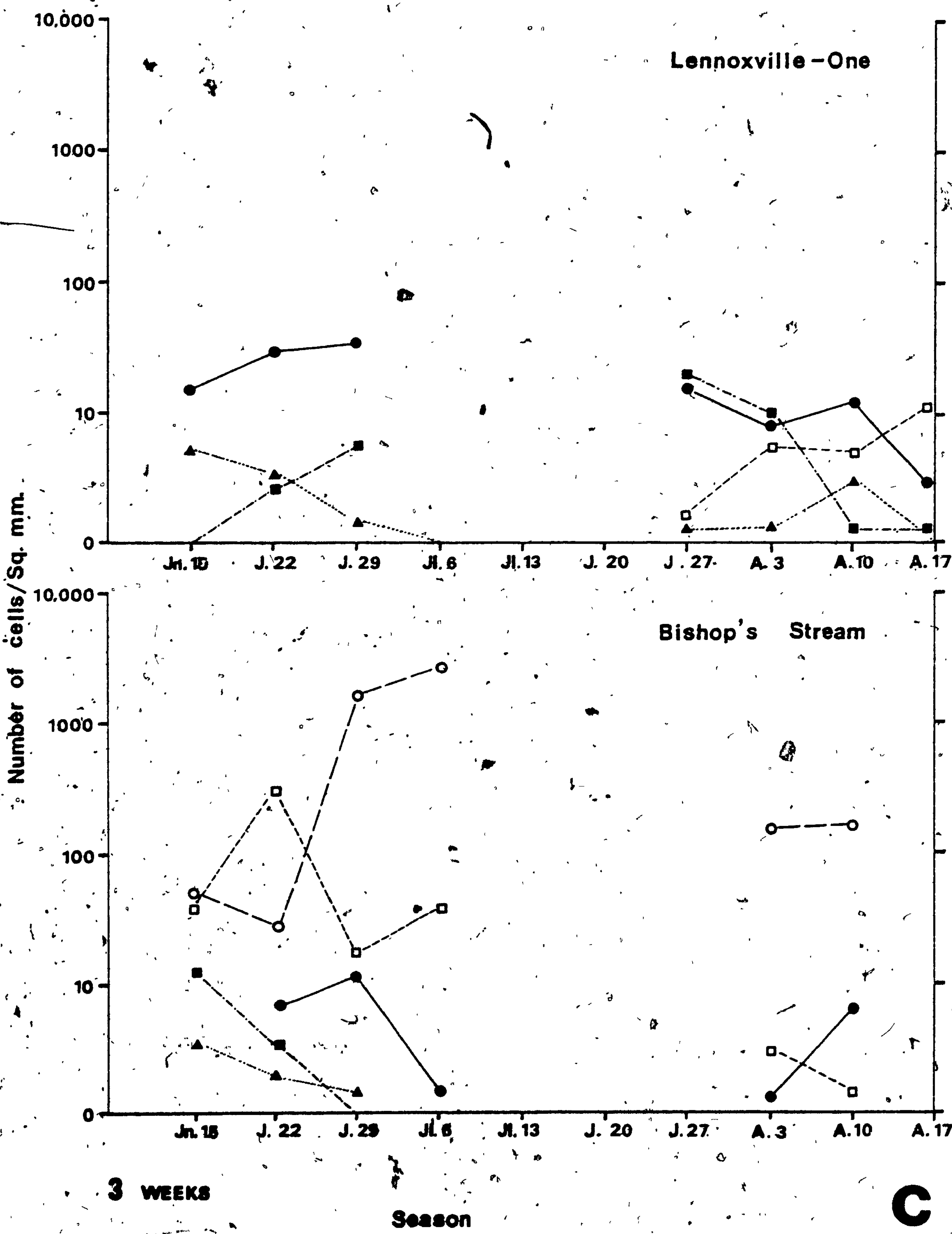
FIGURE 10: Seasonal changes of the dominant periphytic diatoms colonizing submerged glass slides in Bishop's Stream and L-1 in 1976. The five diatoms are: Cocconeis placentula —○—; Achnanthes lanceolata —●—; Achnanthes linearis and A. minutissima --□--; Navicula cryptocephala --■--; and Surirella ovata —▲···. Figure a corresponds to 1 week old slides, b to 2 week old, c to 3 week old, and d to 4 week old slides. The dates marked on the abscissa indicate time of collection.



Lennoxville - One
Bishop's Stream
10,000
1000
100
10
0
Number of cells/Sq. mm.
Jn. 1
J. 8
J. 15
J. 22
J. 29
Jl. 6
J. 13
J. 20
J. 27
A. 3
1 WEEK
Season
a

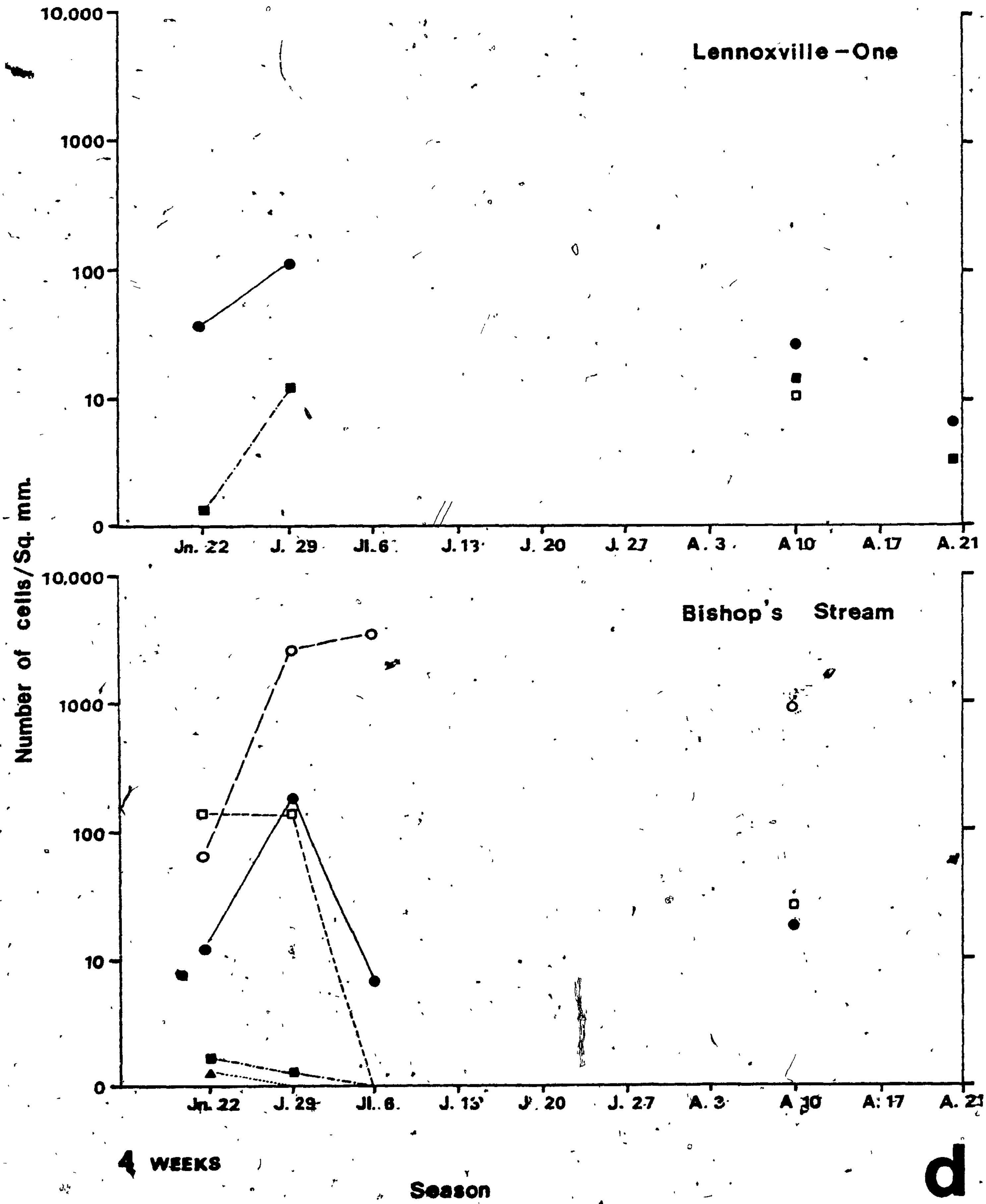


Lennoxville - One
Bishop's Stream
Number of cells/Sq. mm.
10,000
1000
100
10
0
Jn. 8
J. 15
J. 22
J. 29
Jl. 6
J. 13
J. 20
J. 27
A. 3
A. 10
2 WEEKS
Season
b


Lennoxville - One
Bishop's Stream
10,000
1000
100
10
0
Jn. 15
J. 22
J. 29
Jl. 6
Jl. 13
J. 20
J. 27
A. 3
A. 10
A. 17
Number of cells/Sq. mm.
Season

3 WEEKS

C



Lennoxville - One
Bishop's Stream
Number of cells/Sq. mm.
10,000
1000
100
10
0
Jn. 22
J. 29
Jl. 6
J. 13
J. 20
J. 27
A. 3
A 10
A. 17
A. 21
4 WEEKS
Season
d

A consistent pattern emerges from the figures: Cocconeis placentula and Achnanthes lanceolata dominate Bishop's Stream and L-1 respectively. The two species were found in both streams and it may be assumed that larger numbers of Achnanthes lanceolata in L-1 is evidence of its facultative nature and its successful competition over Cocconeis placentula, an oligosaprobe (clean water species) and notorious glass slide colonizer (Kolkwitz & Marsson, 1908; Douglas, 1958; Cattaneo et al., 1975). In Bishop's Stream Cocconeis held the competitive advantage and depressed the Achnanthes population. The competitive advantage of Cocconeis over Achnanthes in Bishop's Stream may be due to selective grazing.

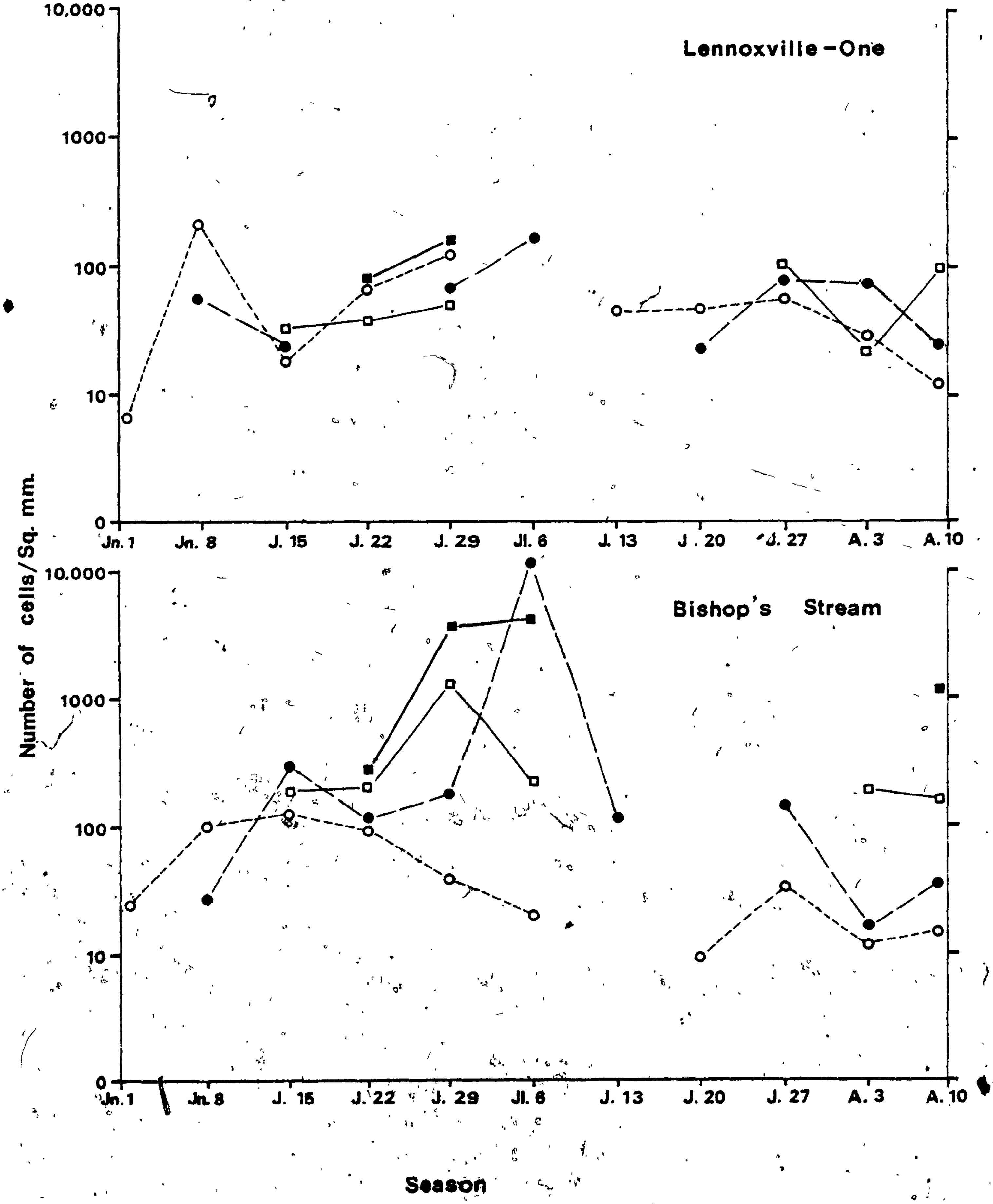
Two other Achnanthes species, A. linearis and A. minutissima (pooled in 1976 due to identification difficulties) preferred Bishop's Stream over L-1. In all cases their numbers were inversely related to numbers of Cocconeis placentula (Figures 10a to d).

In the one week old and two week old slides of Bishop's Stream Navicula cryptocephala and Achnanthes lanceolata appear to be antagonisticly related, while these species evince similar growth patterns on the corresponding slides of L-1. This difference is most likely the result of independent factors.

In most cases slides from Bishop's Stream supported a larger and richer biomass (see Figure 11) with the exception of the one week old communities, where L-1 supported a slightly higher biomass than Bishop's Stream. Figure 10a shows this anomaly to be primarily caused by the early colonization of the slides by Navicula cryptocephala and Surirella ovata in L-1 and the comparatively low numbers of Cocconeis placentula on the slides in Bishop's Stream.

Apparently a new surface must be exposed for close to two weeks be-

**FIGURE 11:** Seasonal changes of total numbers of periphyton colonizing submerged glass slides in Bishop's Stream and L-1 for 1 week old--o--, 2 week old—●—, 3 week old —□—, and 4 week old colonies—■—. Dates marked on the abscissa refer to collection time.


Lennoxville-One
Bishop's Stream
Number of cells/Sq. mm.
10,000
1000
100
10
0
Jn. 1
Jn. 8
J. 15
J. 22
J. 29
Jl. 6
J. 13
J. 20
J. 27
A. 3
A. 10
Season

fore being substantially colonized by Cocconeis placentula. This delay may be due to a requirement by Cocconeis placentula for a bacterial film to form on the glass slides and to serve as a kind of substrate. Indeed, an unidentified organism thought to be an iron bacterium was the pioneer colonizer of the glass slides in Bishop's Stream, forming a ubiquitous film of tawny donut-shaped colonies, upon which Cocconeis readily grew.

ii) Diversity: Diversity was not investigated in 1976.

iii) Total biomass: Total numbers throughout the season did not change ostensibly in L-1 (Figure 11) but a definite summer peak is seen on the slides in Bishop's Stream for colonies of every age. This is mainly due to the presence of Cocconeis placentula which is described by Butcher (1931) as a "summer encrusting" species.

The following 1977 comparison of the glass slide communities of Bishop's Stream with those of L-2 is supported by little data.

i) Dominance hierarchy: Station 4(L-2) is represented in the following histograms of Appendix II for Species 1 to 20: $XaB_1$; $XaC_1$; $XaF_1$; $XaG_1$; $XbF_1$; $XaA_2$; $XaF_2$; $XaG_2$. Only one sample is available from the site below the sewage outlet (4b): $XbF_1$. All the other graphs give relative abundance of the diatoms on slides located above the outlets (4a). In the case of the two week old slides, the variation between stations in Bishop's Stream masked any difference that may have existed between communities there and those in L-2. A major difference existed between the three stations of Bishop's Stream and L-2 in presumably more stable four week old communities. During the optimum growth period for Cocconeis placentula (see histograms, $XaF_2$, $XaG_2$) it dominated the slide community of L-2 entirely while sharing dominance with four or five other diatoms on slides of Bishop's Stream.

## d: Further Analysis of Periphyton Community Structure on Glass Slides

### V. Microdistribution (Orientation of slides to current) --

During the course of the experiments in 1977 it was discovered that the distribution of diatoms on the glass slides was not random but contagious. Preference for upstream edge, downstream edge, or both of slides oriented parallel to the current was witnessed. Figures 12A to D, which are macro-photographs of some representative slides, show microdistribution at various stages of colonization.

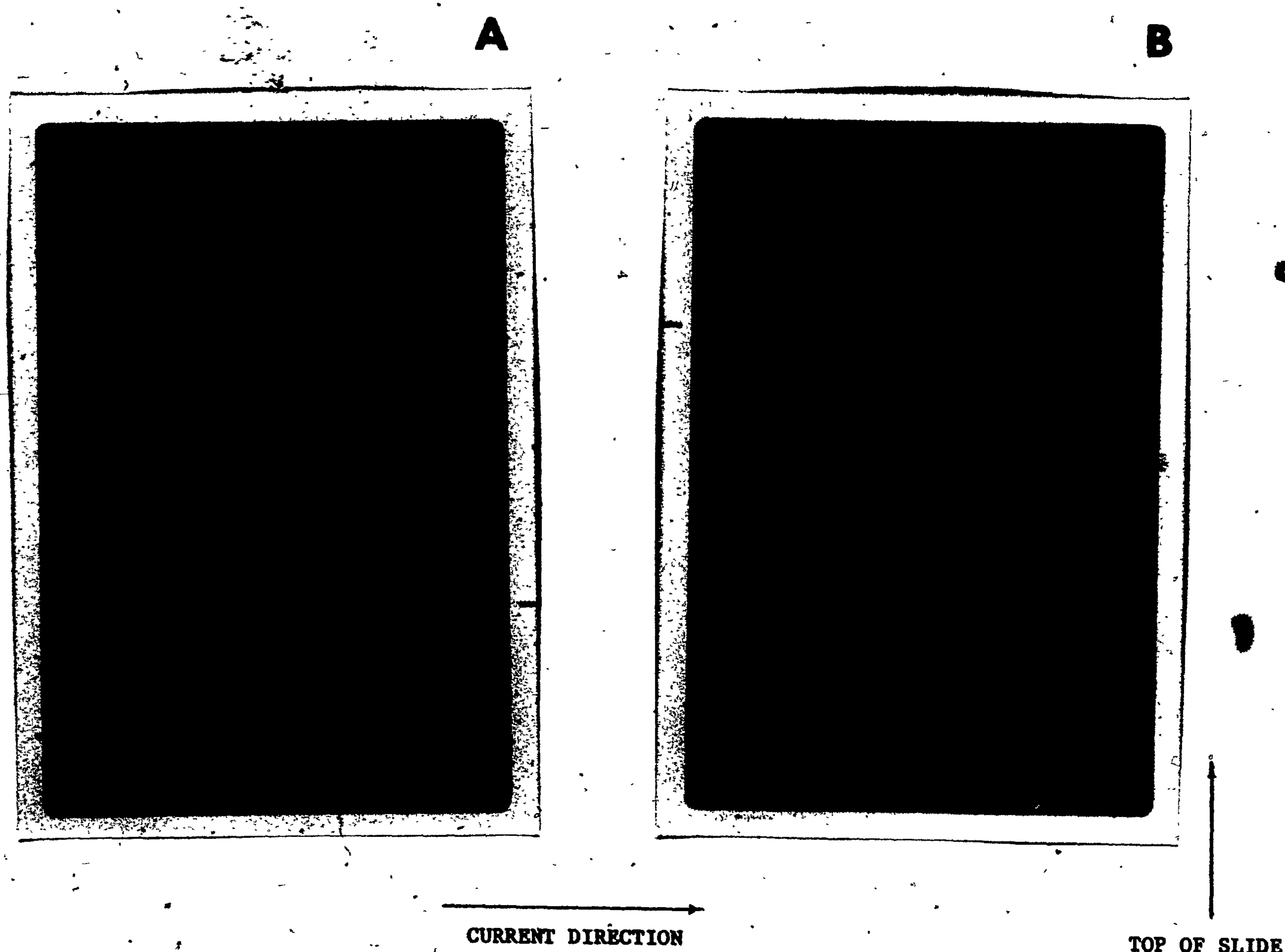
Figures 13 and 14 compare total diatom numbers across the width of slides of two series, B and E, whose dates of initiation are separated by six weeks, the former in mid-May and the latter in late June. (See Figure 8 for explanation of transects and graphs). Two colonization lengths, 2 and 4 weeks, were used for each series (the 6 week slides were similar to the 4 week slides). Concomitant comparison of rocky (a) to muddy (b) subsites was made.

The most ostensible difference between the two series was in the growth rate of the settling community. The earlier series, initiated in mid May, manifested a much slower growth rate than the series begun in late June. This phenomenon can plainly be seen in both 2 and 4 week old slide colonies of Station 2. The 4 week slides initiated in spring ($B_2$) approach the 2 week slides of mid summer ($E_1$) in total biomass (see Figures 13 and 14).

Concentrating our attention for the moment on $E_1$ and $B_2$ slides, particular distributions are apparent:

1) In general, a decided preference for one or both edges over the

FIGURE 12: Macro-photographs of prepared slides showing white frustules against a black background. A, random spotting of diatoms at an early coloniza-tion stage; B, preference for upstream and downstream edge of slide with random patches; C, preference of diatoms for upstream edge only; D, homogeneous cover representative of 6 week old slide communities.


A
B
CURRENT DIRECTION
TOP OF SLIDE

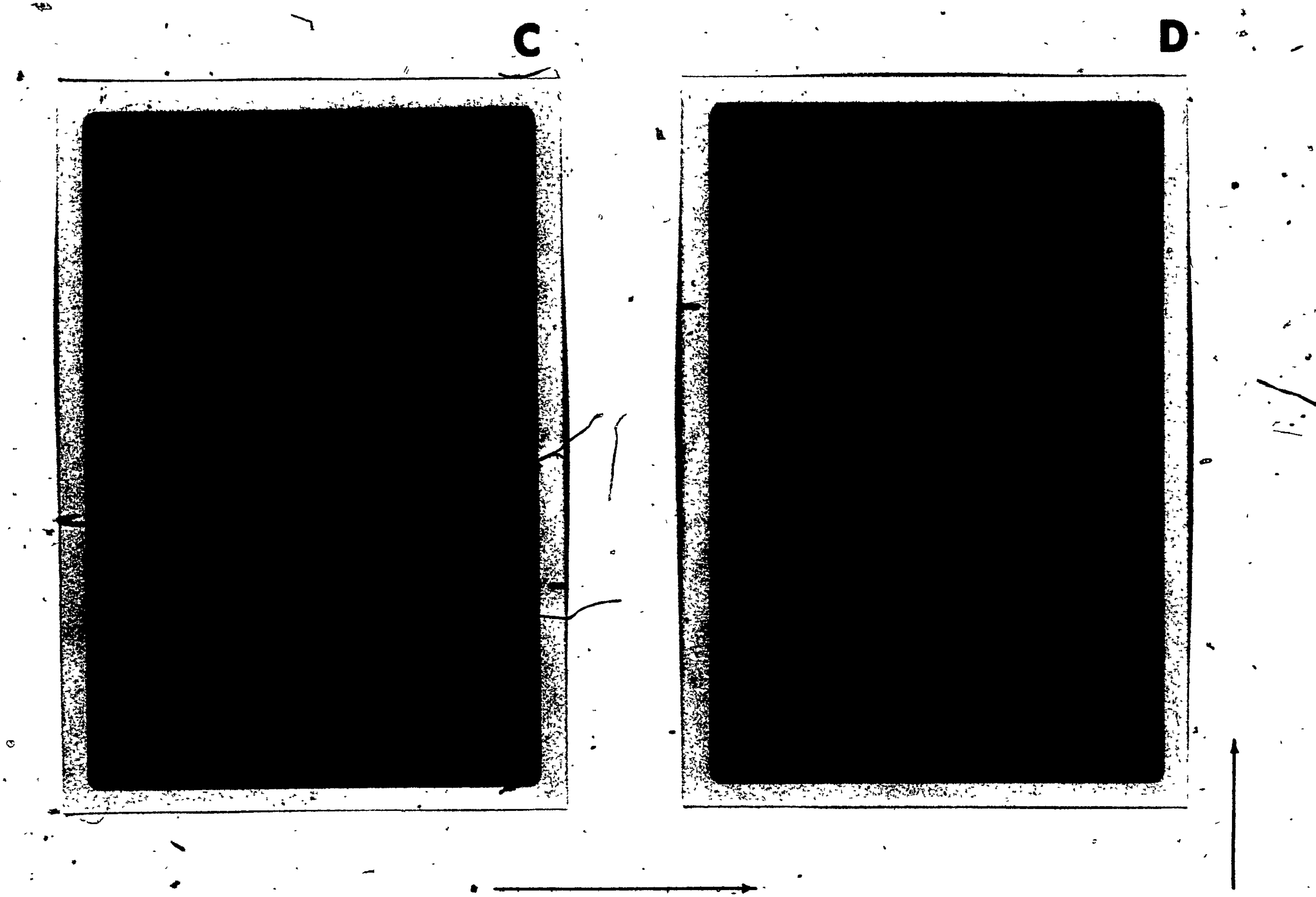

C
D
CURRENT DIRECTION
TOP OF SLIDE

FIGURE 13: Spatial distribution of 2 week old diatom populations from three transects drawn across the width of slides taken from the three stations of Bishop's Stream. Populations on slides from Series $E_1$ (June 29 - July 13) and Series $B_1$ (May 18 - June 1) are compared.

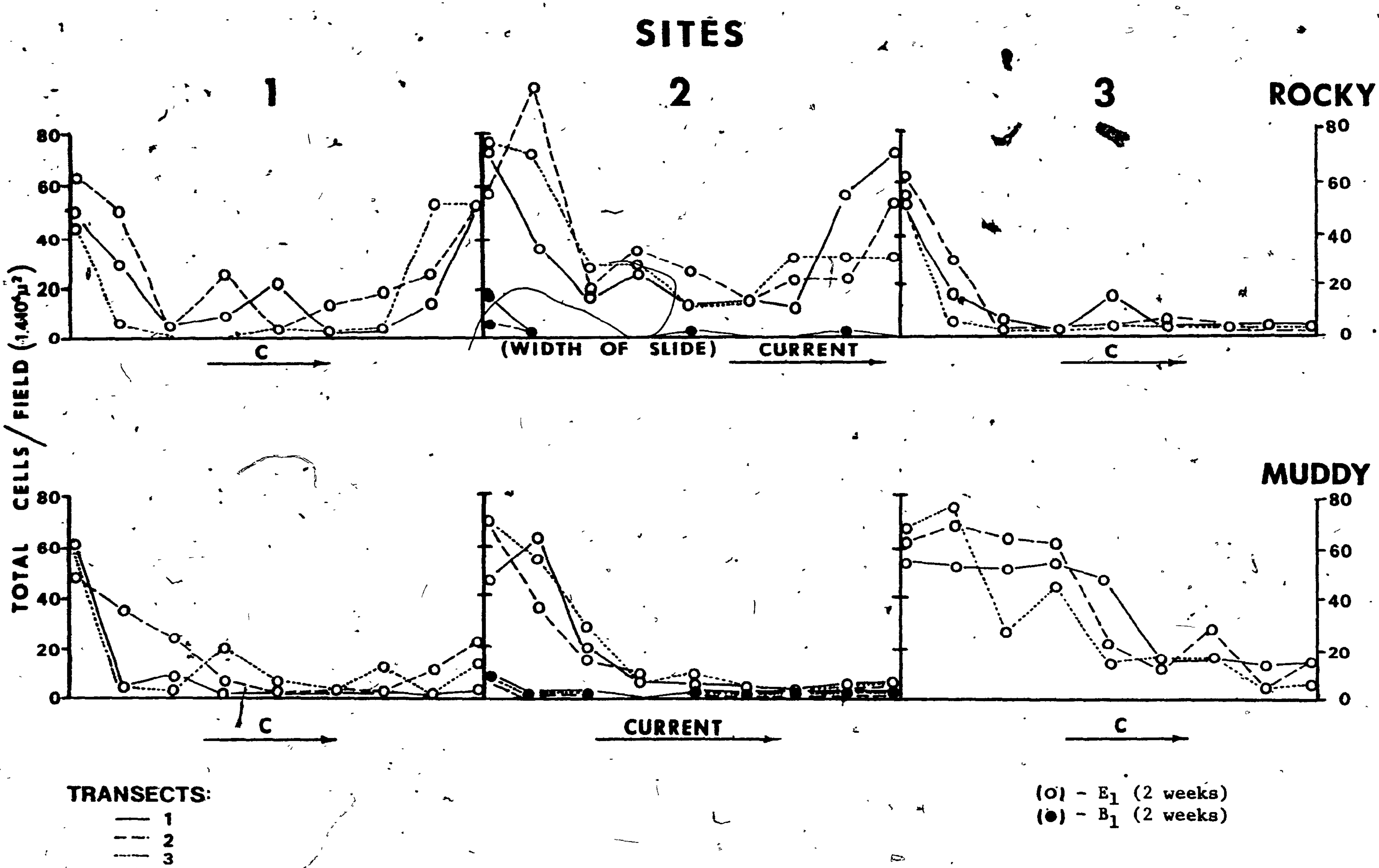
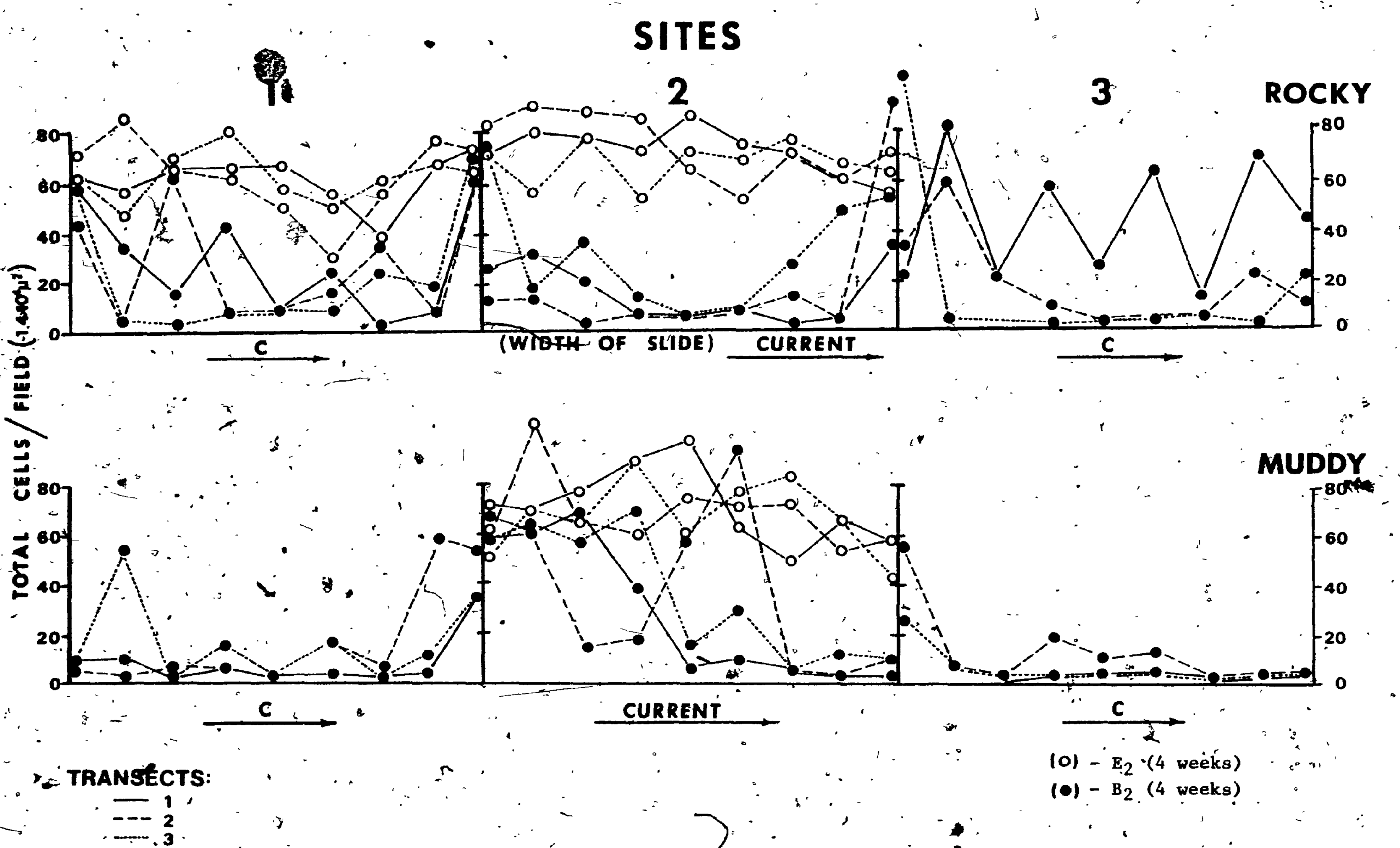

SITES
1
2
3
ROCKY
MUDDY
TOTAL CELLS / FIELD (1,440 μ²)
80
60
40
20
0
C
(WIDTH OF SLIDE)
CURRENT
TRANSECTS:
1
2
3
(o) - E1 (2 weeks)
(●) - B1 (2 weeks)

FIGURE 14: Spatial distribution of 4 week old diatom populations. Observed as in Figure 13. Populations on slides from Series $E_2$(June 29 - July 27) and Series $B_2$(May 18 - June 15) are compared.



SITES
1
2
3
ROCKY
MUDDY
TOTAL CELLS / FIELD (1,440μ²)
80
60
40
20
0
C
(WIDTH OF SLIDE)
CURRENT
TRANSECTS:
1
2
3
(o) - E2 (4 weeks)
(●) - B2 (4 weeks)

middle of the slide during early colonization stages is seen.

2) Slides at Station 1 show diatom preference for both upstream and downstream edges over middle regardless of subsite.

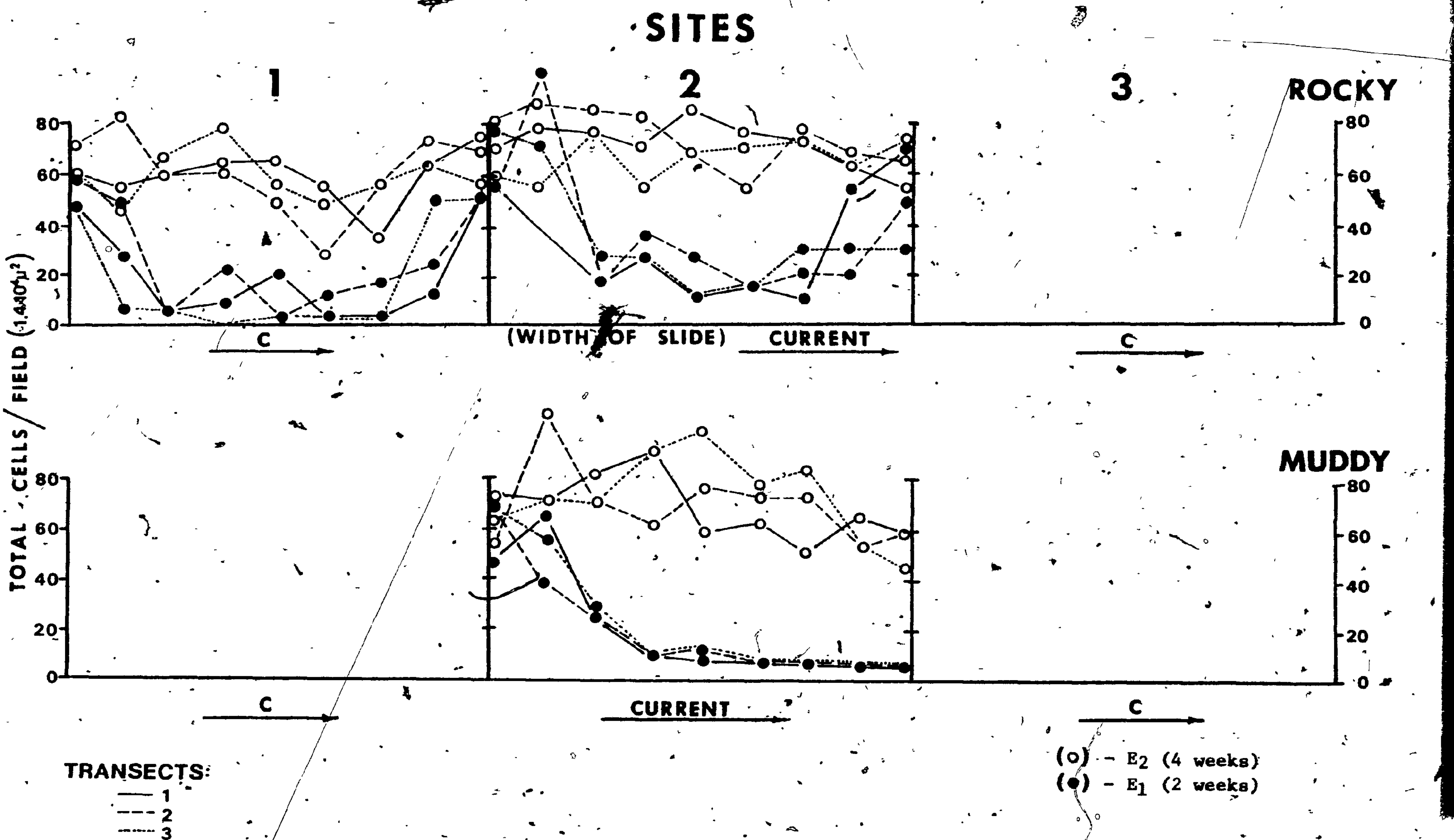
3) Preference of diatoms for both edges over middle of slide at Station 2 occurs only at the rocky subsite, whereas at the muddy subsite preference for only the upstream edge exists. The anomalous peak shown by transect 2 on slide $2bB_2$ is an example of the high degree of clumping which consistently hinders statistical analysis in this experiment. The diatom, Achnanthes linearis, is the chief component of most of these random patches throughout the slide. (Figure 12B, Figure 14).

4) Diatoms prefer only upstream edge of the slide at both subsites of Station 3. The erratic pattern seen in $3aB_2$ of transect 1 is also due to patchy growths and may reflect a vertical trend of diatom distribution.

Figure 15 compares 2 week to 4 week old diatom populations on slides of the E series. Transects taken across the width of the slides show that by the fourth week the diatoms are distributed evenly across the slide and that total numbers correspond closely to the numbers shown by 2 week slide populations at the edges. The negligible increase in diatom numbers on the edges of slides from 2 week to 4 week exposure times in the E-series may be because the diatoms have already reached the carrying capacity of that area of the slide and heavy competition for space limits growth to a large degree; however, at the center of the slide, settling, reproduction and migration from edges can still take place, corresponding to the large increase in numbers from 2 week to 4 week old slide populations (Figure 15).

Preference shown by diatoms for edges of slides was witnessed throughout the entire sampling season.

FIGURE 15: Spatial distribution of 2 and 4 week old diatom populations along the width of slides from Series E. Observed as in Figure 13.


SITES
1
2
3
ROCKY
MUDDY
TOTAL CELLS / FIELD (1,440 μ²)
80
60
40
20
0
C
(WIDTH OF SLIDE)
CURRENT
TRANSECTS:
1
2
3
(o) - E2 (4 weeks)
(●) - E1 (2 weeks)

Cocconeis placentula, already described as dominating the slide community of Bishop's Stream, determined much of the "edge effect" by its preference for edges. Two other species, Achnanthes linearis and Achnanthes minutissima, cohorted with Cocconeis. However, as I mentioned previously, Achnanthes linearis tended to colonize anywhere. All other species which made up the community were too rare and scattered to exhibit significant preferential distribution.

To investigate community differences between edges and middle of slides, the nine designated fields of Transects 1 to 3 were divided into 3 categories: a zone consisting of the first 3 fields counted from the upstream and downstream margins of the slide was considered the upstream and downstream edge respectively; the remaining 3 fields at the center of each transect were defined as the middle. Transects 1 to 3 were pooled for statistical tests and diversity analysis.

Table 8, Appendix III, shows the significant preference of diatoms for both edges at Station 1 on 2 and 4 week old slides; diatoms at Station 2 show preference at only upstream edge over middle on 2 week old slides and no significant preference is shown on 4 week slides (Wilcoxon Test).

The different preference patterns of diatoms at these two stations may be a result of differing growth rates (see Figures 13, 14, 15). Slide populations at Station 2 had a higher biomass throughout the sampling season (see page 55). Qualitative differences in community structure of diatoms along the width of slides between the two stations may account for some of the disparity in edge preference.

Diversity of upstream edge, downstream edge, and central communites was calculated by the formula of Shannon & Weaver for slides A to F of Station 2.

Early and middle series show relatively lower diversities at muddy subsites than rocky ones, while later series show the reverse (Table 4). However, this difference is not highly significant.

Sixty percent of the slides at Station 2 show highest diversity in the middle of the slide, twice that expected it by chance. Thirty-two percent show highest diversity at the downstream edge. Only 8% of the slides have highest diversity at the upstream edge. The higher diversity of the central community is due to a greater number of species, presumably because of less competition for space, as well as to the lower total number of individuals compared to the edges. Both factors will increase diversity. Evidence for a qualitative difference between edge and central community is given by 4 week old slides of the E series. Figure 14 (slides $2aE_2$ and $2bE_2$) and Table 4 show that changes in diversity from edges to middle of slides is not due to differences in total number. I explain it as follows: Cocconeis placentula colonized the edges first and invaded the middle portion of the slide later; in the meantime, other species had a chance to settle on the central part of the slide due to less crowding.

Data from the fourth transect, taken along the vertical length of the slide, suggests that diatoms generally first settled at the top of the slide. Sometimes, however, the bottom was preferred alone or with the top of the slide, leaving a small scarcely inhabited portion in the middle of the slide.

Table 9, Appendix III, gives vertical trends of diatom microdistribution on slides at Stations 1 and 2 for series A to F (Cox & Stuart Test for Trend and Wilcoxon Signed Ranks Analysis).

Communities on 2 week old slides show a negative trend (increasing

TABLE 4: Diversity (Shannon & Weaver) of edge and middle communities on slides A to F at Station 2 in 1977. Of each series, the number at the top represents the diversity index of the upstream edge community; the second number is the diversity of the central community; and the bottom number is the diversity of the downstream edge community. For details of the methods see the text.

| a | b | a | b | a | b | a | b | a | b | a | b |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.76 | 0.21 | | | | | | | | | | |
| 1.38 | 0.19 | | | | | | | | | | |
| 0.22 | 1.09 | | | | | | | | | | |
| | | | | | | | | | | | |
| 0.52 | 0.84 | 1.18 | 1.40 | | | | | | | | |
| 1.25 | 0.32 | 1.70 | 1.75 | | | | | | | | |
| 0.65 | 0.26 | 0.88 | 1.49 | | | | | | | | |
| | | | | | | | | | | | |
| 0.77 | – | 0.96 | 0.44 | 0.96 | 0.44 | | | | | | |
| 0.59 | – | 1.17 | 0.74 | 1.16 | 0.84 | | | | | | |
| 0.82 | – | 0.95 | 0.54 | 1.37 | 0.63 | | | | | | |
| | | | | | | | | | | | |
| | | 0.76 | – | 0.77 | 0.74 | 1.28 | 1.06 | | | | |
| | | 0.69 | – | 0.84 | 0.54 | 1.30 | 0.77 | | | | |
| | | 0.92 | – | 0.86 | 0.61 | 0.96 | 0.98 | | | | |
| | | | | | | | | | | | |
| | | | | 0.44 | 0.53 | 0.78 | 0.74 | 0.63 | 0.69 | | |
| | | | | 0.57 | 0.89 | 0.91 | 0.89 | 0.94 | 1.02 | | |
| | | | | 0.70 | 0.74 | 0.72 | 1.01 | 0.80 | 0.58 | | |
| | | | | | | | | | | | |
| | | | | | | 0.73 | 0.71 | 0.77 | 0.45 | 0.32 | 0.25 |
| | | | | | | 0.86 | 0.92 | 0.86 | 0.87 | 0.32 | 0.34 |
| | | | | | | 0.78 | 0.98 | 0.61 | 0.71 | 0.38 | 0.49 |
| | | | | | | | | | | | |
| | | | | | | | | 0.62 | 0.70 | 0.65 | 0.85 |
| | | | | | | | | 0.72 | 0.90 | 0.65 | 0.86 |
| | | | | | | | | 0.70 | 0.82 | 0.52 | 0.63 |
| | | | | | | | | | | | |
| | | | | | | | | | | 0.72 | 0.79 |
| | | | | | | | | | | 0.71 | 0.50 |
| | | | | | | | | | | 0.73 | 0.72 |

$X_1$ 2 week old slide
$X_2$ 4 weeks
$X_3$ 6 weeks

a rocky subsite
b muddy subsite

numbers toward the bottom of the slide) early in the season, progressing to a positive trend (increasing numbers toward the top of the slide) later on.

Four week and six week old communities consistently exhibit more significantly positive trends at rocky (a) subsites than at muddy (b) ones. Diatoms may have been establishing themselves on the bottom of the slides situated at muddy subsites because they were getting something from the stirred up clay substrate such as nutrients. Seeding from epipelic and epipsammic diatoms may also have affected the diatom distribution.

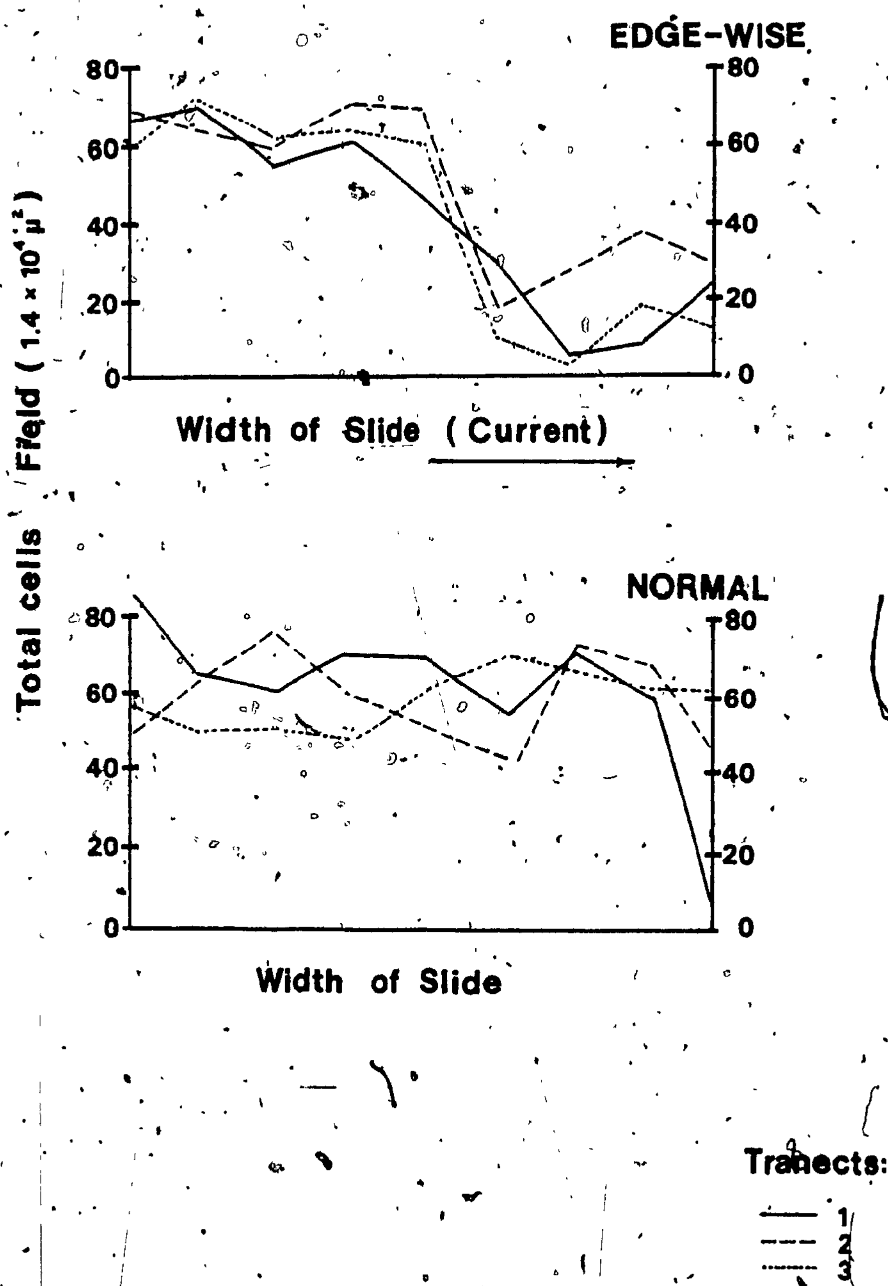
In Fall of 1978 an experiment was conducted at Subsite 2b to evaluate the effects of glass slide orientation to the current on microdistribution of diatoms. Slides were arranged normal and edge-wise to the current. Figure 16 presents graphs depicting spatial distribution along the width of the slides for normal and edge-wise orientation using similar methods as those used for the previous microdistribution studies.

The transects show that diatom numbers, represented mainly by *Cocconeis placentula*, are evenly distributed over the slide facing the current. Diatoms settling on replicates of slides parallel to the current, however, show significant preference for upstream edge of slides. Total numbers at the upstream edge of slides oriented edge-wise to the current approach numbers found throughout the width of the slide oriented normal to the current. The donut-shaped iron bacteria is seen in higher numbers on the slide normal to the current.

Variability within apparatus:

Analysis of variance was carried out on slide replicates located on

FIGURE 16: Spatial distribution of the diatom population from three transects drawn across the width of the slide. Populations on slides oriented edge-wise and normal to the current are compared.


EDGE-WISE
80
60
40
20
0
Width of Slide (Current)
Total cells / Field ( 1.4 × 10⁴ μ² )
NORMAL
80
60
40
20
0
Width of Slide
Transects:
1
2
3

the extreme edge of the slide chamber of the apparatus and at the center of the chamber to see if hypothetical differences in micro-currents were affecting periphyton community structure. Table 10, Appendix III, shows that differences between slides of different locations on the slide chamber are as insignificant as those between replicates from the same location.

VI. Surface Preference (Frosted/Smooth glass slides) --

An experiment was designed in the fall of 1977, using partially frosted slides, to ascertain the existence of substrate selectivity by diatoms. Table 11, Appendix III, establishes that in some cases significant difference in community structure between frosted and smooth glass surfaces exists. However, this phenomenon is not consistent and no conclusion can be made.

Generally, fewer numbers of Cocconeis placentula and greater numbers of Achnanthes linearis and A. minutissima were found on the frosted surfaces than on the smooth surfaces.

## DISCUSSION

The results of the survey on Bishop's Stream suggest that factors such as substrate bottom, spatial succession, and seasonal succession do act upon the periphyton community of glass slides. Water from the stations of Bishop's Stream exhibited only small chemical differences with the exception of $CO_2$ and silica. Apart from these, the differences between stations were physical: turbidity; color; current.

Spatial succession:

The similarity in dominance hierarchy but difference in relative abundance for diatoms at the three stations and their subsites suggests that a discrete association from the diatom pool of the stream is suited to settle on vertically placed glass slides as a unique environment, and that differences in relative abundance from station to station are due to local factors. The afore-mentioned factors, excluding seasonal succession, may be responsible.

It has been suggested that along a hypothetically uniform stretch of stream, the population of algae will increase downstream due to an increase in nutrients and transportation of periphyton downstream resulting in an increase in the species pool (Eddy, 1934; Douglas, 1958). Although an increase in diatom numbers was observed from Station 1 to Station 2, total numbers were lower in Station 3 generally. This pattern is not too surprising when one considers the stream characteristics between each successive station. Much of the stream is underlain by bedrock between Station 1 and 2 (Figure 3). Between Station 2 and 3 the streambed is mostly silt and clay, underlain by gravel and silt. The banks along the stream between Station 1 and 2 are encroached by forest and are often rocky; the banks along the stream between Station 2 and 3 are flanked by field and are muddy, being much more susceptible to erosion and the stream, therefore, to more silting. Because of this phenomenon Station 3 has the highest turbidity (Table 3, Appendix I) especially at times of rainfall. In the spring and summer of 1977 very little rainfall and no scouring floods occurred and populations at Station 3 were higher in number than at the other two stations. In the fall, when it rained more frequently, slides at Station 3 had lower populations than Station 2. The increased density of suspended particles in the lower reaches of Bishop's Stream may diminish light and act as scouring agents on the slides being populated by the diatoms. The higher diversity of 2 week slide populations at Subsite 3a (Table 2) can be explained by the larger species pool (Patrick, 1967).

Subsites:

The effects of turbidity and silting are further seen in the comparisons of rocky (a) with muddy (b) subsites. As the histograms of Appendix II show, fewer species and numbers of individuals per species (Table 5, Appendix III) inhabited slides at muddy subsites while the diversities of these two communities remained comparable (Table 2).

Current tends to be slower at muddy areas of a stream, allowing deposition to take place. Though this was the case generally for Bishop's Stream, both subsites of Station 2 exhibited the same current speed. Since community disparities were observed at Station 2 between the two subsited, a factor related directly to the stream bottom type and not to current, such as invation rate, was deemed the important contributor in determining differences in population sizes and diversity of diatom communities settling on slides located at muddy and rocky subsites.

The possible role of turbidity on periphyton community structure has already been discussed. However, because of its association with stream bottom type, the influence of turbidity alone on the biota is difficult to elucidate. It seems more likely that the stream bottom itself as an integral part of the stream environment, rather than turbidity per se, is responsible for the difference in the glass slide communites between rocky and muddy subsites.

Cedergren (Blum, 1956) stated that sandy bottoms tend to be unfavorable for algal attachments and that these areas are inclined to be poor in benthic algae. Though Cedergren was probably thinking mainly of larger, filamentous algae, this statement holds true for diatoms as well. Though mud supports a population of epipsammic and epipelic diatoms, a much richer and diverse diatom population thrived on surrounding rocks at Subsites 2b and 3b. Seeding from the clay bed, especially of epipsammic species, would appear to be not nearly as great as seeding from rocks either. Slides located at the muddy subsites received pioneer species brought in by the current, whereas slides at the rocky subsites received input from an established community on the rocks just upstream as well as the normal loading from the current.

It is interesting to note that the location of 2a, downstream of a pool, does not seem to affect results. Subsite 1a was also located downstream of a pool, yet slides at 1b possessed higher numbers of diatoms per species and total biomass (see p. 59 and Table 3). Subsite 3a was not located downstream of a pool and still evinced higher total numbers than 3b.

The richer biomass exhibited by slide communities at the muddy subsite of Station 1 may be explained by the luxurious growth of macrophytes able to support epiphytic algae in the proximity of the diatometer. Regrettably these were not sampled for algae. Clumps of grass that had slid down from the overhanging banks were occasionally found near the apparatus of Subsite 3b. But this growth was not permanent and probably did not provide a constant source of algae.

Season:

I showed on page 62 and 63 that diversity and relative abundance of diatoms on slides changed with season. Besides the obvious spring and fall pulses of species such as Surirella ovata, Meridion circulare, and Nitzchia linearis, ubiquitous diatoms showed definite seasonality. Populations of Achnanthes linearis and A. minutissima were highest in the spring and early summer (Figure 9a to c); Cocconeis placentula showed a maximum in late summer. The seasonality shown by these particular species corresponds closely with the seasonal succession exhibited by the same species in Butcher's 1931 study on the River Tees in Britain.

The general decrease in diversity in the summer is due mainly to one species, Cocconeis placentula, and its dominance over all the other components of the slide community. It would seem that, once the optimum conditions are met for Cocconeis, its proliferation goes unchecked to the near competitive exclusion of other interacting species.

On page 78 I showed that colonization rate of slides increased significantly in the late summer. This phenomenon is also due in most part to Cocconeis placentula.

Much as season per se influences the periphyton community structure on slides, other short-lived factors may account for many of the changes in community structure. As Figures 9a to c and 10a to d show, there is a great deal of local fluctuation. Some of the "noise" is consistent for all slides sampled at the same time. Figure 10a to d shows that certain diatoms on slides sampled on the same date but representing varying ages (from 1 to 4 weeks) revealed the same proportion of numbers compared with previous or subsequent sampling dates. Compare, for instance, numbers of Cocconeis with Achnanthes linearis and A. minutissima from June 8 to July 6 in Bishop's Stream. The same pattern is evident whether the slide is 1 or 4 weeks old. In all cases Cocconeis was depressed June 22 while Achnanthes spp. peaked; July 6 Cocconeis rose to a peak and Achnanthes spp. plunged. These fluctuations suggest that short-lived local environmental contingencies like current, light, or temperature play an important role in glass slide periphyton dynamics.

The inverse relationship of Achnanthes linearis and A. minutissima with Cocconeis placentula was also observed by Brown & Austin (1973) on glass slides exposed in Elk Lake, British Columbia, and the authors suggest that this relationship resulted from competition for space.

I believe this relationship is current mediated. The dramatic increase of Cocconeis in 1976 took place shortly after a heavy scouring flood, with a concomitant decrease in numbers of the two Achnanthes species. It is known that current can selectively remove algae (Hynes, 1972). Though these genera belong to the true periphyton (Brown & Austin, 1973), Cocconeis is especially adapted to smooth surfaces. It secures itself to the substrate by lying flat on its hypotheca and secreting a mucilagenous film. Achnanthes linearis and A. minutissima, though usually lying flat on the substrate, may orient themselves differently and attach to a substrate by means of a gelatinous stalk. Their surfaces, too, are not as well adapted to smooth glass as is the surface of Cocconeis; the epitheca and hypotheca of Achnanthes is irregularly shaped. Further evidence of substrate selectivity differences between these two genera is given by the paper of Cattaneo et al. (1975) which reported that Cocconeis was more conspicuous on slides and Achnanthes minutissima was more noticeable on the rocks. In experiments on substrate selectivity, presented on page 95, I observed higher numbers of Cocconeis placentula on smooth surfaces and higher numbers of Achnanthes linearis and A. minutissima on the frosted surfaces, indicating a high adaptability of Cocconeis to smooth glass slides as a substrate. However, my paired analysis (Table 11, Appendix III) show that the difference between populations on frosted and smooth glass was not significant. These results are similar to those of Castenholz (1961).

It would seem, then, that the success of Cocconeis placentula on glass slides over its close competitors, Achnanthes linearis and A. minutissima, is regulated by current.

Current does not explain all the variation shown by these two and other genera. For instance, in 1977, a dry year, Achnanthes linearis and A. minutissima, though existing in much higher numbers than the previous year, were still antagonisticly related to Cocconeis placentula (Figure 9a to c). Other factors, independant or dependant of season, such as differing strategies by the genera involving nutrient uptake, reactions to light, or susceptibilities to selective grazing may act either singly or in conjunction with one another to change community structure of glass slide periphyton throughout the season. Butcher (1946) correlated some of the local fluctuation he saw in his algal populations in a 1937 experiment to differences in amount of sunshine. However, a great deal more of the observed variation was unexplainable.

Notwithstanding the influence of current on the slide community, factors connected with season determine much how current will influence diatom numbers. Although Cocconeis is a swift water organism (Butcher, 1946; Round, 1965) and was shown above to competitively favor high velocities, maximum populations did not coincide generally with times of the year when the current was highest: spring and fall. This was because two other environmental factors were not favorable for Cocconeis: light and temperature. In a laboratory stream study McIntire (1968) showed that current only enhanced Cocconeis growth in the presence of the right light conditions (700 ft-c.). Preference of Cocconeis placentula for higher temperatures was alluded to in the study by Hansmann & Phinney (1973). Dependance of Cocconeis on light intensity was suggested by microdistribution studies carried out by Godward (1934, 1937), Cattaneo (1978), and myself (see page 114).

It is interesting to note here that the seasonality shown by Cocconeis placentula settling on exposed slides does not concur with that shown by this species on natural substrates. Douglas reported Cocconeis as occurring on natural vegetation mainly in winter (1958). Butcher (1931) described Cocconeis placentula as a "summer encrusting" species on glass slides. Tippett (1970) showed that Cocconeis formed an irregularly varying population on Elodea while peaking in summer on glass slides. He ascribed the growth of Cocconeis in summer to a feature of populations on diatometer slides and suggested that species which are normally present in populations on natural substrates may be stimulated to grow at different times of the year on artificial surfaces.

However, virtually all studies of glass slide communities, including the one by Tippett, involved exposing slides for arbitrary time periods, usually 2 and 4 weeks, so that what was really being measured was an arbitrary stage in the colonization of a new substrate. Comparison of this community with an already established one on a natural substrate is not valid. In the former case seasonal differences would be well represented by new growth and settling. In the latter case seasonal differences would be expected to be more subtle as growth by one or another species would be impeded by competing for space with the already established community. The similarity in seasonal growth of artificial and natural substrates is given by the results from a slide which I exposed over the winter and sampled early in the spring. A dense community of Cocconeis was found thriving on the glass slide while being absent on 2 and 4 week slides sampled at about the same time.

Maturity of community:

The few significant differences shown by older slide communities among stations, stream bottoms and even season to a degree suggests to me that the established periphyton community of glass slides is independant from the natural community, which helps to seed the slide community. When diatom blooms occurred on nearbye rocks, 6 week slide communities showed little correlation while 2 week slide communities clearly did.

The erratic patterns and high variability of the immature colonies are ascribed to variable seeding. The 2 week and to a lesser extent 4 week slide communites are more closely associated with the rock communities as succession is still taking place and the slide populations are still unstable. It is this characteristic which makes 2 and 4 week old slide communites more sensitive to short term extraneous changes imposed upon the system such as intermittant pollution though rendering them at the same time difficult to interpret.

The decrease in diversity with maturity of the periphyton community was also observed by Brown & Austin (1973) and Cattaneo et al. (1975) on exposed glass slides.

Presumably, this phenomenon is a result of unique stresses associated with glass slide substrates. Brown & Austin (1973) suggested that with increasing exposure duration and periphyton total cell standing crops, species interaction is intensified, as space becomes more limiting, and diversity decreases as a result of competition for space. Partial competitive exclusion by Cocconeis placentula and the Achnanthes spp. evidently takes place in Bishop's Stream.

Comparison of Bishop's Stream with L-1 and L-2:

The comparative investigation of the three streams using chemical analysis, rock communities, and those settling on exposed slides showed the Lennoxville streams to be mildly polluted and Bishop's Stream to be quite pristine. These conclusions are drawn from all the analyses; no single analysis yielded conclusive results.

Chemistry of water -- The results from the chemical tests are limited to the time of analysis (a few minutes of a day every week or two weeks) and to the chemical tests performed. The analysis of water temperature (see page 50) demonstrates how erroneous conclusions can be drawn from limited tests.

Despite these limitations, chemical data suggest that the two Lennoxville streams, L-1 particularly, were organically polluted. I said on page 50 that the high carbonate hardness of L-1 and L-2 might be due to organic pollution. Heinsen (1938) and others have linked high carbonate hardness to pollution in ground waters, ascribing the connection to increased solubility of $CaCO_2$ in the presence of proteins, humus, and weak acids produced by the oxidation of organic matter.

Chloride, present as sodium chloride in urine to the extent of 1% (Klein, 1959), implies the possibility of sewage in the water.

Nitrate and phosphate, present exclusively in L-1 and L-2, owe their major sources in proximity to civilization to man's activities. Phosphate in streams comes mainly from detergents in municipal waste and fertilizers (monocalcium phosphate and calcium sulfate) usually as runoff from agricultural land. Similarly, nitrogen as commercial fertilizer in the form of synthetic ammonia or one of its derivatives, ammonium nitrate or ammonium sulfate, can enter the stream through runoff (Hodges, 1973). In the case of both streams in Lennoxville, any of the above point or non-point sources may have contributed to the modicum of these two inorganic nutrients in the water. It is interesting to note that both streams are located in proximity to fertilizer factories and warehouses.

The generally higher free $CO_2$ content of L-1 over Bishop's Stream in 1976 may be ascribed to pollution though not exclusively since organic carbonaceous matter arising from a gamut of sources such as dead and living animals and plants, sewage and industrial wastes, and soil erosion is oxidised by aerobic bacteria to $CO_2$ (Klein, 1961). The large increase of carbon dioxide in Bishop's Stream the following year can be explained by the change in water dynamics. Blum (1956) stated that in a small creek rapids tend to be higher in pH due to $CO_2$ removal. The higher than average rainfall in 1976 appears to have depressed the amount of free carbon dioxide in both streams for that year.

<u>Fauna</u> -- I believe that the distinct fauna shown by L-1 and Bishop's Stream in 1976 is indirectly related to the subtle chemical and physi-

cal differences between the water of the two streams and directly related to substrate.

Roback (1974) reported that although all mayflies are restricted to water with high oxygen, many are widely distributed in waters of moderate organic loading. They were found in L-2 but not in L-1. Most mayflies and the Simulidae are indifferent to hardness of water (Hynes, 1972) which is the most outstanding chemical difference, besides chloride, between the two Lennoxville streams and Bishop's Stream.

The occurrence of mayflies and other organisms in Bishop's Stream and L-2 but not in L-1 is best explained by substrate and silting.

Although I chose the sites of L-1 and Bishop's Stream in 1976 to be similar in bottom type, the fact that certain sludge-like materials were being dumped into L-1 precluded their being perfectly similar. Though the site in L-1 was gravelly and rocky, the stones and rubble tended to be covered with a fine silt and gummy coating at times. Their source also raised the turbidity and hense the light extinction. Turbidity itself can act in a deleterious way on certain clean-water organisms. However, since it is usually closely linked to substratum-type, it is hard to judge its affect on fauna.

Most authorities agree upon the importance of substrate to bottom dwelling animals in general (Behning, 1924; Schräder, 1932; Berg et al., 1948; Einsele, 1960; Winkler, 1963). In a study by Sprules (1947) Ephemeroptera, Plecoptera, and Trichoptera were found to prefer rubble surface, while Simulidae preferred gravel, and Chironomidae sand and muck. Moreover, he observed that in an area originally inhabited by a diverse group of insects, silting from a dam reduced greatly the numbers of emerging Trichoperans, Plecopterans, and Ephemeropterans, while increasing the proportion of Chironomidae. The Annelids, Nematodes, Gastrotrichs, Cilliophora and Harpacticoida, all of which inhabited L-1, are associated with organically rich, debris-filled substrates (Reid, 1961; Wetzel, 1975). Nematodes, certain Oligochaetes, and many Protozoans belong to a group of specialized micro-organisms inhabiting soft sand (Hynes, 1972). The Glossosoma, restricted to Bishop's Stream, occurs only where its scraping mechanism is not impeded by fine sand (Hynes, 1972).

As I showed on page 76, much of the substrate preference shown by these animals is intimately linked to diets and it may be supposed that each kingdom (plant and animal) exerts an influence upon the other.

Algae -- On page 72 I suggested that depressed numbers of Achnanthes lanceolata in Bishop's Stream during 1976 experiments was a result of selective grazing. Douglas (1958) showed convincingly how the Trichopteran, Agapetus fuscipes, grazed selectively upon species of Achnanthes, including A. lanceolata. Although Agapetus was not found in Bishop's Stream, two other genera of the same family existed in large numbers: Anagapetus and Glossosoma. It is reasonable to assume that the diet control exhibited by Agapetus fuscipes is not unique. Its cold-water relatives may share its specific appetite for Achnanthes spp.

I also mentioned on page 72 that Cocconeis placentula may require a bacterial film to settle on, and that iron bacteria formed ubiquitous masses on slides in Bishop's Stream, while a paucity were found on slides in L-1. Though the length of time for these bacteria to colonize the glass slides (from 1 to 2 weeks) seems rather long, the premise for the requirement of a bacterial film before Cocconeis can settle is founded upon previous studies which indicated that the first colonizers of slides are generally bacteria and that bacteria films influence diatom colonization (Smyth, 1955). ZoBell and Allen (1935) noticed larger numbers of micro-organisms on film-coated slides than on sterilized ones, and regarded this as due to the provision of a mucilagenous surface and a richer nutrient supply. Coe & Allen (1937) and Sheer (1945) also observed that more diatoms settled on slides with a bacterial film.

Light is a third possible factor involved in differential growth of Cocconeis placentula and Achnanthes lanceolata. McIntire (1968) found that Achnanthes growth rate was correlated (P=.01) negatively with light and positively correlated with current. The positive correlation of Cocconeis to light has already been discussed on page 102. Another species which preferred L-1, Navicula cryptocephala, was shown to be negatively correlated with light and positively correlated with current (McIntire, 1968).

The slide data and rock data given in Tables 1 and 2 of Appendix II is consistent with several studies discussing "indicator species":

Amphora ovalis v. pediculus, exclusive to Bishop's Stream, favors high aeration and is an oligohalobe and an alkaliphyl. Cymbella amphicephala, an oxygen-loving species, is also restricted to Bishop's Stream, as are Cymbella cymbiformis and Cymbella tumida, which are oligohalobes. Cymbella tumida especially disfavors organic pollution (Patrick & Reimer, 1972). Species found in higher numbers in L-1, though not exclusive to this stream, favor organically enriched waters: Gonphonema parvulum; and Navicula atomus (Rice, 1938). The latter species is tolerant of chromium, a possible toxicant in L-1 (Palmer, 1959).

Nitzchia linearis and Synedra ulna, diatoms which are considered by Kolkwitz and Marsson as oligosaprobic species (restricted to clean water) were both found in large numbers in L-1. Nitzchia linearis and Surirella ovata, also found in large numbers in L-1, favor a high percentage of nitrates over phosphates (Hustedt, 1939). High levels of nitrates in L-1 compared with Bishop's Stream may be responsible for higher numbers of these two species in the former stream. Synedra ulna, Gonphonema parvulum, Nitzchia palea, Cymbella ventricosa, Fragellaris virescens, and Navicula viridula can tolerate copper concentrations of 1.5 mg./l. (Schroeder, 1939). The first three diatoms inhabit L-1, which may receive traces of copper from a plating factory. The presence of Synedra ulna, an otherwise clean water species may be explained by its competitive advantage over other species when copper is present. Synedra also favors large amounts of calcium in the water, like that found in L-1, which may explain Synedra's tolerance to copper. Calcium antagonizes toxic effects of various heavy metals by precipitating them (Patrick, 1977).

Stigeoclonium tenue, not found in Bishop's Stream, is an alpha-mesosaprobe (tolerant of high pollution) according to Kolkwitz & Marsson (1908) and is considered to be tolerant of chromium and copper (Palmer, 1959).

The higher numbers of the Chlorophyceae in Bishop's Stream may be a result of hardness. Pearsall (1924) states that in calcium-poor waters carbohydrate-producing organisms dominate, while in calcium-rich waters fat-producing organisms dominate. This could partially explain the larger biomass of Chlorophyceae, which produce starch for storage, in Bishop's Stream while a large and diverse diatom population flourishes in both streams. Calcium hardness in L-1 is about a third higher than in Bishop's Stream.

There is, I think, a certain danger in drawing too many conclusions from information such as just outlined above. Apart from providing some missing pieces of a puzzle, such information can be highly misleading, and can, in fact, hamper more than help a descriptive taxanomic study. In this case the general information from the literature as applied to the three streams is quite consistent. It would seem that the principal stressing factor in L-1 is organic load with possible complications arising from trace toxicants and low light.

Patrick (1974) describes a floral community with low diversity but moderate biomass such as the community of L-1 and L-2 as indicative of a low level of toxicity, or light organic load, or adverse temperature effects. She further asserts that this kind of condition (low diversity; moderate biomass) is difficult to diagnose except to say that pollution is present. Indeed, any or all of the above mentioned sources of perturbation may be responsible for creating the community structure witnessed on the rocks and slides of L-1 and, to a lesser extent, L-2.

Orientation of slides to current:

Preference of diatoms for edges of slides oriented edge-wise to the current can be observed with the naked eye. This non-random distribution is in large part caused by the presence of Cocconeis placentula, described by Backhaus (1968) as being current indifferent. I disagree with him.

I ascribe the preference for upstream and downstream edges of slides to current. Figure 17A, taken from theoretical fluid mechanics, shows the movement of a viscous liquid around a cylinder. Fluid piles up at the face of the obstructive surface, rendering the velocity here to zero. This is called the stagnation point. A layer of molecules, the boundary layer, extends from the forward stagnation point to the two edges of the wake where the separation point exists. Due to viscosity and frictional drag (no-slip condition) the momentum of the fluid is appreciably less in the boundary layer than it is a little further away from the object. There is a velocity gradient that eventually reaches zero immediately adjecent to the boundary surface. In the current shadow, the wake exists due to the low momentum of the boundary layer fluid. The flow of the wake is irregular and unsteady and often turbulent (Evans, 1968).

Cocconeis placentula was shown to grow on experimental spheres suspended in a stream, on the side exposed to the current and in the current shadow, but not on the sides where the water shears past (Gessner, 1952).

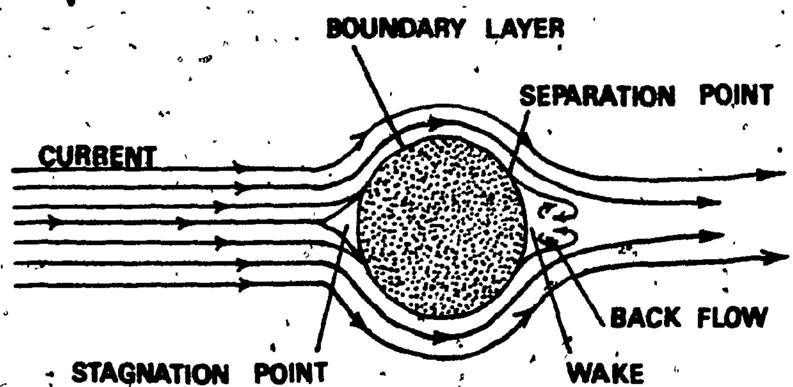
Figure 17B shows how I apply the theory of fluid mechanics to a rectancular object meant to represent the glass slide. Note the stagnation point, wake, and backflow as in the theoretical model. The boundary layer most certainly exists as well but does not enter into our discussion as it is only a few molecules thick and the velocity gradient would be too minute to effect large diatoms in the neighbourhood of 25 microns. I postulate the existence of micro-eddies at the front and back of the slide resulting from the stagnation point and wake respectively. It must be kept in mind that the theoretical model (Figure 17A) assumes laminar flow or low Reynold's number. This is an assumption I can not make in the case of the stream nor in the case of Gessner's suspended spheres.

Two reasons have been postulated to explain preference of Cocconeis placentula of edges of the slide that is oriented edge-wise to the curmet. Distances of area A and B of Figure 17B being equal:

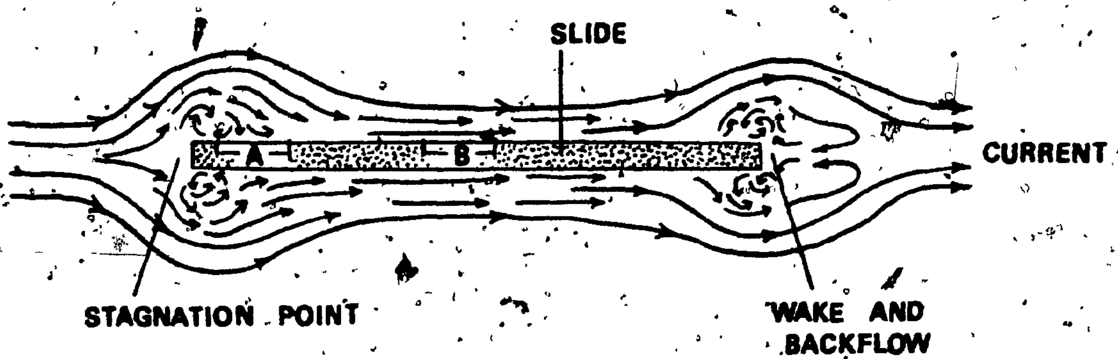
1) At an area of turbulence the drift velocity is less than at an area of laminar flow. Therefore there is more time for the diatom to settle on area A(turbulent flow) than area B(laminar).

2) Turbulence in itself increases the number of chance hits upon a

FIGURE 17: A, movement of a viscous liquid around a cylinder from Evans, "Laminar-Boundary-Layer Theory", 1968; B, movement of water around a glass slide oriented edge-wise to the current.


BOUNDARY LAYER
SEPARATION POINT
CURRENT
BACK FLOW
STAGNATION POINT
WAKE

A


SLIDE
A
B
CURRENT
STAGNATION POINT
WAKE AND BACKFLOW

B

bluff surface over laminar flow which is parallel to the object's surface.

These two reasons also explain the results of Gessner (1952). The generally higher preference of upstream over downstream edges of slides parallel to the current evinced by Cocconeis may be a simple case of availability. The first surface encountered would be assumed to have higher numbers.

The high biomass found homogeneously throughout the current-exposed surface of the slide oriented normal to the current and comparable to the diatom biomass on the edges of the slides oriented parallel to the current (see Figure 16) is explained by the stagnation point and resultant turbulence. A high Reynold's number found in Bishop's Stream ensures turbulence associated with the stagnation point so that diatoms will readily settle anywhere on the current-exposed slide.

I suggested on page 92 that preference for bottom of slides by diatoms at muddy subsites may be due to seeding from the mud or to higher nutrient renewal from sediment stirring. Three reasons why more diatoms were found at the tops of the slides at rocky subsites are:

1) The higher velocity at the top, near the surface, may increase the number of chance hits or invasion rate.

2) Light conditions are superior at the top of the slide.

3) Higher aeration exists at the top.

I encountered several slides which showed preference by diatoms for all edges, leaving a small central unoccupied area.

The effect of season on the gradient and intensity of preferential distribution is explained by its influence on Cocconeis placentula, the main colonizer of the slides. Species pool, reproduction and settling rates are all affected by season.

Preference of diatoms for top or bottom of slides was never as marked as the horizontal zoning, demonstrating that current is more important than light or nutrient renewal in preferential microdistribution of diatoms on slides.

## SUMMARY AND CONCLUSION

Field experiments using diatometers show that spatial succession, substrate, and seasonal succession all significantly affect the diatom community settling on slides.

Communities were not independant from station to station. Diversity and total numbers were highest at Station 2. The slide community downstream of Station 2 were precluded from growing due to the increased clay and sand particles which acted as scouring agents on the slide periphyton numbers and species richness by affecting species pool and settling efficiency.

Though communities were not independant between subsites, and diversity differed insignificantly, higher numbers of diatoms were found on slides situated at rocky areas. This appears to be a result of higher seeding from heavily colonized rocks as compared to that experienced by slides situated near muddy substrates.

Seasonal changes of slide communities matched the patterns given in the literature for periphyton growing on slides in rivers and streams. The dominant community shifts from a more diverse, less populated, group in spring to a larger populated and less diverse group in late summer. This is a result of partial competitive exclusion by _Achnanthes lanceolata_, _Achanthes lanceolata v. dubia_, _Achnanthes linearis_, _Achnanthes minutissima_, _Eunotia pectinalis v. minor_, and _Cocconeis placentula_. This phenomenon is a function of differential growth rates in terms of settling and reproduction. Seasonal fluctuations of the slide community can be explained by differential growth rates: _Cocconeis placentula_ grows faster in late summer. Current changes play a fundamental role in seasonality of diatoms. The antagonistic relationship of Cocconeis placentula and two Achanthes species, Achnanthes linearis and A. minutissima is explained by differing strategies of these two genera to current, adhesion to surfaces, and to their differing growth rates. Therefore, seasonality of diatoms may be a result of competitive factors as well as strict environmental contingencies.

Comparison results of Bishop's Stream with L-1 suggest that no one method of testing ( chemical analysis, measurements of flora and fauna community on rocks, and diatometer) is conclusive. Pooled, the results are consistent with the conclusion that L-1 is organically polluted. Flora populations on slides and rocks differed between L-1 and Bishop's Stream. Achnanthes lanceolata dominated slides in L-1 and Cocconeis placentula dominated slides in Bishop's Stream. The different chemistries of the two streams may have caused this inverse relationship through direct means or indirect means, by acting upon other biota: selective grazing or a requirement by Cocconeis for a bacterial film as a substrate may have been responsible. Different light requirements by Achnanthes and Cocconeis may also have influenced their distribution.

Non-random distribution of diatoms on slides sampled in 1977 was observed. Data from transects drawn across slide surfaces showed that individuals first settled on the edges of the slide, particularly the upstream and downstream edges, and, to a lesser extent, the edge closest to the surface. Generally by six weeks diatoms were homogeneously distributed on the slide. The non-random distribution was most pronounced on slides containing Cocconeis placentula. Micro-eddies due to a stagnation point and wake at the upstream and downstream edges of the slide respectively are postulated as the cause for this preferential distribution.

At the areas of higher turbulence the drift velocity is less than at the areas of laminar flow. Also, turbulence in itself increases the number of chance hits upon a bluff surface over laminar flow which is parallel to the object's surface. Both these factors would serve to increase diatom numbers at the upstream and downstream edges of slides parallel to the current. Experiments done in 1978 compared microdistribution of diatoms on slides oriented parallel to the current and facing the current. Results concurred with the hypothesis: current is mainly responsible for preferential distribution of diatoms on slides.

No significant substrate preference by diatoms, using frosted and smooth glass slides, was observed. However, Cocconeis placentula appeared to prefer the smooth surface and Achnanthes linearis preferred the frosted surface.

## FINAL CONCLUSION

It is the opinion of this author that careful consideration should be given to all aspects of the environment when doing field studies, epsecially for the purpose of studying man made changes in the environment.

Diversity, used in pollution studies to measure stress and instability of communities caused by various toxicants and pollutants, is seen here to be affected by natural variables (especially season): low diversity does not show instability of a community; rather, it alludes to stability.

Year to year variation (as seen by comparing seasonal growth of *Cocconeis* in 1976 with 1977) is so drastic so as to preclude accurate before and after comparisons unless all the relevant environmental factors are known and taken into consideration.

## DIATOMETERS AND POLLUTION

There has been of late, since Tippett's study in 1970, doubt as to the ecological significance of using glass slides in periphyton investigations. This is largely unfounded. One must simply keep in mind precisely what one is testing: colonization of a bare surface by invading microorganisms -- not to be confused with what already exists on the natural surfaces. To reiterate, I believe that exposing slides in water systems is a highly sensitive technique in periphyton research whose advantages far outweigh the disadvantages. So long as one acknowledges the existence of a community prejudiced toward glass slide surfaces and positions, one can make sound ecological judgments. The diameter is an efficient way of bringing the laboratory to the field, so to speak, and, in many cases, the field to the laboratory.

However, my results indicate that too much inherent variability exists in the environment for the diatometer to be used at the present time as an accurate gauge in pollution studies, particularly in the case of mild pollution. The potential of the diatometer regarding predictability is good. However, it is presently hampered by the paucity of reliable and consistent *in situ* information on natural environmental factors and how they affect the glass slide community. As I said earlier, these must be understood before predictions regarding extraneous changes imposed on the community can be accurately weighed.

## BIBLIOGRAPHY


Abdin, 1950. Benthic algal flora of Aswan reservoir (Egypt). Hydrobiologia 2: 118-133.

Backhaus, D. 1968. Okologische Untersuchnungen an den Aufwuchs-algen der obersten Donau und ihrer Quellflüsse. III Die Algenverteilung und ihre Beziehungen zur Milienofferte. Arch. Hydrobiol., Suppl. XXXIV: 130-149.

Behning, A.L. 1924. Zur Erforschung der am Flussboden der Wolga lebenden Organismen. Monogr. Biol. Wolga Statt 1: 1-398.

Berg, K. et al. 1948. Biological studies in the River Susaa. Folia limnol. Scand. 4: 318pp.

Bissonette, T.H. 1930. A method of securing marine invertebrates. Science 71: 464-465.

Blum, J. 1956. The ecology of river algae. Bot. Rev. 22(5): 291-

Booth, J.D. 1973. Land use and water quality in an agricultural watershed in the Eastern Townships, unpublished.

Brown, S. and Austin, A. 1973. Diatom succession and interaction in littoral periphyton and plankton. Hydrobiologia 43(3-4): 333-356.

Butcher, R.W. 1931. An apparatus for studying the growth of epiphytic algae with special reference to the River Tees. Trans. Nth Nat. Un. 1(1): 1-15.

_______. 1946. Studies in the ecology of rivers. VI. The algal growth in certain highly calcareous streams. J. Ecol. 33: 268-283.

_______. 1947. Studies in the ecology of rivers. VII. The algae of organically enriched waters. J. Ecol. 35: 186-191.

Cairns, J., Lanza, G., and Parker, B. 1972. Pollution related structural and functional changes in aquatic communities with emphasis on freshwater algae and protozoa. Proc. Ac. Na. Sc. Phil. 124(5): 79-127.

Castnholz, R.W. 1961. An evaluation of a submerged glass method of estimating production of attached algae. Verh. int. Verein Limnol. 14: 155-159.

Cattaneo, A. 1978. The microdistribution of epiphytes on the leaves of natural and artificial macrophytes. Br. Phycol. J. 13: 183-188.

Cattaneo, A., Ghittori, S., and Vendegna, V. 1975. The development of benthic phytocoenosis on artificial substrates in the Ticino River. Oecologia (Berl.) 19: 315-327.

Cleve von-Euler, M. 1951-55. Die Diatomeen von Schweden und Finnland. Almquist und Wiksells, Stockholm.

Chu, P. 1949. How to know the immature insects. W.C. Brown Co., Dubuque, Iowa.

Coe, W.R., & Allén, W.E. 1937. Growth of sedentary marine organisms on experimental blocks and plates for nine successive years. Bull. Scripps Instn. Oceanogr. Tech. 4: 101.

Conover, W.J. 1971. Practical nonparametric statistics. John Wiley & Sons Inc., New York.

Cooke, W.M. 1956. Colonization of artificial bare areas by microorganisms. Bot. Rev. 22: 613-638.

Côté, Lemieux, Carignan, & Royer, 1964. Preliminary study for collection of sewage and construction of a sewage treatment plant, Sherbrooke.

Devlin, R. 1975. Plant Physiology, 3rd. ed. D. Van Nostrand Co., New York.

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

Drouet, F. 1968. Revision of the classification of the Oscillatoriaceae. Academy of Nat. Sciences of Phil., Philadelphia, 370 pp.

Eddy, S. 1934. A study of freshwater plankton communities. Illinois biol. Monogr. 12: 1-93.

Einsele, W. 1960. Die Stromungsgeschwindigkeit als beherrschender Factor bei den limnologischen Gestaltung der Gewasser. Osterreichs Fischerei, Suppl. 1, 2: 40pp.

Elliott, J.M. 1971. Some methods for statistical analysis of samples of benthic invertebrates. Freshwater Biological Association, Scientific Publi. No. 25.

Fjerdingstad, 1962. Some remarks on a new saprobic system. In Biological Problems in Water Pollution, 3rd. seminar. Public Health Service Publication 999-WP-25, pp. 252-5.

Foerster, J.W., Schlichting, H.E. 1965. Phycoperiphyton in an oligotrophic lake. Trans. Am. microsc. Soc. 68: 355-361.

Gaufin, A. 1958. The effects of pollution on a mid western stream. Ohio J. Sc. 58(4): 197-208.

Geitler, L. 1927. Uber einige haufige aber wenigbekannt Algen aus Gebirgsbachen. Mikrosk. f. Naturfreunde, p. 1.

Gessner, F. 1952. Der druck in seiner bedeutung fur das wachstum submerser wasserpflanzen. Planta 40: 391-397.

Godward, M.B. 1934. An investigation of the causal distribution of algal epiphytes. Beih. Bot. Zbl. 52: 506-539.

______. 1937. An ecological and taxanomic investigation of the littoral algal flora of Lake Windermere. J. Ecol. 25: 496-568.

Hairston, N.G. 1959. Species abundance and community organization. Ecology 40: 404-416.

Hansmann, E., Phinney, H. 1973. Effects of logging on periphyton in coastal streams in Oregon. Ecology 54(1): 195-199.

Heinsen, E. 1938. Increased hardness - an indication of pollution of ground water. Water Pollution Abstracts - summary of current literature in Water Pollution, 11: 164-.

Hentschel, E. 1916. Biologisch Untersuchungen uber den tierischen und pflanzlichen Bewuchs im Hamburger Hafen. Mitteil ans d. Zool. Mus. Hamburg, xxxiii, p. 176.

Heurck, van H. 1896. A treatise in the Diatomaceae. William Wesley & Son, London.

Hurter, E. 1928. Beobachtungen an Litoralgen des Vierwaldslattersees, Luzern.

Hustedt, F. 1930. Die Susswasser-flora Mitteleuropas, Heft 10: Bacillariophyta, Jena, Verlag von Guslav Fischer.

______. 1939. Systematische und okologische Untersuchungen uber die Diatomeen flora von Java, Bali und Sumatra. Arch. Hydrobiol. Suppl. 16: 274-394.

Hutchinson, G.E. 1957. Concluding remarks Cold Spring Harbor Symposium, Cold Spring Harbor Symposium, Quantitative Biology 22: 415-427.

Johannsen, O.A. 1933. Aquatic Diptera. Entomological Reprint Specialists, Los Angeles.

Klein, L. 1959. River Pollution: I. Chemical Analysis. Butterworths Scientific Publications, London.

______. 1961. River Pollution: II. Causes and Effects. Butterworths Scientific Publications, London.

Kolkwitz, E., Marsson, M. 1908. Okologie der pflanlichen Saprobien. Berichte der Deutschen Botanischen Gesselschaft 26: 509-519.

Leonard, J. 1961. Mayflies of Mishigan trout streams. Cranbrook Institute of Science, Bloomfield Hills, Mich.

Margalef, R. 1955. Los organismos indicadores en la limnologia. XII Biologia de las aguas continentales. Ministerio de Agricultura, Madrid.

McDonald, B.C., Shilts, W.W. 1971. Quaternary stratigraphy and events in southeastern Quebec. Geological Society of America Bulletin, v. 82, p. 683-697.

McIntire, C.D. 1968. Structural characteriscs of benthic algal communities in laboratory streams. Ecology 49(3): 520-537.

Needham, 1938. Trout Streams. Comstock, Ithaca, New York.

Newcombe, C.L. 1949. Attached materials in relation to water productivity. Trans. Am. microsc. Soc. 68: 355-361.

Palmer, 1959. Algae in Water Supplies; an illustrated manual on the identification, significance, and control of algae in water supplies. U. S. Public Health Service Publication No. 657, Washington Gov. Printing Office, 96 pp.

Patrick, R. 1949. A proposed biological measure of stream conditions based on a survey of the Conestoga Basin, Lancaster County, Pennsylvania. Proc. Ac. Nat. Sc. Phil. 101: 277-341.

________. 1949a. Diatoms as an indication of river change. Proc. Eng. Graphics Conf., Purdue University, Extensive series #84: 324-330.

________. 1961. A study of the number and kinds of species found in rivers in the eastern U.S. Proc. Acad. Nat. Sc. Phil. 113(10): 215-258.

________. 1963. The structure of diatom communities under varying ecological conditions. Ann. N.Y. Acad. Sci. 108: 359-365.

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

________. 1968. The structure of diatom communities in similar ecological conditions. Am. Nat. 102(924): 173-183.

________. 1971. The effects of increasing light and temperature on the structure of diatom communites. Limnol. Oceanogr. 16(2): 405-421.

________. 1974. Diatoms as bioassay organisms. Bioassay techniques and environmental chemistry, Ann Arbor Science Publishers Inc., Glass, G. E. ed.; ;;. 139-151.

________. 1977. Ecology of freshwater diatoms and diatom communites. In The Biology of Diatoms, D. Werner, ed. Blackwell Scientific Publications, University of California Press, Berkley.

________, Cairns, J., Scheier, A. 1968. The relative sensitivity of diatoms, snails, and fish to twenty common constituents of industrial wastes. Prog. Fish-Culturist 30(3): 137-140.

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

________, Hohn, M., Wallace, J. 1954. A new method for determining the pattern of the diatom flora. Notul. nat. Acad. Phil. No. 259: 1-12.

________, and Reimer, C. 1966, 1972. The diatoms of the United States. Monographs Acad. Natur. Sci. Phil., vol. I, II.

Pearsall, W.H. 1924. Phytoplankton and environment in the English Lake District. Revue algol. 1: 53-67.

Pennak, R. 1953. Freshwater Invertebrates of the U.S. Ronald Press Co., New York.

Prescott, G.W. 1962. Algae of the Western Great Lakes Area. W.M.C Brown Co. Publishers, Iowa.

Reid, G.K. 1961. Ecology of Inland Waters and Estuaries. D. Van Nostrand Co., New York.

Rice, C.H. 1938. Studies in the phytoplankton of the River Thames, (1928-1932), Part I and II. Ann. Bot. 2: 539-557, 559-581.

Roback, S.S. 1974. Insects (Arthropoda: Insecta) In C.W. Hard Jr. and S.L.H. Fuller, eds. Pollution Ecology of Freshwater Invertebrates. Academic Press, New York; 313-376.

Rodina, A.G. 1956. (Methods of microbiological investigation of water bodies). In Zhizn Presnykh Vod IV. pp. 7-122 Izd. AN SSSR.

Round, F.E. 1965. The Biology of Algae. Edward Arnold Ltd., London, pp. 269.

Shannon, C.E., Weaver, W. 1948. The mathematical theory of communication. Urbana: University of Illinois Press, pp. 3-91.

Schröder, T. 1932. Uber die Moglichkeit einer quantitativeen Untersuchung der Boden-und Ufertierwelt fliessender Gewasser. Zugleich: Fischerei-biologische Untersuchungen im Wesergebiet I. Z. Fisch. 30: 105-125.

Sheer, B.T. 1945. The development of marine fouling communites. Biol. Bull. 89(1): 103-121.

Sladecek, V., Sladeckova, A. 1964. Determination of the periphyton production by means of the glass slide method. Hydrobiologia 23: 125-158.

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

Smith, G.M. 1950. The Freshwater Algae of the U.S., 2nd. ed. McGraw Hill Book Co., Inc., New York.

Smyth, J.C. 1955. The study of benthic diatoms of Lock Sween(Argyll). J. Ecol. 43(1): 149-171.

Sprules, W.M. 1947. An ecological investigation of stream insects in Algonquin Park, Ontario. Univ. Toronto Stud. biol. ser. 56: 1-81.

Strahler, A.N. 1969. Physical Geography, 3rd. ed. John Wiley & Sons, Inc., New York.

Tippett, R. 1970. Artificial surfaces as a method of studying populations of benthic micro-algae in fresh water. Br. phycol. J 5(2): 187-199.

Ward, Whipple, 1958. Freshwater Biology. John Wiley & Sons, Inc., New York.

Weber, C. 1974. Recent developments in the measurements of the response of plankton and periphyton to changes in their environment. In Bioassay Techniques and Environmental Chemistry, Glass, ed. Ann Arbor Science Publishers Inc. pp. 119-137.

Welch, P.S. 1948. Limnological Methods. Blakiston Co., Philadelphia, pp. 381.

Wetzel, R.G. 1965. Techniques and problems of primary productivity measurements in higher aquatic plants and periphyton. Mem. Ist. Ital. Idrobiol. 18(suppl.): 249-267.

______. 1975. Limnology. W.B. Saunders Co., Philadelphia.

Wiggens, G. 1977. Larvae of the North American Caddisfly Genera (Trichopera). University of Toronto Press.

Winkler, O. 1963. Beitrag zur Kenntnis der Boden fauna der oberen Moldau vor der Errichtung der Talsperre in Lipno Acta Univ. Carol. Biol. 85-101.

Wysocka, 1952. (algues de la Vistule au rayon de Varsovie, Partie II. Periphyton). Acta Soc. Bot.. Polon. 21(3): 369-400.

ZoBell, C.E., Allen, E.C. 1935. The significance of marine bacteria in the fouling of submerged surfaces. J. Bacteriol. 29: 247-.

Additional References:

Hodges, L. 1973. Environmental Pollution. Holt, Rinehart and Winston, Inc., Ney York.

Hynes, H.B. 1960. The Biology of Polluted Waters. Liverpool University Press, Liverpool, pp. 202.

______. 1970. The Ecology of Running Waters. University of Toronto Press, Toronto.

APPENDIX I: Chemical and Physical data on Bishop's Stream, L-1 and L-2; Environmental characteristics of the Lennoxville region. See text for explanation.

TABLE 1: Comparison of total sunshine (hours), total rainfall (mm.), and average temperature ( C) for the months May to August of 1976 and 1977 with normal figures. The figures are taken from monthly meteorological summaries provided by Environment Canada for the Lennoxville region.

| | TOTAL SUNSHINE | | | TOTAL RAINFALL | | | AVERAGE TEMPERATURE | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1976 | 1977 | Normal | 1976 | 1977 | Normal | 1976 | 1977 | Normal |
| MAY | 171.4 | 310.8 | 212.0 | 158.9 | 43.7 | 83.6 | 11.2 | 12.7 | 11.3 |
| JUNE | 213.9 | 141.5 | 229.0 | 96.0 | 110.7 | 102.9 | 18.8 | 16.2 | 16.7 |
| JULY | 218.6 | 236.7 | 256.0 | 182.8 | 55.4 | 101.3 | 18.5 | 18.5 | 19.3 |
| AUGUST | 226.5 | 207.7 | 229.0 | 199.2 | 79.8 | 95.5 | 18.1 | 17.4 | 17.9 |

TABLE 2: Comparison of water chemistry and physics of Bishop's Stream with L-1 for 1976. Mean (x) results are given with standard deviation (s).

| VARIABLE (UNIT) | BISHOP'S STREAM | | L-1 | |
|---|---|---|---|---|
| | x | s | x | s |
| $CO_2$ (mg./l) | 3.8 | 1.3 | 4.0 | 3.0 |
| Total alkalinity (mg./l) | 83.0 | 42.5 | 93.0 | 27.7 |
| Carbonate alkalinity (mg./l) | 0.0 | | 3.4 | 6.4 |
| Bicarbonate alkalinity (mg./l) | 83.0 | 42.5 | 90.0 | 25.8 |
| Dissolved oxygen (mg./l) | 7.3 | 0.9 | 7.2 | 1.5 |
| % saturation of oxygen | 70.8 | 8.2 | 69.9 | 12.9 |
| pH | 7.5 | 0.2 | 7.7 | 0.5 |
| Chloride (mg./l) | 9.2 | 2.9 | 41.8 | 13.9 |
| Silica (mg./l) | 6.0 | 1.8 | 7.1 | 1.2 |
| Total hardness (mg./l) | 117.0 | 52.8 | 128.0 | 38.9 |
| Calcium hardness (mg./l) | 53.0 | 12.4 | 77.0 | 28.2 |
| Turbidity (jtu) | 5.8 | 3.4 | 6.5 | 5.0 |
| Color (Hazen units) | 40.0 | 17.1 | 29.0 | 12.5 |
| Surface velocity (meters/sec.) | 0.34 | 0.23 | 0.25 | 0.15 |
| Temperature ( C) | 12.7 | 5.7 | 12.2 | 5.1 |
| Depth (centimeters) | 18.0 | 3.6 | 11.0 | 2.0 |
| Width (meters) | 1.5 | 0.5 | 1.3 | 0.2 |

TABLE 3: Comparison of water chemistry and physics for all stations at Bishop's Stream in 1977. Mean (x) results are given with standard deviation (s).

| VARIABLE (UNIT) | Site 1a x s | Site 1b x s | Site 2a x s | Site 2b x s | Site 3a x s | Site 3b x s | Site 4a x s |
|---|---|---|---|---|---|---|---|
| $CO_2$ (mg./1.) | 6.5 ± 1.4 | 7.4 ± 3.0 | 7.0 ± 3.0 | 8.8 ± 5.6 | 4.9 ± 2.7 | 5.5 ± 1.1 | 9.5 ± 8.0 |
| Total alkalinity (mg./1.) | 72 ± 20.5 | 70 ± 22.8 | 71 ± 13.1 | 69 ± 13.3 | 75 ± 14.7 | 72 ± 13.6 | 133 ± 24.8 |
| Carbonate alk. (mg./1) | 0 | 0 | 0 | 0 | 6.0 ± 9.5 | 0 | 16.0 ± 11.5 |
| Bicarbonate alk. (mg./1.) | 72 ± 20.5 | 70 ± 22.8 | 71 ± 13.1 | 69 ± 13.3 | 69 ± 14.3 | 72 ± 13.6 | 118 ± 22.8 |
| Dissolved oxygen (mg./1.) | 8.6 ± 1.2 | 8.6 ± 0.8 | 8.4 ± 1.2 | 8.4 ± 1.2 | 9.2 ± 1.7 | 8.6 ± 1.4 | 11.2 ± 2.8 |
| pH | 7.7 ± 0.3 | 7.7 ± 0.3 | 7.7 ± 0.3 | 7.7 ± 0.3 | 7.9 ± 0.4 | 7.8 ± 0.4 | 8.1 ± 0.4 |
| Chloride (mg./1.) | 11.4 ± 0 | 11.4 ± 0 | 11.4 ± 0 | 11.4 ± 0 | 11.4 ± 0 | 11.4 ± 0 | 11.4 ± 0 |
| Silica (mg./1.) | 8.9 ± 2.3 | 8.9 ± 2.0 | 7.8 ± 2.4 | 7.8 ± 2.3 | 7.5 ± 1.7 | 7.4 ± 1.8 | 8.5 ± 1.1 |
| Total hardness (mg./1.) | 94 ± 17.4 | 89 ± 21.7 | 83 ± 11.4 | 81 ± 10.2 | 94 ± 17.8 | 106 ± 39.3 | 181 ± 49.0 |
| Calcium hard. (mg./1.) | 59 ± 17.2 | 59 ± 15.5 | 50 ± 11.4 | 52 ± 10.5 | 57 ± 8.5 | 52 ± 5.3 | 114 ± 27.5 |
| Turbidity (jtu) | 12 ± 6.8 | 10 ± 5.3 | 16 ± 13.9 | 16 ± 15.2 | 30 ± 12.3 | 31 ± 8.9 | 5 - |
| Color (Hazen units) | 38 ± 17.2 | 39 ± 16.8 | 50 ± 11.4 | 50 ± 24.5 | 71 ± 28.8 | 73 ± 27.7 | 10 - |
| Surface velocity (M/sec.) | 0.5 ± 0.2 | 0.3 ± 0.1 | 0.3 ± 0.2 | 0.3 ± 0.1 | 0.6 ± 0.5 | 0.4 ± 0.2 | 0.5 ± 0.1 |

TABLE 4: BISHOP'S STREAM: spring and summer, 1976.

| VARIABLE(UNIT) | M. 17 | M. 24 | M. 31 | Ju. 7 | J. 14 | J. 28 | Jl. 5 | J. 12 |
|---|---|---|---|---|---|---|---|---|
| free $CO_2$(mg./l) | 5.0 | 3.0 | 3.0 | 4.0 | 3.0 | 6.5 | 3.0 | 3.0 |
| total alkalinity(mg./l) | 50 | 41.5 | 65 | 70 | 70 | 62 | 70 | 64 |
| hydroxide alk.(mg./l) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alk.(mg./l) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| bicarbonate alk.(mg./l) | 50 | 41.5 | 65 | 70 | 70 | 62 | 70 | 64 |
| dissolved oxygen(mg./l) | 6.8 | 8.4 | 6.9 | 5.9 | 7.3 | 6.2 | 7.2 | 6.5 |
| % saturation of oxygen | 68 | 77 | 72 | 59 | 75 | 65 | 74 | 65 |
| pH | 7.8 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| nitrate(mg./l) | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./l) | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./l) | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| phosphate(mg./l) | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| chloride(mg./l) | 11.0 | 8.0 | 4.0 | 11.4 | 5.0 | 4.0 | 11.4 | 11.0 |
| silica(mg./l) | 6.0 | 5.0 | 7.0 | 7.0 | 7.0 | -- | 8.0 | 7.0 |
| total hardness(mg./l) | 72 | 62 | 90 | 110 | 105 | 100 | 95 | 50 |
| calcium hard.(mg./l) | 42 | 31 | -- | 66 | 54 | 44 | 60 | 50 |
| turbidity(jtu) | -- | -- | -- | -- | 3 | 3 | 3 | 15 |
| color(hazen units) | -- | -- | -- | -- | 25 | 45 | 30 | 60 |
| surface velocity(M/sec.) | 0.25 | 0.6 | 0.3 | 0.3 | -- | 0.18 | -- | 0.5 |
| temperature of water(C°) | 17 | 12 | 17 | 16 | 17 | 18 | 17.5 | 17.5 |
| depth(cm.) | -- | -- | 18 | 18 | -- | -- | 10 | 18 |
| width(meters) | -- | -- | 1.1 | 1.15 | 1.1 | -- | -- | 1.3 |
| scouring flood | | | | + | | + | | |

TABLE 5: LENNOXVILLE-ONE STREAM : spring and summer, 1976.

| VARIABLE(UNIT) | M. 17 | M. 24 | M. 31 | Ju. 7 | J. 14 | J. 28 | Jl. 5 | J. 12 |
|---|---|---|---|---|---|---|---|---|
| free $CO_2$(mg./l).......... | 2.0 | 3.0 | 4.0 | 7.0 | 8.5 | 4.5 | 5.5 | 4.0 |
| total alkalinity(mg./l).. | -- | 41.0 | 91.0 | 110.5 | 72.0 | 72.0 | 73.0 | 68.0 |
| hydroxide alkalinity(mg./l) | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alkalinity(mg./l) | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| bicarbonate alk. (mg./l).. | -- | 41.0 | 91.0 | 110.5 | 72.0 | 72.0 | 73.0 | 68.0 |
| dissolved oxygen(mg./l).. | 7.2 | 7.4 | -- | 6.4 | 5.9 | -- | 5.9 | 6.2 |
| saturation % of oxygen... | -- | 65 | -- | 60 | 57 | -- | 57 | 63 |
| pH ..................... | 7.8 | 7.5 | 7.5 | 6.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| nitrate(mg./l)........... | <0.1 | 0.1 | 0.05 | 0.05 | 0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./l)........... | <0.4 | 0.4 | 0.2 | 0.2 | 0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./l)........... | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| phosphate(mg./l)......... | <0.1 | <0.1 | <0.1 | 0.07 | 0.07 | <0.1 | 0.08 | <0.1 |
| chloride(mg./l).......... | 33 | 33 | 45 | 67 | 68 | 28 | 30 | 36 |
| silica(mg./l)............ | 6.0 | 6.0 | 7.0 | 8.0 | 9.0 | 7.0 | 7.0 | 7.0 |
| total hardness(mg./l).... | 100 | 74 | 130 | 160 | 185 | 110 | 85 | 75 |
| calcium hard.(mg./l)..... | 54 | 44 | 88 | 118 | 118 | 52 | 68 | 64 |
| turbidity(jtu)........... | - | - | - | - | 5 | 5 | 5 | 5 |
| color(hazen units)....... | - | - | - | - | 35 | 6 | 20 | 20 |
| surface velocity(M/sec.) | 0.25 | 0.6 | - | - | 0.13 | 0.14 | 0.16 | - |
| temperature of water(C°) | - | 10 | 14 | 14 | 15 | 18 | 15 | 16.5 |
| scouring flood .......... | | | | + | | + | | |

TABLE 6: BISHOP'S STREAM: summer and fall, 1976.

| VARIABLE(UNIT) | Jl. 19 | J. 26 | A. 2 | A. 9 | A. 18 | A. 25 | S. 30 | O. 30 |
|---|---|---|---|---|---|---|---|---|
| free $CO_2$(mg./1).......... | 4.0 | 4.0 | 3.0 | 4.0 | 3.0 | 3.0 | 2.7 | 7.5 |
| total alkalinity(mg./1).. | 80 | 74 | -- | 200 | 72 | 91 | 80 | 68 |
| hydroxide alk.(mg./1).... | 0 | 0 | -- | 0 | 0 | 0 | 0 | 0 |
| carbonate alk.(mg./1).... | 0 | 0 | -- | 0 | 0 | 0 | 0 | 0 |
| bicarbonate alk.(mg./1).. | 80 | 74 | -- | 200 | 72 | 91 | 80 | 68 |
| dissolved oxygen(mg./1).. | -- | 6.8 | 7.9 | 7.9 | 7.4 | 8.7 | 9.0 | 6.8 |
| % saturation of oxygen... | -- | 63 | 77 | 78 | 77 | 82 | 77 | 53 |
| pH ..................... | 7.8 | 7.8 | 7.5 | 7.5 | 7.0 | 7.5 | 7.5 | 7.5 |
| nitrate(mg./1).......... | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./1).......... | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./1).......... | 1.5 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| phosphate(mg./1)........ | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| chloride(mg./1)......... | 5.0 | 11.0 | 11.0 | 11.0 | 8.0 | 11.4 | 11.0 | 11.0 |
| silica(mg./1)........... | 7.0 | 6.0 | 7.0 | 4.0 | 6.0 | 8.0 | 3.0 | 7.0 |
| total hardness(mg./1).... | 135 | 175 | 110 | 100 | 80 | 130 | 157 | 75 |
| calcium hard.(mg./1)..... | 61 | 52 | 40 | 70 | 62 | 74 | 70 | 48 |
| turbidity(jtu).......... | 5 | 5 | 10 | 5 | 5 | 5 | 5 | 5 |
| color(hazen units)........ | 40 | 40 | 80 | 30 | 60 | 30 | 30 | 20 |
| surface velocity(M/sec.) | 0.16 | 0.2 | 1.0 | 0.25 | 0.25 | 0.2 | -- | 0.25 |
| depth(cm.)............... | 17 | 19 | 21 | 22 | 22 | 20 | -- | 23 |
| width(meters)........... | 1.2 | 1.4 | 2.0 | 1.3 | 2.2 | 2.0 | -- | 2.5 |
| temperature of water(C°) | 16.3 | 12.7 | 14.8 | 15.4 | 15.4 | 12.8 | 8.3 | 4.8 |
| scouring flood .......... | | | + | | + | + | | |

TABLE 7: LENNOXVILLE-ONE STREAM: summer and fall, 1976.

| VARIABLE (UNIT) | Jl. 19 | J. 26 | A. 2 | A. 9 | A. 18 | A. 25 | S. 30 | O. 30 |
|---|---|---|---|---|---|---|---|---|
| free $CO_2$(mg./l) | 0 | 0 | 3.5 | 10.0 | 4.65 | 7.0 | 0 | 5.0 |
| total alkalinity(mg./l) | 130 | 104 | 125 | 112 | 71 | 140 | 100 | 80 |
| hydroxide alk.(mg./l) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alk.(mg./l) | 21 | 12 | 0 | 0 | 0 | 0 | 10 | 0 |
| bicarbonate alk.(mg./l) | 109 | 92 | 125 | 112 | 71 | 140 | 100 | 80 |
| dissolved oxygen(mg./l) | 5.5 | 7.4 | 8.6 | 7.4 | 5.6 | 7.0 | 10.2 | 9.8 |
| % saturation of oxygen | 55 | 75 | 87 | 77 | - | 68 | 95 | 80 |
| pH | 8.5 | 8.5 | 7.8 | 7.5 | 7.5 | 7.8 | 8.5 | 7.5 |
| nitrate(mg./l) | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | 0.08 | <0.1 | <0.1 |
| nitrite(mg./l) | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | 0.3 | <0.4 | <0.4 |
| ammonia(mg./l) | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| phosphate(mg./l) | 1.5 | 1.0 | 0.08 | <0.1 | <0.1 | 1.5 | 0.05 | -- |
| chloride(mg./l) | 47 | 53 | 33 | 47 | 45 | 67 | 40 | 19 |
| silica(mg./l) | 8.0 | 8.0 | 6.0 | 8.0 | - | 8.0 | 4.0 | 7.0 |
| total hardness(mg./l) | 133 | 130 | 100 | 135 | 110 | 158 | 139 | 95 |
| calcium hard.(mg./l) | 110 | 88 | 48 | 100 | 74 | 110 | 94 | 64 |
| turbidity(jtu) | 5 | 20 | 10 | 5 | 0 | 5 | 10 | 3 |
| color(hazen units) | 40 | 50 | 40 | 40 | 25 | 20 | 30 | 20 |
| surface velocity(M/sec.) | 0.16 | 0.14 | 0.33 | 0.12 | 0.5 | 0.2 | 0.3 | ~~0.2~~ |
| depth(cm.) | 17 | 14 | -- | 19 | 17 | 19 | -- | 15 |
| width(meters) | 1.2 | 1.0 | -- | 1.3 | 1.5 | -- | -- | 1.3 |
| temperature of water(C°) | 16 | 16 | 16 | 15.5 | -- | 13 | 12 | 6.5 |
| scouring flood | | | + | | + | + | | |

TABLE 8: LENNOXVILLE-ONE STREAM: winter, 1977. BISHOP'S STREAM: winter, 1977.

| VARIABLE(UNIT) | Lennoxville-One Nov. | Lennoxville-One Jan. | Bishop's Nov. | Bishop's Jan. |
|---|---|---|---|---|
| free $CO_2$(mg./l).......... | -- | 0 | -- | 3.3 |
| total alkalinity(mg./l) | -- | 71 | -- | 175 |
| carbonate alk.(mg./l).... | -- | 11 | -- | 0 |
| bicarbonate alk.(mg./l).. | -- | 60 | -- | 175 |
| dissolved oxygen(mg./l).. | -- | -- | -- | -- |
| % saturation of oxygen .. | -- | -- | -- | -- |
| pH .................... | 7.5 | 8.5 | 7.8 | 7.5 |
| nitrate(mg./l).......... | -- | 0.1 | -- | -- |
| nitrite(mg./l).......... | -- | 0.4 | -- | -- |
| ammonia(mg./l).......... | -- | -- | -- | -- |
| phosphate(mg./l)........ | 0.1 | 0.1 | -- | -- |
| chloride(mg./l)......... | -- | 28 | -- | 11.4 |
| silica(mg./l)........... | -- | 8.0 | -- | 1.5 |
| total hardness(mg./l).... | 180 | 210 | 215 | 250 |
| calcium hard.(mg./l)..... | 20 | 64 | 40 | 50 |
| turbidity(jtu).......... | -- | -- | -- | -- |
| color(Hazen units)....... | -- | -- | -- | -- |
| surface velocity(M/sec.) | -- | -- | -- | -- |
| depth(cm.).............. | -- | -- | -- | -- |
| width(meters)........... | -- | -- | -- | -- |
| temperature of water(C°) | 6.0 | 1.0 | -- | -- |
| scouring flood .......... | | | | |

TABLE 9: STATION ONE -- ROCKY , 1977, Bishop's Stream.

| VARIABLE(UNIT) | E. May | L. May | E. June | L. June | E. July | L. July | E. Aug. | L. Aug. |
|---|---|---|---|---|---|---|---|---|
| free $CO_2$(mg./l).......... | 5.5 | 5.5 | 5.5 | 6.0 | 9.0 | 6.0 | -- | 8.5 |
| total alkalinity(mg./l).. | 41 | 74 | 72 | 42 | 102 | 93 | 84 | 68 |
| hydroxide alk. (mg./l)... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alk. (mg./l)... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| bicarbonate alk.(mg./l).. | 41 | 74 | 72 | 42 | 102 | 93 | 84 | 68 |
| dissolved oxygen(mg./l).. | 10.16 | 8.96 | 8.88 | 7.21 | 8.08 | 7.6 | 10.56 | 7.6 |
| % saturation oxygen ..... | 87 | 92 | 88 | 79 | 80 | 83 | 120 | 74 |
| pH ...................... | 7.3 | 7.8 | 7.5 | 7.3 | 7.8 | 8.0 | 8.0 | 7.8 |
| nitrate(mg./l) .......... | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./l) .......... | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./l) .......... | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| phosphate(mg./l) ........ | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| chloride(mg./l) ......... | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 |
| silica(mg./l) ........... | 6.0 | 10.0 | 8.0 | 6.0 | 11.0 | 11.0 | 11.0 | 7.0 |
| total hardness(mg./l) ... | 80 | 110 | 110 | 60 | 105 | 110 | 96 | 80 |
| calcium hard. (mg./l) ... | 40 | 60 | 90 | 35 | 55 | 70 | -- | 64 |
| manganese(mg./l) ........ | -- | -- | -- | 0.2 | -- | -- | 0.2 | -- |
| turbidity(jtu) .......... | 20 | -- | -- | -- | 5 | 5 | 10 | 20 |
| color(hazen units) ...... | 40 | -- | -- | -- | 30 | 20 | 30 | 70 |
| surface velocity(M/sec.) | 0.66 | 0.29 | 0.4 | 0.66 | 0.37 | 0.28 | 0.5 | 0.66 |
| depth(cm.) .............. | -- | 10 | 14 | -- | 15 | 6 | 7.5 | -- |
| width(meters) ........... | -- | 1.0 | 1.2 | -- | 1.2 | 0.8 | 1.0 | -- |
| temperature of water(C°) | 9 | 17 | 14 | 14 | 15 | 19 | 18 | 15 |
| temp. of air(C°) ........ | 14 | 25 | 22 | 24 | 27 | 29 | 33 | 26 |
| scouring flood .......... | - | - | - | + | - | - | - | + |

TABLE 10: STATION ONE -- MUDDY, Bishop's Stream, 1977.

| VARIABLE(UNIT) | E. May | L. May | E. June | L. June | E. July | L. July | E. Aug. | L. Aug. |
|---|---|---|---|---|---|---|---|---|
| free $CO_2$(mg./l)........... | 5.0 | 6.0 | 5.5 | 6.0 | 6.0 | 6.0 | 10.0 | 14.5 |
| total alkalinity(mg./l).. | 42 | 73 | 62 | 32 | 82 | 91 | 106 | 70 |
| hydroxide alk.(mg./l).... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alk.(mg./l).... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| bicarbonate alk.(mg./l).. | 42 | 73 | 62 | 32 | 82 | 91 | 106 | 70 |
| dissolved oxygen(mg./l).. | 9.56 | 8.96 | 9.24 | 7.21 | 8.08 | 9.4 | 8.88 | 7.68 |
| % saturation oxygen ..... | 83 | 95 | 87 | 67 | 79 | 112 | 95 | 75 |
| pH ...................... | 7.5 | 7.8 | 7.5 | 7.3 | 7.8 | 8.0 | 8.3 | 7.8 |
| nitrate(mg./l)........... | -- | <0.1 | -- | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./l)........... | -- | <0.4 | -- | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./l)........... | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| phosphate(mg./l)......... | 0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| chloride(mg./l).......... | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 |
| silica(mg./l)............ | 7.0 | 10.0 | -- | 6.0 | 10.5 | 11.0 | 11.0 | 7.0 |
| sulfide(mg./l)........... | 0.2 | -- | -- | 0.2 | -- | -- | -- | -- |
| total hardness(mg./l).... | 100 | 105 | 70 | 40 | 105 | 105 | 100 | 86 |
| calcium hard.(mg./l)..... | 40 | 60 | 60 | 30 | 75 | 75 | 73 | 62 |
| manganese(mg./l)......... | -- | -- | -- | 0.2 | -- | -- | 0.2 | 0.2 |
| turbidity(jtu)........... | 10 | -- | -- | -- | 6 | 5 | 10 | 20 |
| color(hazen units)....... | 35 | -- | -- | -- | 30 | 20 | 40 | 70 |
| surface velocity(M/sec.) | 0.4 | 0.17 | 0.28 | 0.5 | 0.1 | 0.25 | 0.33 | 0.5 |
| depth(cm.)............... | -- | 10 | -- | -- | -- | -- | -- | -- |
| width(meters)............ | -- | 1.5 | -- | -- | -- | -- | -- | -- |
| temperature of water(C°) | 9 | 18 | 14 | 14 | 15 | 21.5 | 18.5 | 15.2 |
| temp. of air(C°)......... | 14 | 25 | 22 | 24 | 27 | 29 | 32.5 | 26 |
| scouring flood .......... | - | - | - | - | - | - | - | - |

TABLE 11: STATION TWO -- ROCKY, Bishop's Stream, 1977.

| VARIABLE(UNIT) | E. May | L. May | E. June | L. June | E. July | L. July | E. Aug. | L. Aug. |
|---|---|---|---|---|---|---|---|---|
| free $CO_2$(mg./l)........... | 4.0 | 20.0 | 5.5 | 5.5 | 6.0 | 11.0 | 5.5 | 12.0 |
| total alkalinity(mg./l).. | 63 | 82 | 63 | 42 | 78 | 82 | 80 | 76 |
| hydroxide alk.(mg./l).... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alk.(mg./l).... | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| bicarbonate alk.(mg./l).. | 63 | 82 | 63 | 42 | 78 | 82 | 80 | 76 |
| dissolved oxygen(mg./l).. | 9.72 | 8.32 | 9.92 | 9.8 | 6.4 | 7.64 | 7.92 | 7.6 |
| % saturation oxygen ..... | 87 | 92 | 87 | 87 | 62 | 93 | 80 | 74 |
| pH ...................... | 7.8 | 8.0 | 7.8 | 7.0 | 7.8 | 7.5 | 8.0 | 8.0 |
| nitrate(mg./l)........... | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./l)........... | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./l)........... | <1.0 | <1.0 | <1.0 | 1.5 | <1.0 | <1.0 | <1.0 | <1.0 |
| phosphate(mg./l)......... | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| chloride(mg./l).......... | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 |
| silica(mg./l)............ | 7.5 | 6.3 | -- | 3.5 | 9.5 | -- | 11.0 | 9.0 |
| total hardness(mg./l)..... | 85 | 90 | 70 | 60 | 105 | 90 | 84 | -- |
| calcium hard.(mg./l)..... | 42 | 55 | -- | 30 | 50 | 60 | 64 | -- |
| manganese(mg./l)......... | -- | -- | -- | 0.2 | -- | -- | -- | -- |
| turbidity(jtu)........... | 5 | -- | -- | 7 | -- | 5 | 25 | 40 |
| color(hazen units)....... | 30 | -- | -- | 60 | -- | 40 | 40 | 80 |
| surface velocity(M/sec.) | 0.4 | 0.1 | 0.4 | 0.66 | 0.1 | 0.1 | 0.11 | 0.33 |
| depth(cm.)............... | -- | 21 | -- | 35 | 18 | -- | 20 | -- |
| width(meters)............ | -- | 2.3 | -- | 4 | 3 | -- | 4 | -- |
| temperature of water(C°) | 11 | 18 | 10 | 10 | 15 | 27 | 18 | 15 |
| temp. of air(C°)......... | 24.5 | 30 | 10 | -- | 23 | 34 | -- | 26 |
| scouring flood .......... | - | - | - | + | - | - | - | + |

TABLE 12: STATION TWO -- MUDDY , Bishop's Stream, 1977.

| VARIABLE(UNIT) | E. May | L. May | E. June | L. June | E. July | L. July | E. Aug. | L. Aug. |
|---|---|---|---|---|---|---|---|---|
| $CO_2$(mg./1)................ | 3.0 | 20.0 | 5.5 | 5.5 | 6.0 | -- | 6.5 | 12.0 |
| total alkalinity(mg./1).. | -- | 84 | 60 | 42 | 78 | 80 | 72 | 70 |
| hydroxide alk.(mg./1).... | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alk.(mg./1).... | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| bicarbonate alk.(mg./1).. | -- | 84 | 60 | 42 | 78 | 80 | 72 | 70 |
| dissolved oxygen(mg./1).. | 9.72 | 8.2 | 10.0 | 9.8 | 6.4 | 7.64 | 7.92 | 7.6 |
| % saturation oxygen ..... | 87 | 90 | 88 | 87 | 62 | 93 | 80 | 77 |
| pH ....................... | 7.8 | 7.8 | 7.5 | 7.0 | 7.8 | 7.8 | 7.8 | 8.0 |
| nitrate(mg./1)........... | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./1)........... | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./1)........... | -- | -- | -- | 1.0 | -- | -- | <1.0 | <1.0 |
| phosphate(mg./1)......... | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| chloride(mg./1).......... | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | -- | 11.4 | 11.4 |
| silica(mg./1)............ | -- | 7.0 | 7.0 | 3.5 | 9.5 | -- | 11.0 | 9.0 |
| total hardness(mg./1).... | 93 | 80 | 75 | 60 | 85 | 90 | 86 | -- |
| calcium hard.(mg./1)..... | 51 | 55 | 60 | 30 | 55 | 50 | 66 | -- |
| manganese(mg./1)......... | -- | -- | -- | 0.2 | 0.2 | -- | -- | -- |
| turbidity(jtu)........... | 5 | -- | -- | 7 | 5 | 5 | 30 | 45 |
| color(hazen units)....... | 30 | -- | -- | 60 | 40 | 30 | 40 | 100 |
| surface velocity(M/sec.) | 0.28 | 0.29 | -- | 0.4 | 0.2 | 0.1 | 0.28 | 0.4 |
| depth(cm.)............... | -- | 25 | -- | -- | -- | -- | -- | -- |
| width(meters)............ | -- | 2.5 | -- | -- | -- | -- | -- | -- |
| temperature of water(C°) | 11 | 18 | 10 | 10 | 15 | -- | 18 | 16 |
| temp. of air(C°)......... | 25 | 30 | 10 | -- | 23 | -- | -- | 26 |
| scouring flood .......... | - | - | - | + | - | - | - | + |

TABLE 13: STATION THREE -- ROCKY, Bishop's Stream, 1977.

| VARIABLE(UNIT) | E. May | L. May | E. June | L. June | E. July | L. July | E. Aug. | L. Aug. |
|---|---|---|---|---|---|---|---|---|
| $CO_2$(mg./l)................ | -- | 3.0 | 5.5 | 7.0 | 5.5 | 8.0 | -- | 0.0 |
| total alkalinity(mg./l).. | -- | 84 | 91 | 42 | 70 | 78 | 76 | 82 |
| hydroxide alk.(mg./l).... | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alk.(mg./l).... | -- | 22 | 0 | 0 | 0 | 0 | 0 | 20 |
| bicarbonate alk.(mg./l).. | -- | 62 | 91 | 42 | 70 | 78 | 76 | 62 |
| dissolved oxygen(mg./l).. | -- | 9.32 | 10.0 | 8.28 | 12.6 | 7.2 | 8.04 | -- |
| % saturation oxygen ..... | -- | 88 | 98 | 80 | 150 | 93 | 95 | -- |
| pH ...................... | -- | 8.0 | 8.0 | 7.0 | 8.0 | 8.0 | 7.8 | 8.3 |
| nitrate(mg./l)........... | -- | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./l)........... | -- | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./l)........... | -- | -- | 1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| phosphate(mg./l)......... | -- | 0.1 | 0.1 | 0.1 | -- | 0.1 | 0.1 | 0.1 |
| chloride(mg./l).......... | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 |
| silica(mg./l)............ | 7.0 | 6.5 | 8.0 | 4.0 | 9.0 | 9.0 | -- | 9.0 |
| total hardness(mg./l).... | 130 | 90 | 95 | 60 | 100 | 90 | 95 | 94 |
| calcium hard.(mg./l)...... | -- | 55 | 50 | 45 | 70 | 50 | 65 | 62 |
| manganese(mg./l)......... | -- | -- | -- | 0.2 | -- | -- | 0.2 | 0.2 |
| turbidity(jtu)........... | -- | -- | -- | 40 | -- | 30 | 40 | 10 |
| color(hazen units)....... | -- | -- | -- | 100 | -- | 40 | 100 | 45 |
| surface velocity(M/sec.) | 0.66 | 0.29 | 0.58 | 2.0 | 0.37 | 0.22 | 0.33 | 0.5 |
| depth(cm.)............... | -- | -- | 16 | 30 | 15 | 10 | -- | 15 |
| width(meters)............ | -- | 0.5 | 1.75 | 2.5 | 1.0 | 1.5 | -- | 1.5 |
| temperature of water(C°) | 16 | 13 | 16 | 15 | 24 | 28 | 23 | 16 |
| temp. of air(C°)......... | -- | -- | 17 | 21 | 29 | 37 | 30 | 21 |
| scouring flood .......... | - | - | - | + | - | - | - | - |

TABLE 14: STATION THREE -- MUDDY, Bishop's Stream, 1977.

| VARIABLE(UNIT) | E. May | L. May | E. June | L. June | E. July | L. July | E. Aug. | L. Aug. |
|---|---|---|---|---|---|---|---|---|
| $CO_2$(mg./1)............... | 5.0 | 3.0 | 5.5 | 7.0 | 6.5 | 5.5 | -- | 5.5 |
| total alkalinity(mg./1).. | -- | 80 | 70 | 42 | 88 | 76 | 80 | 70 |
| hydroxide alk.(mg./1).... | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alk.(mg./1).... | -- | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| bicarbonate alk.(mg./1).. | -- | 72 | 70 | 42 | 88 | 76 | 80 | 70 |
| dissolved oxygen(mg./1).. | 10.84 | 8.32 | 9.92 | 8.28 | -- | 6.4 | 8.0 | -- |
| % saturation oxygen...... | 118 | 80 | 105 | 80 | -- | 78 | 92 | -- |
| pH ...................... | 8.0 | 8.3 | 8.0 | 7.0 | 7.5 | 7.8 | 8.0 | 7.8 |
| nitrate(mg./1)........... | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./1)........... | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./1)........... | <1.0 | -- | 1.5 | <1.0 | <1.0 | <1.0 | -- | <1.0 |
| phosphate(mg./1)......... | <0.1 | <0.1 | 0.2 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| chloride(mg./1).......... | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 | 11.4 |
| silica(mg./1)............ | 7.0 | 6.5 | 7.0 | 4.0 | 9.5 | 9.0 | -- | 9.0 |
| total hardness(mg./1).... | 200 | 105 | 75 | 60 | 105 | 105 | 110 | 86 |
| calcium hard.(mg./1)..... | -- | 55 | 55 | 45 | 50 | 45 | 55 | 60 |
| manganese(mg./1)......... | -- | -- | -- | 0.2 | -- | -- | 0.2 | -- |
| turbidity(jtu)........... | -- | -- | -- | 40 | -- | 25 | 40 | 20 |
| color(hazen units)....... | -- | -- | -- | 100 | -- | 40 | 100 | 50 |
| surface velocity(M/sec.) | 0.5 | 0.25 | 0.5 | 1.0 | 0.33 | 0.14 | 0.4 | 0.33 |
| depth(cm.)............... | -- | -- | 16 | -- | -- | -- | -- | -- |
| width(meters)............ | -- | -- | 1.8 | -- | -- | -- | -- | -- |
| temperature of water(C°) | 16 | 15 | 16 | 15 | -- | 28 | 23 | 15 |
| temp. of air(C°)......... | -- | 29 | 17 | 21 | [illegible] | 37 | 30 | 21 |
| scouring flood .......... | - | - | - | + | - | - | - | - |

TABLE 15: STATION FOUR --UPSTREAM OF MAIN SEWAGE OUTLET, L-2, 1977.

| VARIABLE(UNIT) | E. May | L. May | E. June | L. June | L. July | E. Aug. |
|---|---|---|---|---|---|---|
| free $CO_2$(mg./l)............ | 2.5 | 0 | 0 | 5.5 | 0 | 0 |
| total alkalinity(mg./l)... | 170 | 132 | 150 | 140 | 116 | 92 |
| hydroxide alk.(mg./l)..... | 0 | 0 | 0 | 0 | 0 | 0 |
| carbonate alk.(mg./l)..... | 20 | 30 | 22 | 0 | 22 | 0 |
| bicarbonate alk.(mg./l)... | 150 | 102 | 128 | 140 | 94 | 92 |
| dissolved oxygen(mg./l)... | -- | 9.0 | 10.28 | 8.12 | 14.0 | 12.68 |
| % saturation oxygen ...... | -- | 88 | 99 | 78 | 135 | 130 |
| pH ...................... | 8.3 | 8.3 | 8.3 | 8.0 | 8.5 | 7.3 |
| nitrate(mg./l)........... | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| nitrite(mg./l)........... | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 | <0.4 |
| ammonia(mg./l)........... | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 | <1.0 |
| phosphate(mg./l)......... | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 |
| chloride(mg./l).......... | 32.65 | 21.35 | 19.95 | 28.5 | 25.65 | 29.92 |
| silica(mg./l)............ | -- | 7.0 | -- | 9.0 | 9.5 | -- |
| total hardness(mg./l)..... | -- | 165 | 170 | 132 | 275 | 160 |
| calcium hard.(mg./l)...... | -- | 130 | 95 | 85 | 100 | 160 |
| manganese(mg./l).......... | -- | -- | -- | 0.2 | -- | -- |
| turbidity(jtu)............ | -- | -- | -- | -- | 5 | -- |
| color(hazen units)........ | -- | -- | -- | -- | <10 | -- |
| surface velocity(M/sec.) | -- | 0.4 | 0.4 | 0.5 | 0.66 | 0.5 |
| depth(cm.)............... | -- | 16 | -- | 16 | -- | -- |
| width(meters)............ | -- | -- | -- | 5 | -- | -- |
| temperature of water(C°) | -- | 15 | 15 | 15 | 14 | 17 |
| temp. of air(C°).......... | -- | 25 | 24 | 26 | 17 | 27 |
| scouring flood ........... | - | - | - | + | - | - |

TABLE 16: STATION FOUR -- DOWNSTREAM OF OUTLETS, L-2, 1977.

| VARIABLE(UNIT) | L. July | E. August |
|---|---|---|
| free $CO_2$(mg./l) | 0 | -- |
| total alkalinity(mg./l) | 154 | 142 |
| hydroxide alk.(mg./l) | 0 | 0 |
| carbonate alk.(mg./l) | 20 | 22 |
| bicarbonate alk.(mg./l) | 134 | 120 |
| dissolved oxygen(mg./l) | 8.24 | -- |
| % saturation oxygen | 80 | -- |
| pH | 8.5 | 8.3 |
| nitrate(mg./l) | <0.1 | <0.1 |
| nitrite(mg./l) | <0.4 | <0.4 |
| ammonia(mg./l) | <1.0 | 1.0 |
| phosphate(mg./l) | <0.1 | <0.1 |
| chloride(mg./l) | 25.0 | 28.5 |
| silica(mg./l) | 10.5 | 9.0 |
| total hardness(mg./l) | 290 | 162 |
| calcium hard.(mg./l) | 120 | 100 |
| manganese(mg./l) | -- | -- |
| turbidity(jtu) | 5 | 10 |
| color(hazen units) | 10 | 30 |
| surface velocity(M/sec.) | 0.5 | 0.5 |
| depth(cm.) | -- | -- |
| width(meters) | -- | -- |
| temperature of water(C°) | 14 | -- |
| temp. of air(C°) | 17 | -- |
| scouring flood | + | - |

APPENDIX II: Biota of Bishop's Stream, L-1 and L-2.

TABLE 1: List of diatoms that colonize glass slides (x), and rocks (*) of Bishop's Stream in 1976 (Site 2a), 1977 (all sites); L-1 (1976) and L-2 (1977).

| SPECIES | BISHOP'S STREAM 1977 | 1976 | L-1 1976 | L-2 1977 |
|---|---|---|---|---|
| Achnanthes lanceolata Bréb. | x* | x | x | x* |
| Achnanthes lanceolata v. dubia Grun | x* | x | x | x |
| Achnanthes linearis W. Sm. | x* | x* | x | x* |
| Achnanthes minutissima Kutz. | x* | x* | x | x* |
| Amphipleura pellucida Kutz. | x* | x | | |
| Amphiprora serans | x | | | |
| Amphora delicatissima Kraske | x* | | | |
| Amphora ovalis v. pediculus Kutz | x* | x | | * |
| Anomoensis serians v. brachysira (Bréb) Hust. | x | | | |
| Caloneis ventricosa v. subundulata (Grun.)Patr. | x* | | | |
| Cocconeis pediculus Ehr. | x* | | | * |
| Cocconeis placentula Ehr. | x* | x* | x* | x* |
| Cyclotella catanata Grun. | x* | | | |
| Cyclotella glomerata Bachm. | x* | x | | * |
| Cymatopleura solea (Bréb) W. Sm. | x* | | | * |
| Cymbella affinis Kutz. | x* | | | * |
| C. amphicephala Naegeli | x* | x* | | * |
| C. bremi Hust. | x* | * | | |
| C. cymbiformis (Kutz.) V. Heurck | x* | x* | | |
| C. lanceolata (Ehr.) V. Heurck | x | | | |
| C. naviculiformis Auersward | x | | | |
| C. obtusiuscula (Kutz) Grun. | x* | | | |
| C. parva (W Sm.) Cleve | x | | | |
| C. sinuata Greg. | x* | x* | x | * |
| C. tumida Bréb. | x* | * | | |
| C. turgida (Greg.) Cleve | x* | | | x* |
| C. ventricosa Kutz. | x* | * | x* | x* |
| Diatoma elongatum Agardh. | x | | | |
| Diatoma vulgaris Bory | x | | | |
| Diatoma sp. | x | | | |
| Diploneis elliptica (Kutz.) Cleve | x* | x | | |
| Diploneis puella (Shumann) Cleve | x | | | |
| Epithemia turgida | * | | | |
| Eunotia curvata (Kutz.)Lagerst. | x* | | | |
| Eunotia pectinalis v. minor (Kutz.) Rabh. | x* | x | | * |
| Eunotia suecica Cleve | * | | | |
| Eunotia incisa (W. Sm.) Greg. | x* | | | |
| Eunotia tenella (Grun.) Hust. | x | | | |
| Eunotia valida Hust. | x* | | | |
| Eunotia sp. | x* | * | | |

TABLE 1: Continued.

| SPECIES | BISHOP'S 1977 | STREAM 1976 | L-1 1976 | L-2 1977 |
|---|---|---|---|---|
| Fragillaria capucina Desm | x* | x | x* | * |
| F. capucina v. mesolepta (Rabh) Grun. | x* | | | |
| F. construens (Ehr.) Grun. | x* | x | | * |
| F. construens v. subsalina Hust. | x | | | |
| F. construens v. venter (Ehr.) Grun. | x | | | |
| F. crotonensis Kitton | * | | | x |
| F. pinnata Ehr. | x* | x | | |
| F. virescens Ralfs. | x* | x | | |
| Frustula rhomboides (Ehr.) de Toni | x* | | | |
| Frustula vulgaris Thwaites | | * | | * |
| F. vulgaris v. capitata Kraske | x* | | | |
| F. weinholdii Hust. | x* | | | * |
| Gonphonema acuminatum Ehr. | x* | x | | * |
| G. acuminatum v. brebissonii | * | | | |
| G. acuminatum v. coronata (Ehr) W. Sm. | x* | x* | | |
| G. augur Ehr. | x | | | |
| G. constrictum Ehr. | x* | x* | | |
| G. intricatum Kutz | x* | | | |
| G. longiceps v. subsalina fo gracilis Hust. | x* | | | |
| G. olivaceum (Lyngb.) Kutz. | x* | x* | x* | * |
| G. olivaceum v. calcarea Cleve | x* | * | x | * |
| G. parvulum (Kutz.) Grun. | x* | * | x* | x* |
| G. spheorophorum Ehr. | x* | x* | x | |
| Gyrosigma obtusatum (Sull.&Wor.) Boy. | x | | | x |
| Gyrosigma sp. | x* | x | | * |
| Hantzschia amphioxys (Ehr.) Grun. | * | | | |
| Melosira varians C.A. Ag. | x* | x* | * | x* |
| Meridion circulare Agardh. | x* | x | x | * |
| Meridion circulare v. constricta (Ralfs) V. Heurck | x* | | x | |
| Navicula atomus (Naegeli) Grun. | x* | x | x | * |
| N. cryptocephala Kutz. | x* | x* | x* | x* |
| N. cryptocephala v. veneta (Kutz.) Grun. | x* | | | * |
| N. gothlandica Grun. | x* | | | |
| N. graciloides A. Mayor | x | | | |
| N. festiva Krasske | x* | | | |
| N. hungarica v. capitata (Ehr) Cleve | x* | x | | * |
| N. minima Grun. | x | | | |
| N. odiosa A.G.C. | x* | x | | * |
| N. pupula v. rectangularis (Greg.) Grun. | x* | | | * |
| N. platystroma Ehr. | x* | | | * |
| N. radiosa Kutz | x* | x | | x* |
| N. radiosa v. parva Wallace | x | | | |

TABLE 1: Continued.

| SPECIES | BISHOP'S STREAM 1977 | BISHOP'S STREAM 1976 | L-1 1976 | L-2 1977 |
|---|---|---|---|---|
| Navicula radiosa v. tenella(Brêb) Grun. | x | x | | x* |
| N. rhyncocephala Kutz | x* | x | | * |
| N. rhyncocephala v. germainii | x* | x | | * |
| N. tripunctata v. schizonemoides (V. H.)Patr. | x* | | | * |
| N. viridula Kutz. | x* | * | | * |
| N. seminulum Grun. | | | x | |
| Nitzchia acicularis W. Sm. | x* | x* | * | * |
| N. acuta Hantzch | x | | | |
| N. amphibia Grun. | x | | | |
| N. capitellata Hust. | x | | | |
| N. closterium (Ehr.) W. Sm. | x | | | |
| N. clausii Hant. | x* | | | |
| N. communis Rabh. | x* | | x | |
| N. commutata Grun. | x | | | |
| N. dissipata (Kutz.) Grun. | x* | x | x | |
| N. gracilis Hant. | x* | | | * |
| N. ignorata Krasske | x* | | | * |
| N. holstatica Hust. | x* | | x | * |
| N. kutzingiana Hilse | x | x | x | x* |
| N. linearis W. Sm. | x* | x* | x* | x* |
| N. palea (Kutz.) W. Sm. | x* | x | x* | * |
| N. paleaceae Grun. | x* | x | x | * |
| N. recta Hant. | x* | x | x | * |
| N. romana Grun. | x | | | |
| N. sigmoidea (Ehr.) W. Sm. | * | | | |
| N. subtilis (Kutz.) Grun. | x* | | x | * |
| N. sublinearis Hust. | x* | x | x* | * |
| N. thermalis v. intermedia Grun. | x* | | x | |
| N. thermalis v. minor Hilse | x* | | | |
| N. vermicularis (Kutz.) Grun. | x* | x | | |
| Pinnularia biceps | x | * | | |
| P. major (Kutz.)Rabh. | x | | | |
| P. mesolepta (Ehr.) W. Sm. | x | * | | |
| P. nodosa (Ehr.)W. Sm. | x | | | |
| Pinnularia sp. | x | x | | |
| Rhapolodia gibba (Ehr.) O. Mull | x* | | | |
| Rhoicosphenia curvata (Kutz.)Grun. | x | | | * |
| Rhoicosphenia Van Heurki | x | x | | |
| Stauroneis anceps Ehr. | x | | x | |
| Stauroneis Smithii Grun. | x* | | | * |
| Surirella angustata Kutz. | x* | | x | * |
| S. ovata Kutz. | x* | x* | x* | * |
| S. ovata v. pinnata W. Sm. | x* | | x | * |
| S. robusta v. splendida(Ehr.)V.H. | x* | | | |

TABLE 1: Continued.

| SPECIES | BISHOP'S STREAM 1977 | BISHOP'S STREAM 1976 | L-1 1976 | L-2 1977 |
|---|---|---|---|---|
| Synedra actinastroides Lemm. | * | | x | |
| S. rumpans v. familiare (Kutz.)Grun. | x | | | |
| S. socia Wallace | x* | x | | * |
| S. ulna (Nitzch.) Ehr. | x* | x* | x* | * |
| S. ulna v. danica | x | x* | | |
| Tabellaria fenestrata(Lyng.) Kutz. | x* | | | |
| T. flocculosa (Roth) Kutz. | x* | | | |

TABLE 2: List of algal taxa other than the Bacillariophyceae which colonize glass slides (x) and rocks (*) of Bishop's Stream (1976, 1977), L-1 (1976), and L-2 (1977).

| TAXON | BISHOP'S STREAM | L-1 | L-2 |
|---|---|---|---|
| CYANOPHYTA | | | |
| Botridiopsis sp. | x* | x* | x* |
| Eucapsis sp. | x* | x* | |
| Lyngbya Duguetii Gomont | * | * | |
| Oscillatoria Agardhii Haegeli | | x* | |
| Oscillatoria limosa (Roth) C.A. Ag. | x* | | |
| Oscillatoria sp. | x* | x* | x* |
| Spirulina sp. | | | * |
| Stichosyphon sp. | * | | |
| Synechoccocus aeruginosus Naegeli | * | * | |
| Phormidium sp. | x | | |
| Nostoc sp. | x | | * |
| CHRYSOPHYTA | | | |
| Goniochloris sculpta Geitler | x* | | x |
| CHLOROPHYTA | | | |
| Ankistrodesmus falcatus (Corda)Ralfs. | x | | * |
| Chlamydomonas sp. | x* | | |
| Chlorosarcina optsis | x* | | |
| Chaetophora sp. | x | | |
| Cladophora sp. | * | | |
| Closteriopsis sp. | * | | |
| Closterium moniliforme | x* | | x* |
| Coleochate orbicularis Pring. | x | | |
| Coleochate scutata de Brêb. | x* | | * |
| Coleochate soluta de Brêb. | x* | | |
| Cosmarium sp. | * | * | x* |
| Microspora loefgrenii Nordst. | x* | | |
| Mougeotia sp. | * | | |
| Oedogonium sp. | x* | | |
| Palmella sp. | * | | |
| Pediastrum boryanum (Turp.) Meneg. | | | * |
| Rhizoclonium sp. | x* | | |
| Spirogira sp. | x* | | x |
| Scenedesmus incrassulatus Bohlin | * | | x* |
| Scenedesmus obliquus (Turp.) Kutz. | * | | |
| Stigeoclonium lubricum (Dill.) Kutz. | x* | x* | * |
| Stigeoclonium tenue (C.A.Ag.) Kutz. | | x* | * |
| Tetraspora sp. | x* | | |
| Ulothrix aequalis Kutz. | * | | * |
| Ulothrix zonata (Weber & Mohr) Kutz. | x* | | * |
| Vaucheria sp. | | | * |

TABLE 3: List of prominent diatoms found in the streams with ecological descriptions (as in Patrick & Reimer, 1966; and Hustedt, 1930).

1: Cocconeis placentula Ehr. Widespread; eurytopous; epiphytic on aquatic plants and other objects; commonly found in circumneutral to alkaline waters; salt indifferent; rheophil.

2: Achnanthes lanceolata (Bréb.)Grun. Common species occurring under a wide range of ecological conditions; rheophil; indifferent to pH or alkaliphil; appears in low numbers under conditions of heavy organic enrichment.

3: Achnanthes lanceolata v. dubia Grun. As nominate variety.

4: Achnanthes linearis (W. Sm.)Grun. Apparently pH indifferent and halophobic; little reliable data.

5: Achnanthes minutissima Kutz. Very widespread taxon; eurytopic; found at very widerange of pH but prefers pH from 6.5 to 9.0; oligohalobe.

6: Eunotia pectinalis v. minor (Kutz.)Rabh. Found in acid to circumneutral water; tolerates more calcium than other Eunotia species.

7: Surirella ovata Kutz. Widespread; common in fresh water.

8: Surirella angustata Kutz. As S. ovata.

9: Cymbella sinuata Greg. pH indifferent; oligohalobe.

10: Cymbella ventricosa Kutz. Very widespread; eurytopic; pH indifferent; oligohalobe.

11: Cymbella amphicephala Naegeli Insufficiently known; frequently found under conditions of high oxygen and pH of above 7.0.

12: Navicula cryptocephala Kutz. Widely distributed in bogs, lakes, and rivers; fresh to slightly brackish waters.

13: Navicula rhyncocephala Kutz. Widely distributed in fresh water; prefers water of high mineral content; halophilous to indifferent to small amounts of chloride.

14: Navicula odiosa Wallace Seems to prefer water of high conductivity.

15: Nitzchia linearis W. Sm. Widespread; common.

16: Nitzchia paleaceae Grun. Widespread; prefers slow moving to still water.

17: Nitzchia kutzingiana Hilse Widespread in fresh water; common.

TABLE 3: Continued.

18: Fragellaria construens (Ehr.)Grun. Prefers slightly alkaline water; often indifferent to chlorides; both planktor and benthic.

19: Gonphonema olivaceum (Lyngb.)Kutz. Prefers cool, flowing water that is fairly hard; found in water with great variation in calcium content; does not thrive in calcium poor water.

20: Meridion circulare (Greg.)Agardh. Prefers flowing, fresh water.

TABLE 4: Fauna found on rocks and slides (*) from surveys taken in in 1975, 1976, 1977 for Bishop's Stream; 1975, 1976 for L-1; 1977 for L-2. Diets are included.

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BISHOP'S STREAM

ROTIFERA: Resticula sp.*(algae, detritus).
ARTHROPODA: Diptera - Simulium sp.*; Tanytarsus exiguus*; Tanytarsus tenuis*; Pentaneura flavifrons*; Tripula sp.* (algae and detritus); sub. fam. Chironominae (algae, detritus, animals).
Decapoda - Procambrus sp. (algae, other plants, dead animals).
Hydrocarina - Limmesia sp.(crustaceans, worms and other animals).
Coleoptera - Ectoporia sp.; Optioservus sp. (predaceous); fam. Hydrophilidae (algae and plants).
Hemiptera - Notonecta sp.; Gerris sp. (predators and scavengers).
Plecoptera - fam. Perlidae; Perlesta sp. (prey on smaller animals); fam. Nemourdae (herbivourous).
Ephemeroptera - Stenonema fuscum; Stenonema canadense; Paraleptophlebia sp.; Epeorus vitreus; Litobranchia recurvata (periphyton); Baetis levitans* (algae, detritus); Ephemeralla invaria; Ephemera sp. (detritus, smaller fauna.
Trichoptera - Glossosoma sp.*; Anagapetus sp.*; Goera sp.*; Ochrotriche sp.; Dolophilodes sp.; Cheumatopsyche sp.; Ryocophyla sp. (epilithic algae, diatoms, detritus); Hydropsyche sp.* (algae, detritus, animals).
Odonata - ( voracious predators).
MOLLUSCA: fam. Neritidae (algae, other plant material); Ancylastrum fluviatile (algae).
CHORDATA: fam. Salmonidae; fam. Cyprinidae (small invertebrates, algae, other plant material); fam. Percidae: Boleosoma sp. (insects, esp. midge).
PROTOZOA: Cilliophora*(algae, detritus).

L-1

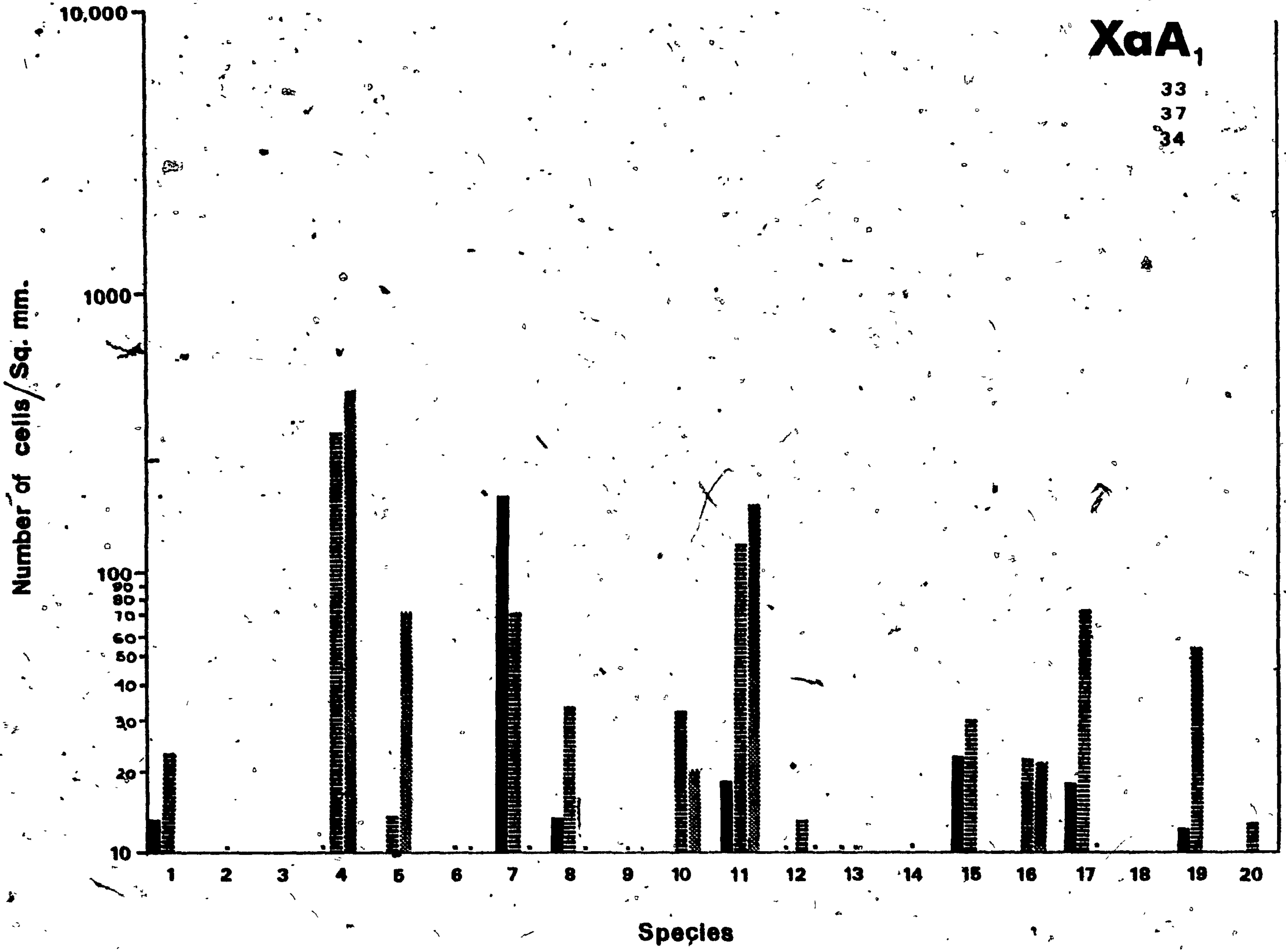
ROTIFERA: Resticula sp*; Lepadella sp*; Philodina sp.*(algae, detritus).
ARTHROPODA: Diptera - fam. Chironomidae*(algae, detritus, animals).
Copepoda - s. order Harpacticoida* (detritus, algae).
Trichoptera - Hydropsyche sp. (algae, detritus, animals).
PROTOZOA: Paramecium sp*; Vorticella sp.*and other cilliates* (algae and detritus); Amoeba sp.*(algae, bacteria, protozoa, detritus).
GASTROTRICHA: Chaetonotus sp.* (bacteria, algae, protozoans).
ANNELIDA: Oligochaeta (several species)* (bacteria, other microorganisms, detritus).
COELENTERATA: Hydra americana* (detritus, small animals).
NEMATODA: several species* (detritus, algae, animals).

TABLE 4: Continued.

| |
|---|
| L-2 |
| ROTIFERA:* (algae, detritus)<br>ARTHROPODA: Diptera - _Simulium_ sp. (algae, detritus); Chironomidae (algae, detritus, animals). Copepoda - Harpacticoida*(algae, detritus). Ephemeroptera - _Baetis_ spp. (algae, detritus).<br>PROTOZOA: Cilliophora*; _Vorticella_ sp.*(algae, detritus, animals).<br>ANNELIDA:* (bacteria, microorganisms, algae).<br>COELENTERATA: _Hydra_ sp. (detritus, small animals) |

Compiled from Douglas (1958), Reid (1961), Hynes (1972), Wetzel (1975), and Wiggens (1977).

FIGURES 1 to 48: Histograms showing mean abundance taken from 50 random counts of Species 1 to 20 from Table 3, Appendix II, on slides from Series A to K. Each histogram represents slide communites from the same series, colonization age and subsite for the three stations of Bishop's Stream. Station 4 of L-2 is also represented when slides are available. Station 1 ; Station 2 ; Station 3 ; Station 4 . Refer to Figure 7 for explanation of coded slides. Numbers beneath the codes on the upper left are the species number of Stations 1 through 4 from top to bottom respectively.



XaA1
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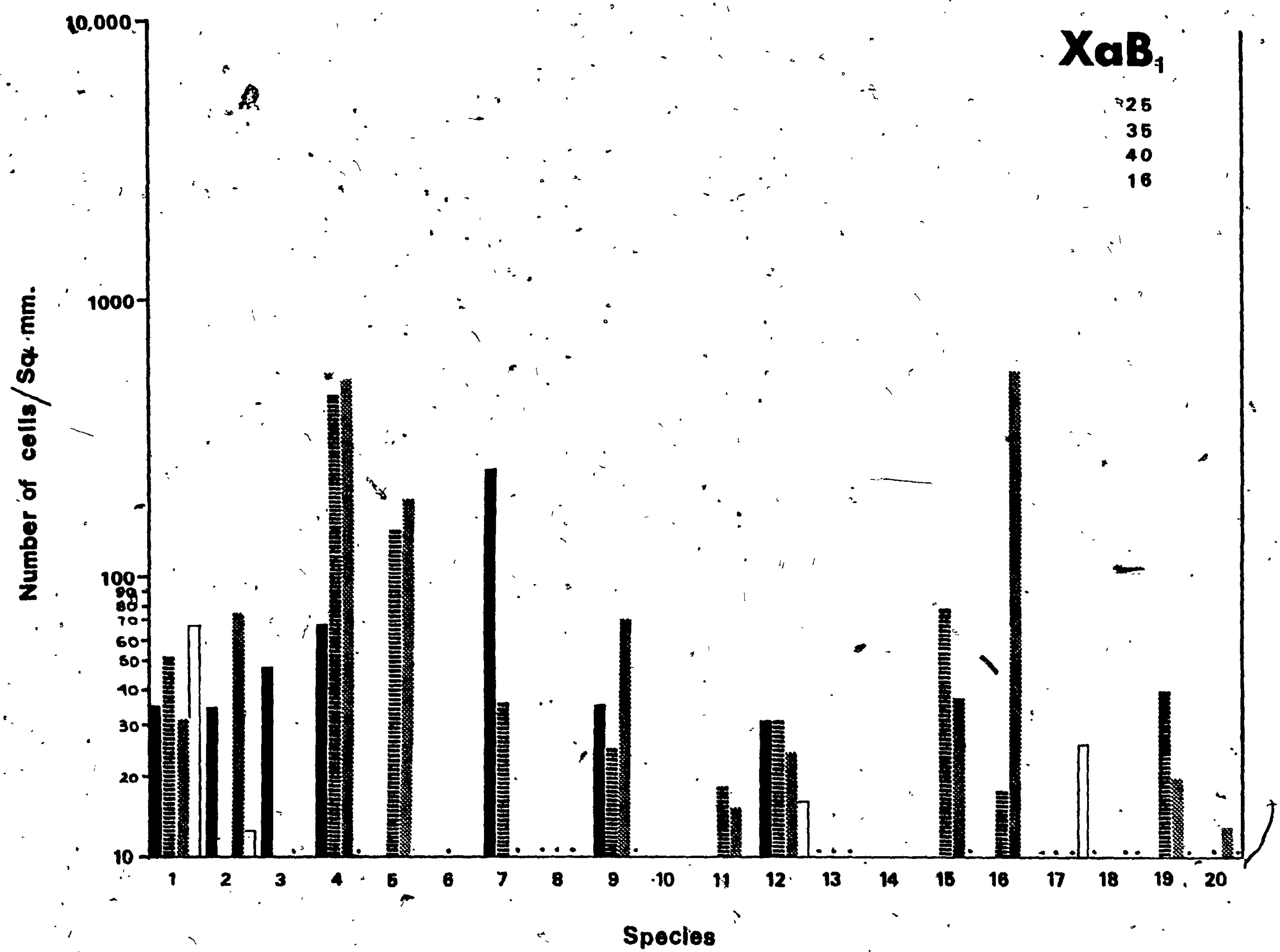
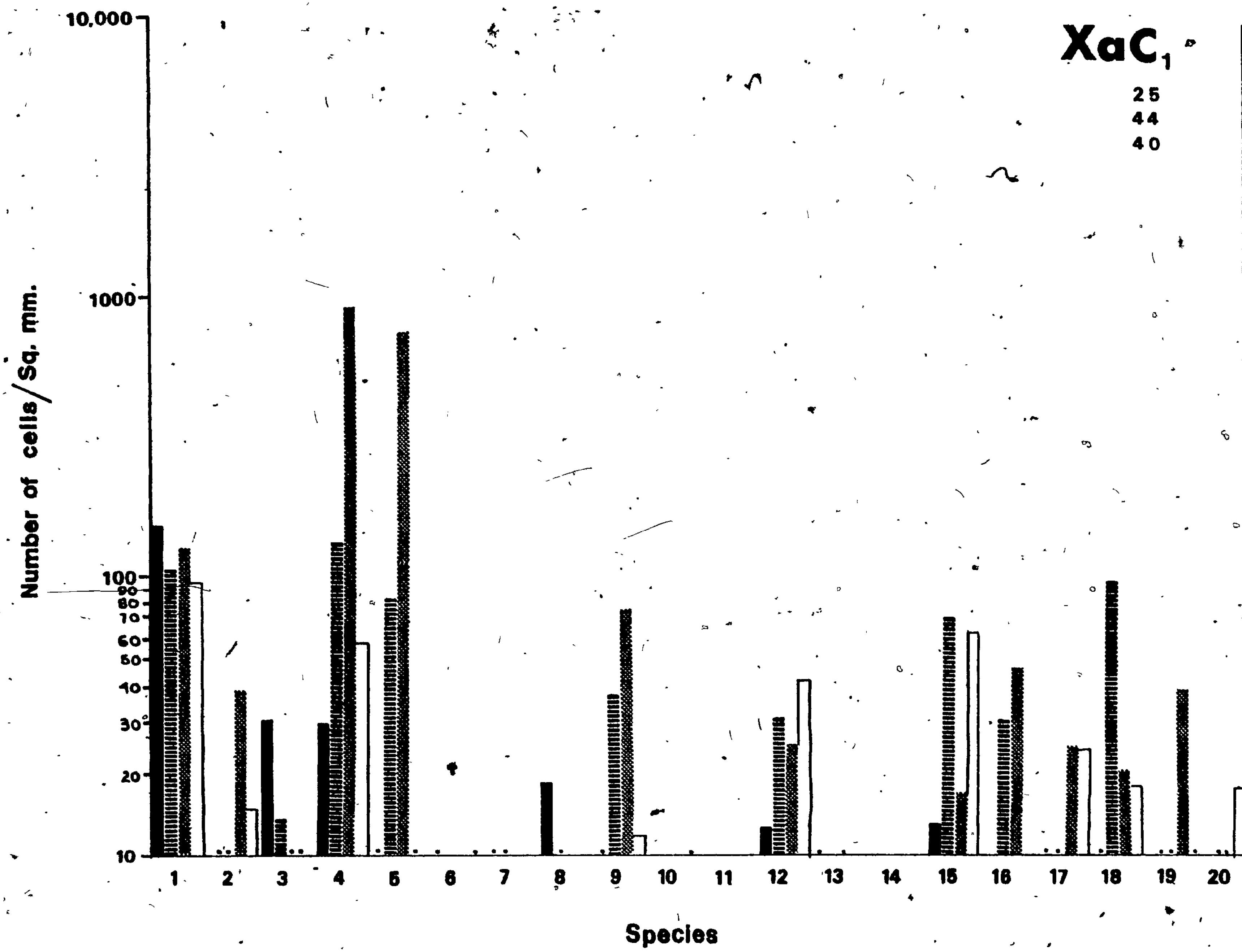
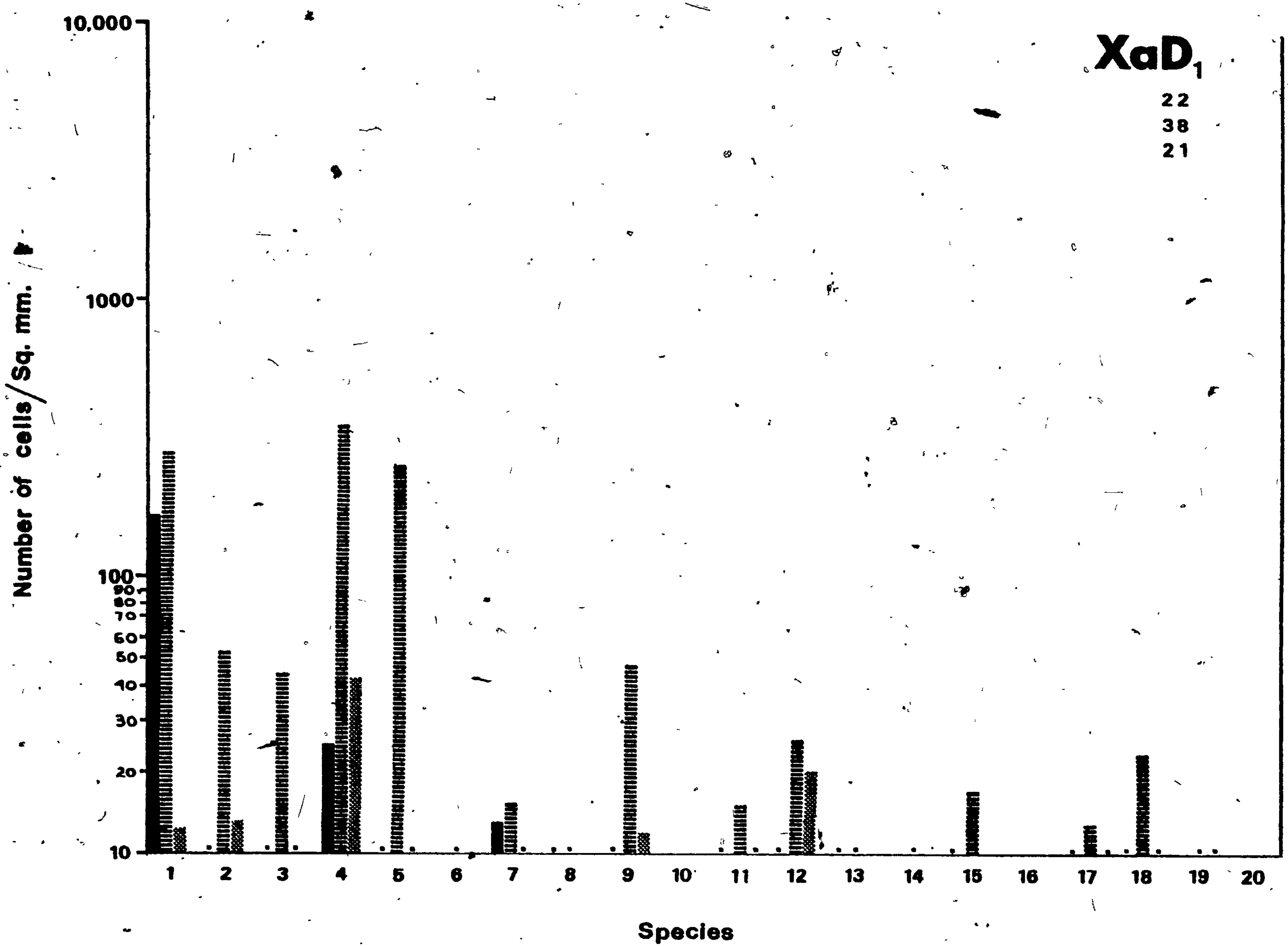
37
34
Number of cells/Sq. mm.
10,000
1000
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Species


XaB1
25
35
40
16
Number of cells/Sq. mm.
10,000
1000
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Species



XaC1
25
44
40
10,000
1000
100
90
80
70
60
50
40
30
20
10
Number of cells/Sq. mm.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Species



XaD$_1$
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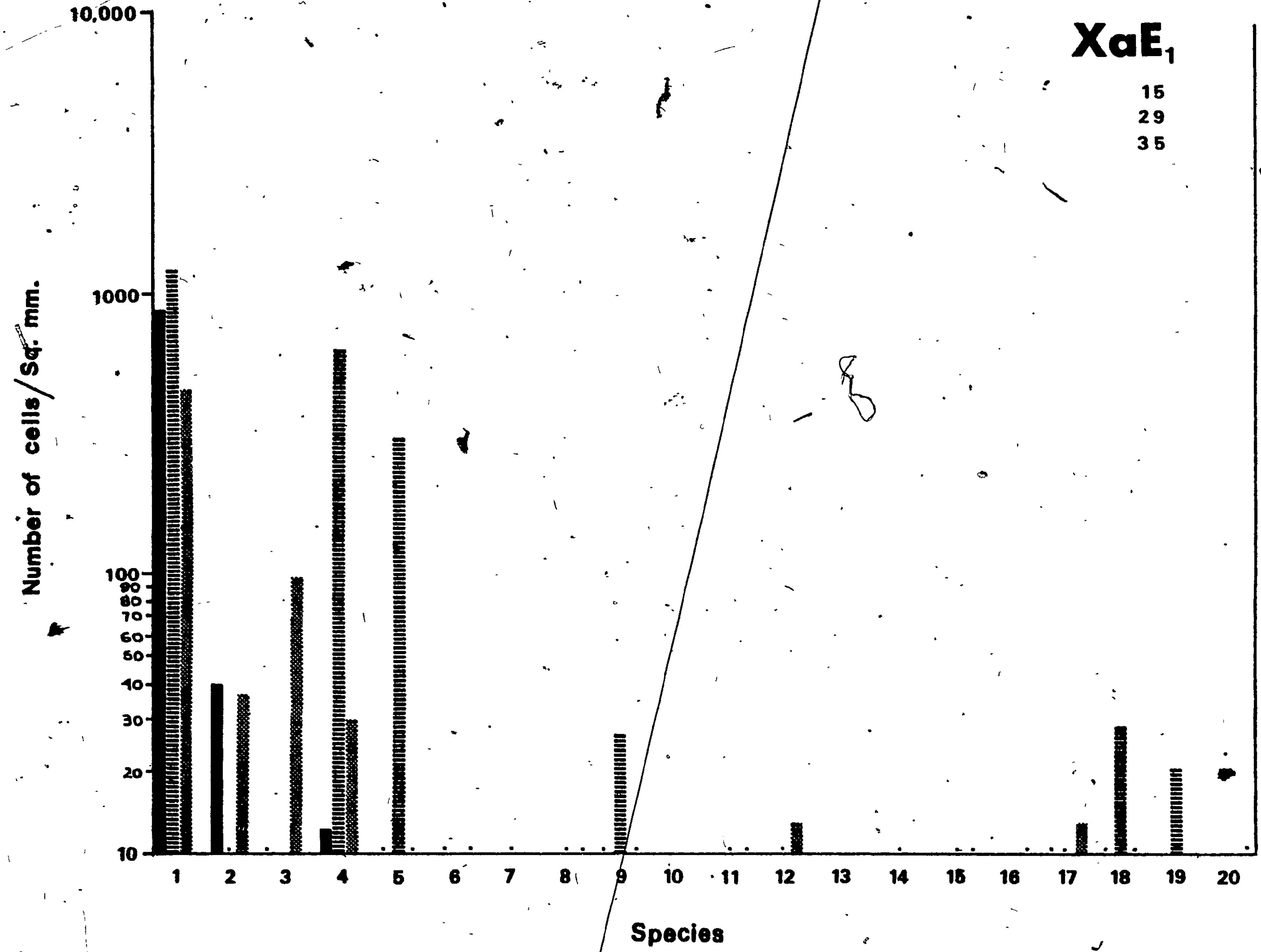
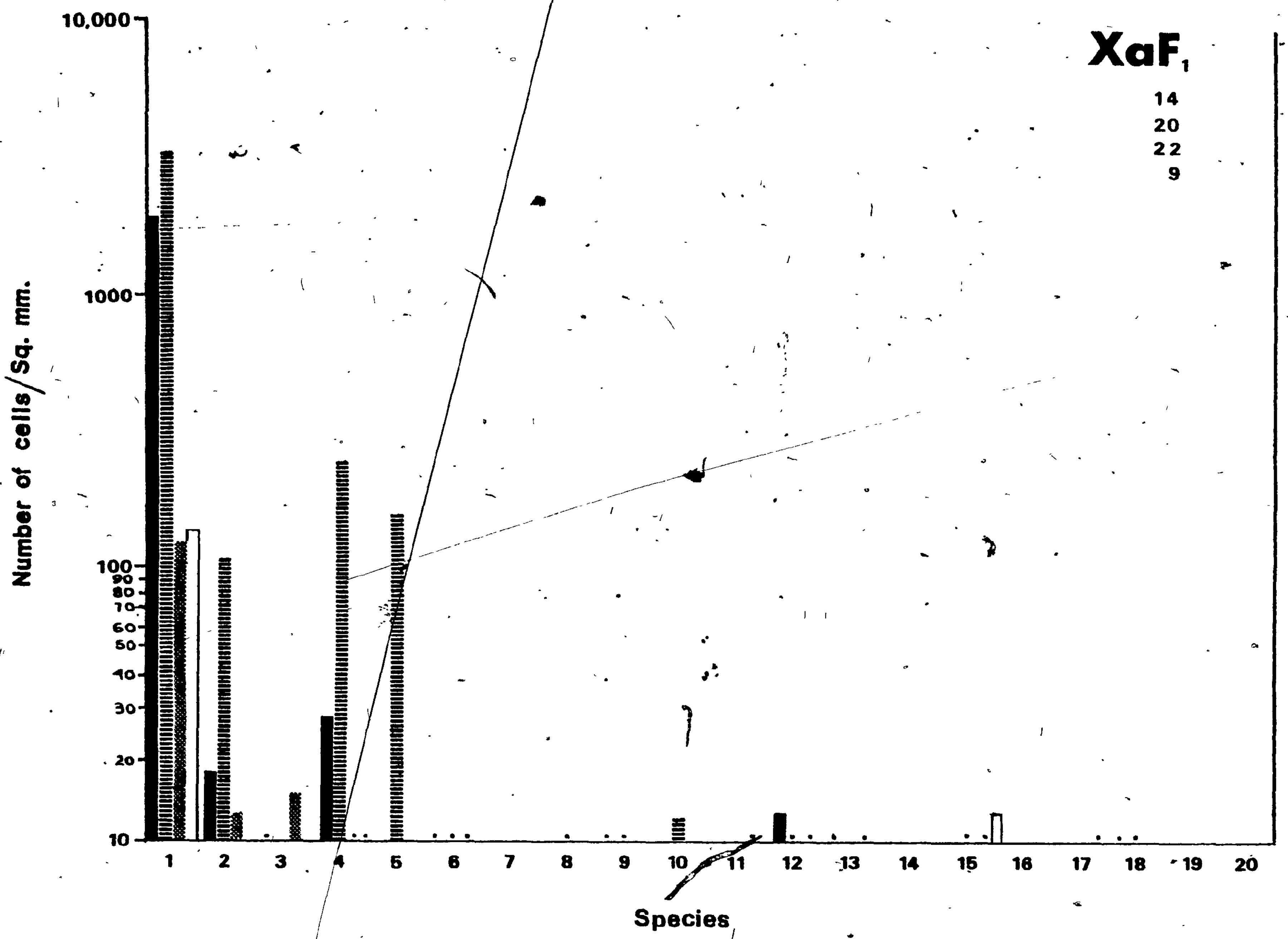
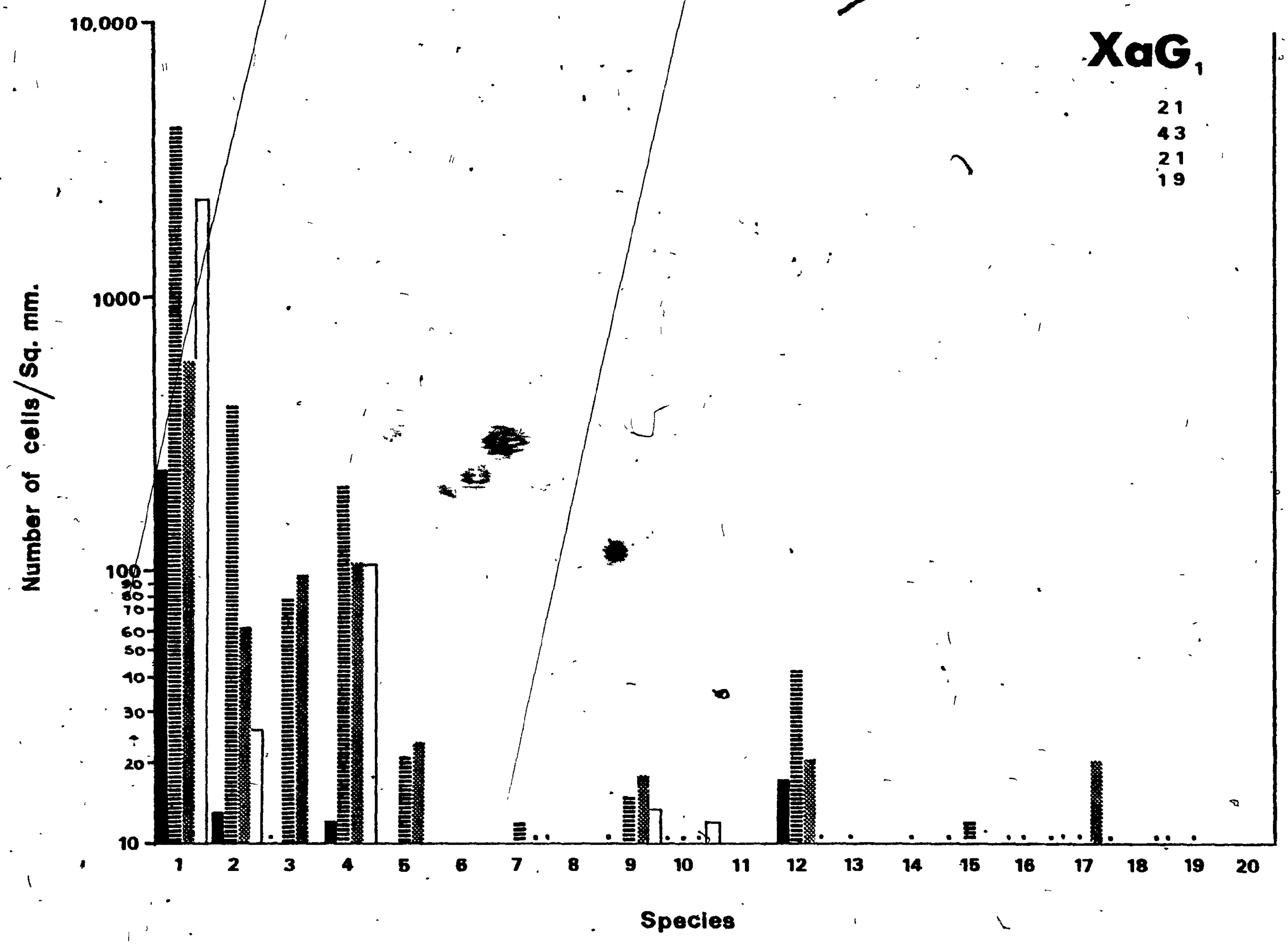
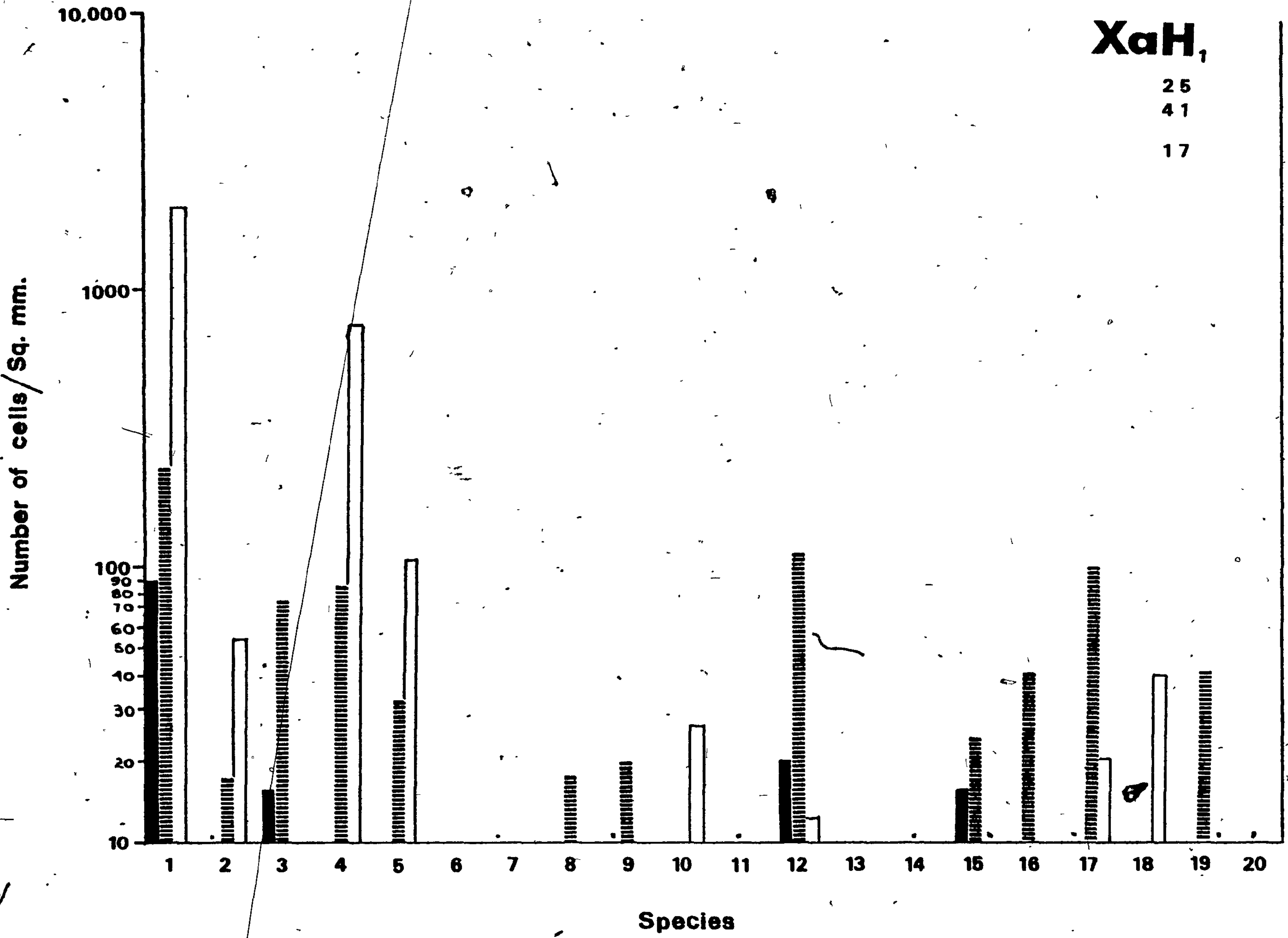
38
21
10,000
1000
100
90
80
70
60
50
40
30
20
10
Number of cells/Sq. mm.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Species

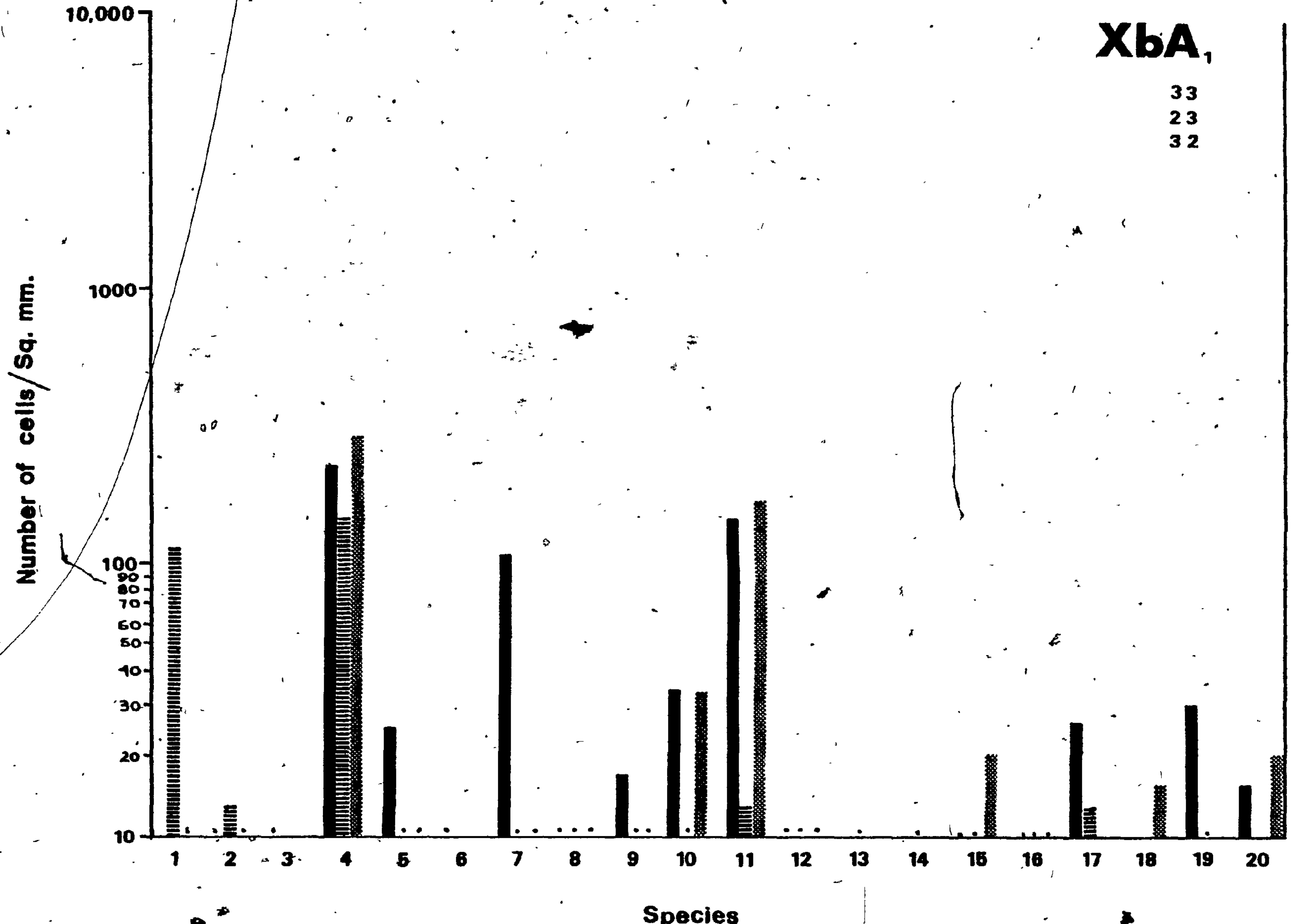

XaE1
15
29
35
Number of cells/Sq. mm.
10,000
1000
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Species


XaF1
14
20
22
9
Number of cells/Sq. mm.
10,000
1000
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Species

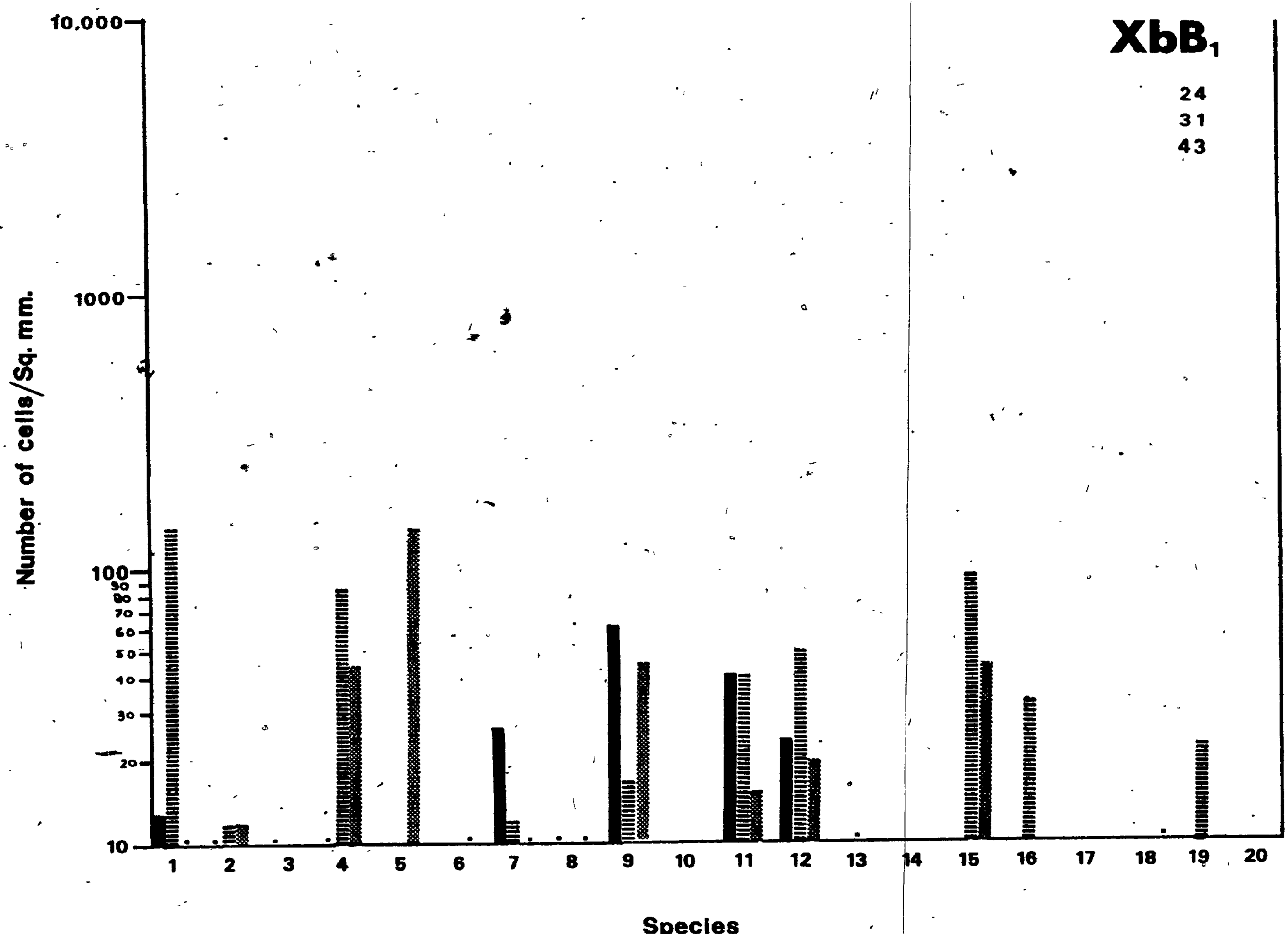

XaG1
21
43
21
19
Number of cells/Sq. mm.
10,000
1000
100
90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Species



XaH1
25
41
17
Number of cells/Sq. mm.
10,000
1000
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Species



XbA$_1$
33
23
32
Number of cells/Sq. mm.
10,000
1000
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Species


XbB1
24
31
43
Number of cells/Sq. mm.
10,000
1000
100
90
80
70
60
50
40
30
20
10
1
2
3
4
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6
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8
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10
11
12
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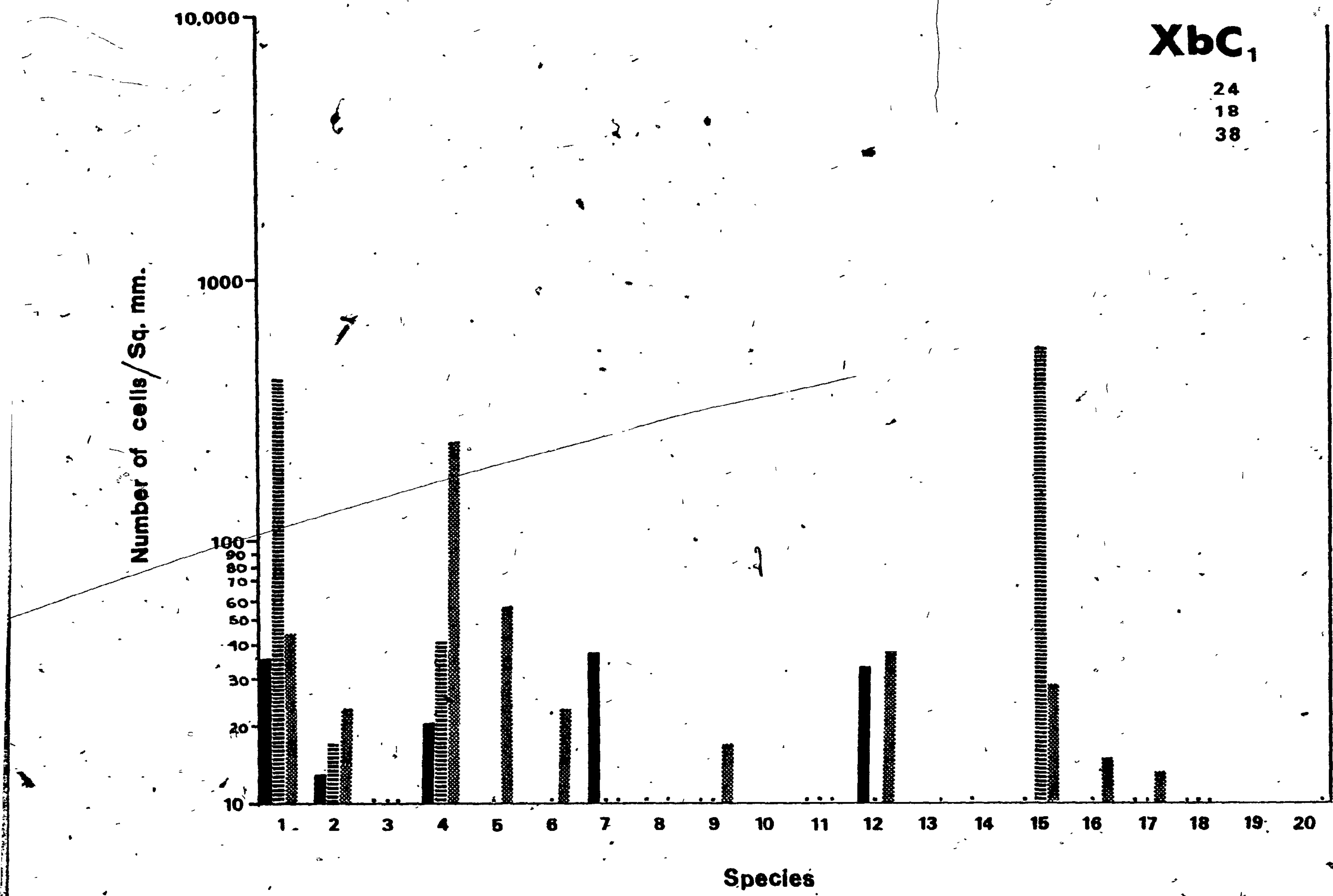
14
15
16
17
18
19
20
Species


XbC1
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38
Number of cells/Sq. mm.
10,000
1000
100
90
80
70
60
50
40
30
20
10
1
2
3
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6
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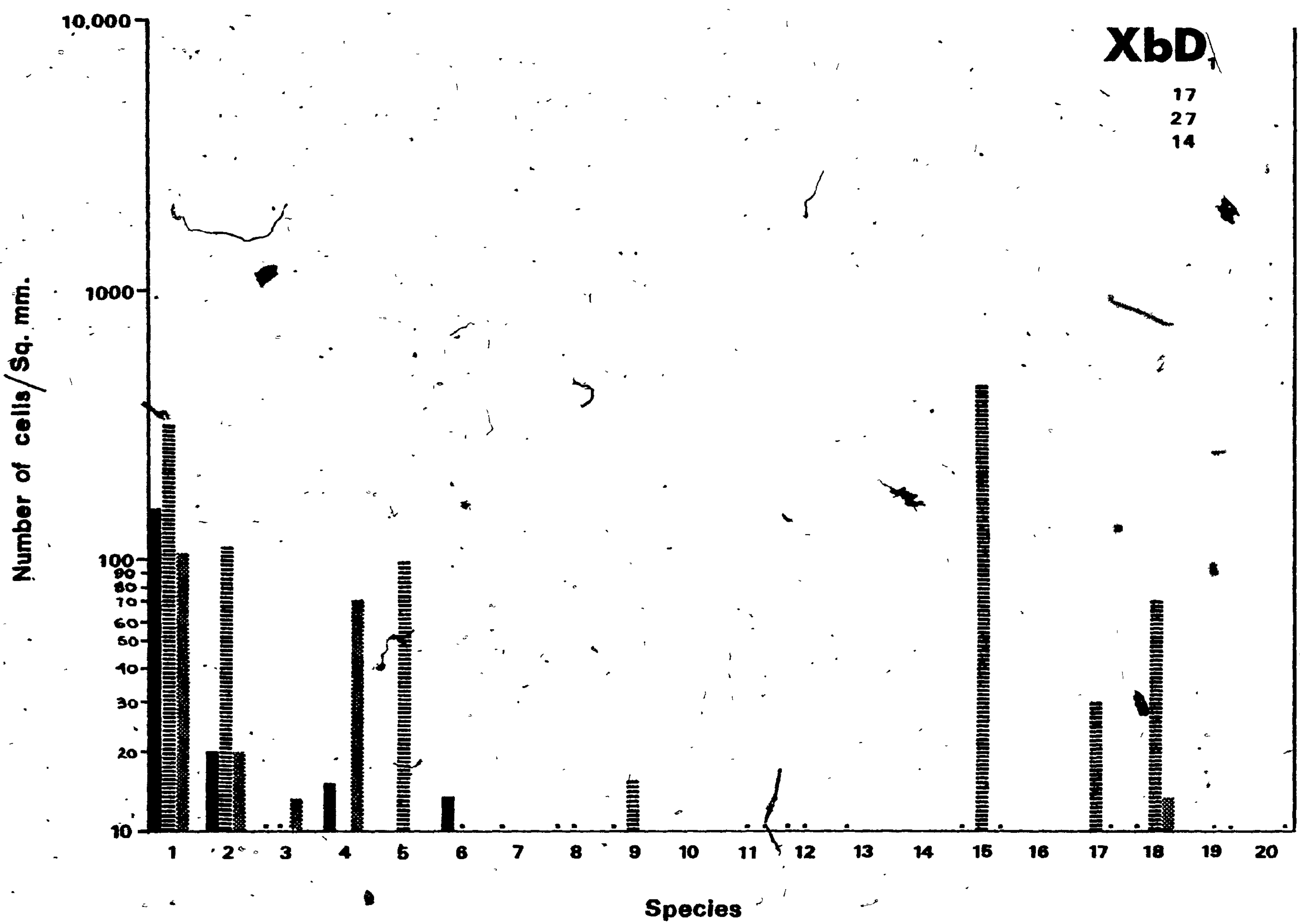
19
20
Species


XbD
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27
14
Number of cells/Sq. mm.
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1000
100
90
80
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60
50
40
30
20
10
1
2
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6
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8
9
10
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14
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18
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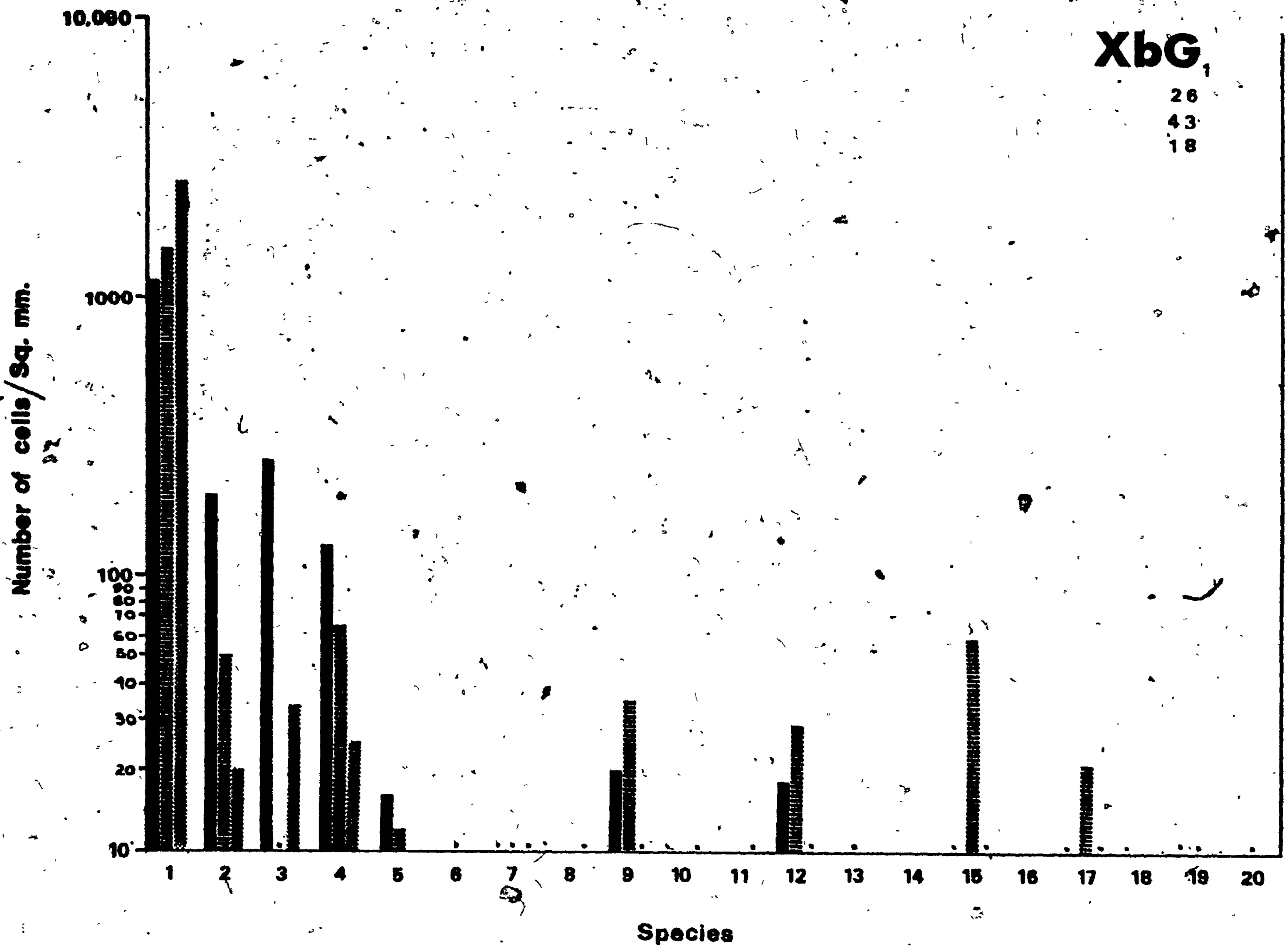
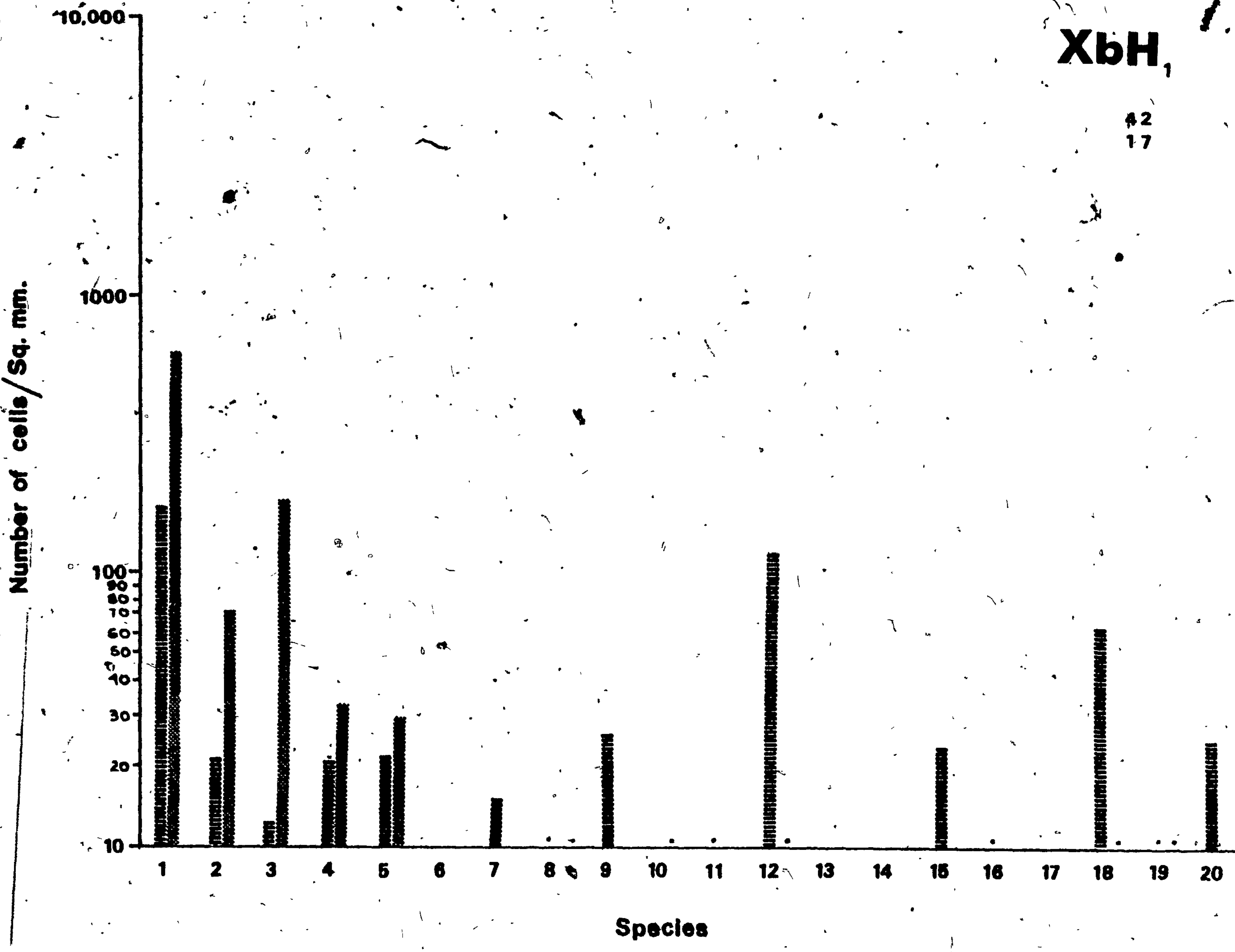
20
Species


XbG1
26
43
18
10,000
1000
100
90
80
70
60
50
40
30
20
10
Number of cells/Sq. mm.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Species



XbH1
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17
Number of cells/Sq. mm.
10,000
1000
100
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80
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60
50
40
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20
10
1
2
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4
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7
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14
15
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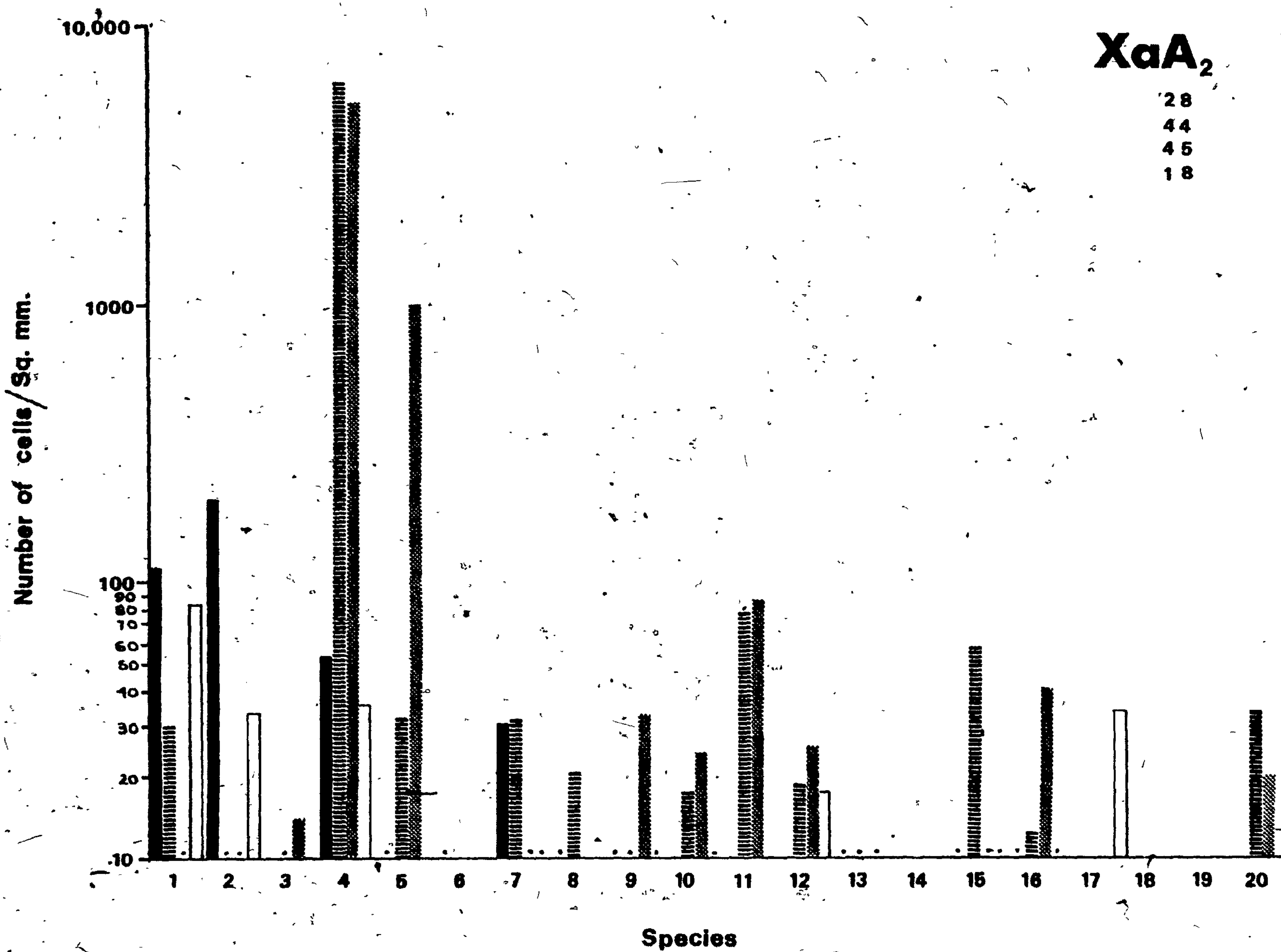
18
19
20
Species


XaA2
'28
44
45
18
Number of cells/Sq. mm.
10,000
1000
100
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80
70
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50
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20
10
1
2
3
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14
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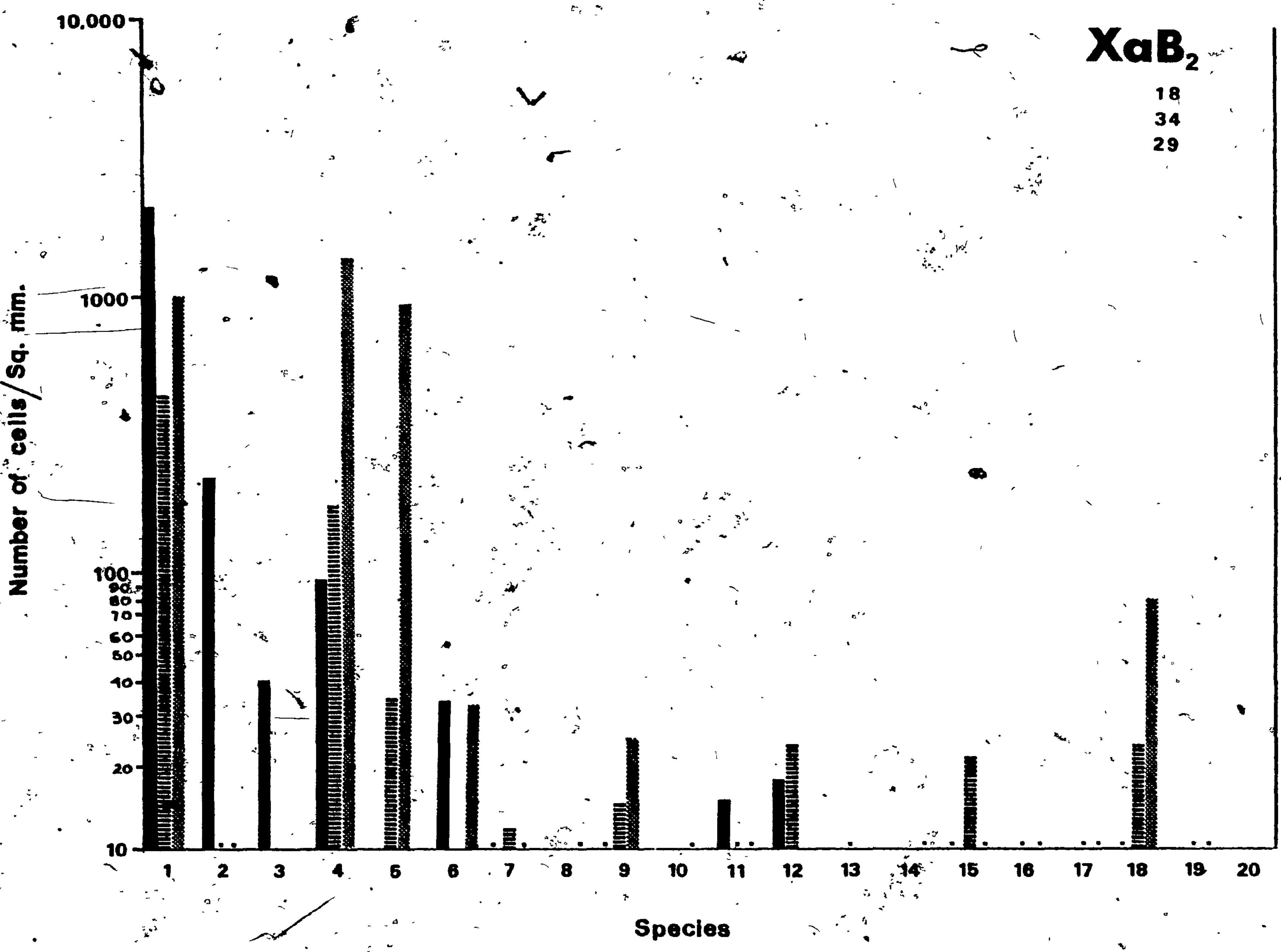
17
18
19
20
Species



XaB₂
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34
29
10,000
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100
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80
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Number of cells/Sq. mm.
1
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3
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6
7
8
9
10
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12
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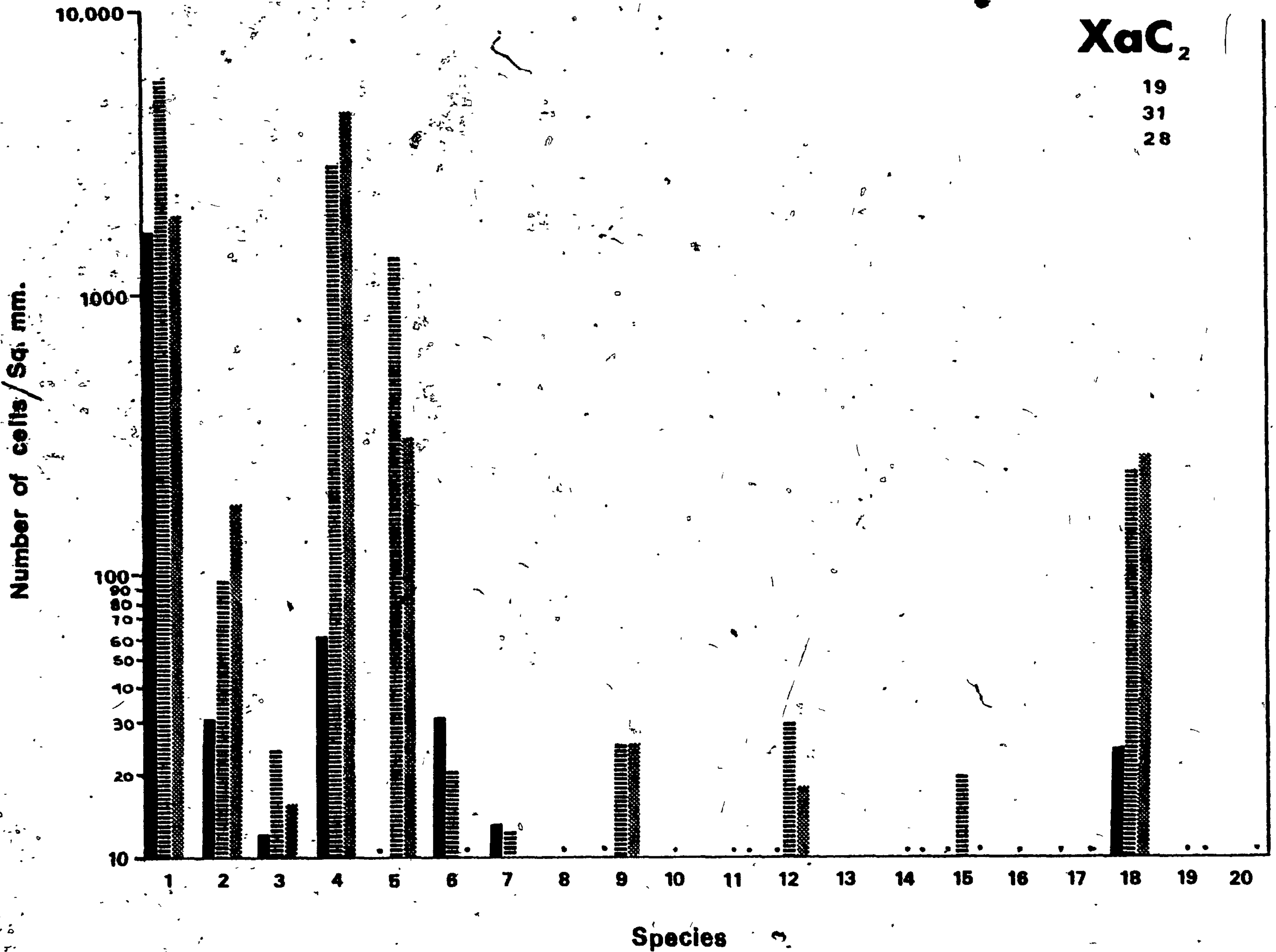
14
15
16
17
18
19
20
Species


XaC2
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Number of cells/Sq. mm.
1
2
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16
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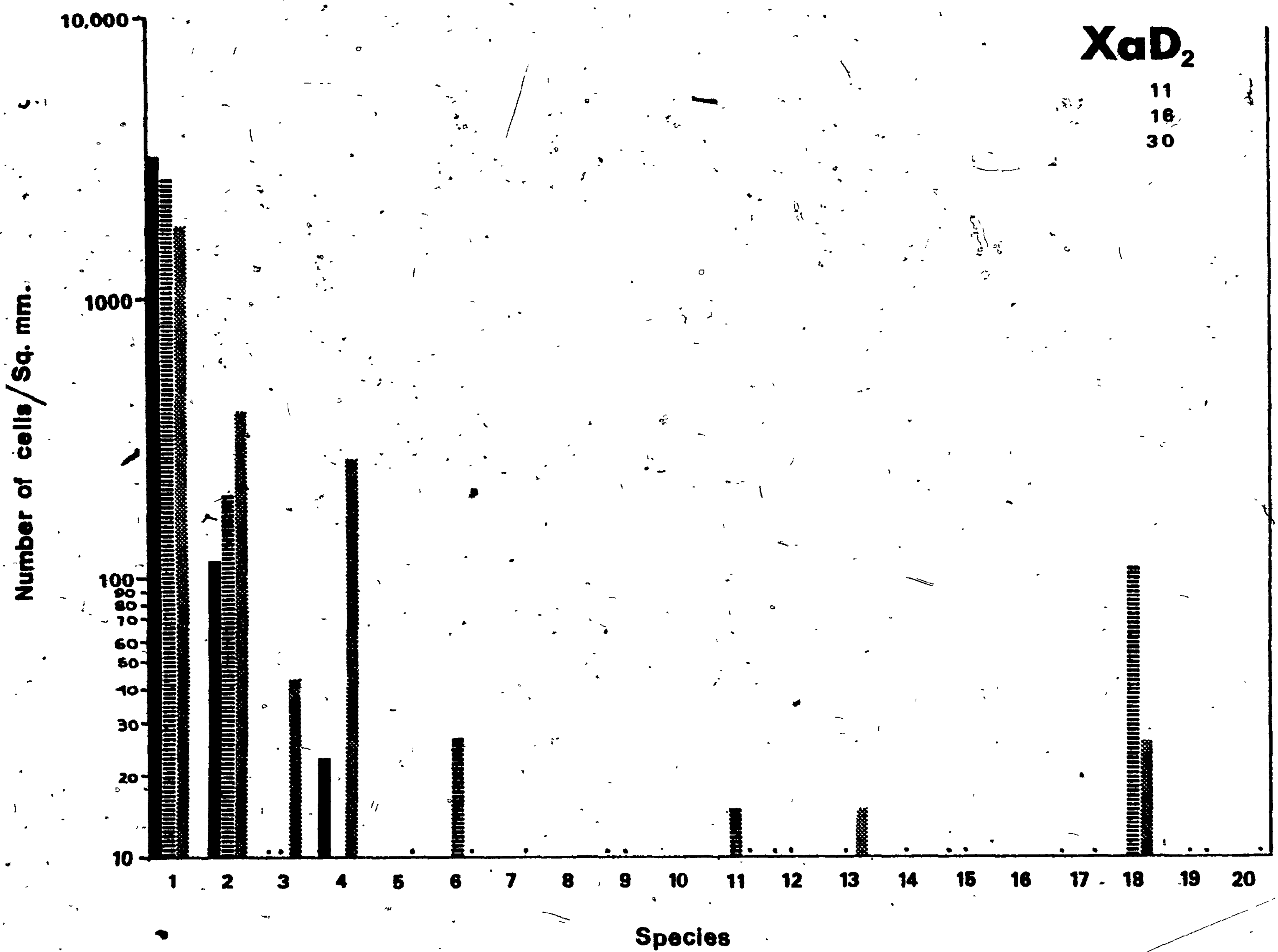
18
19
20
Species


XaD2
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Number of cells/Sq. mm.
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10
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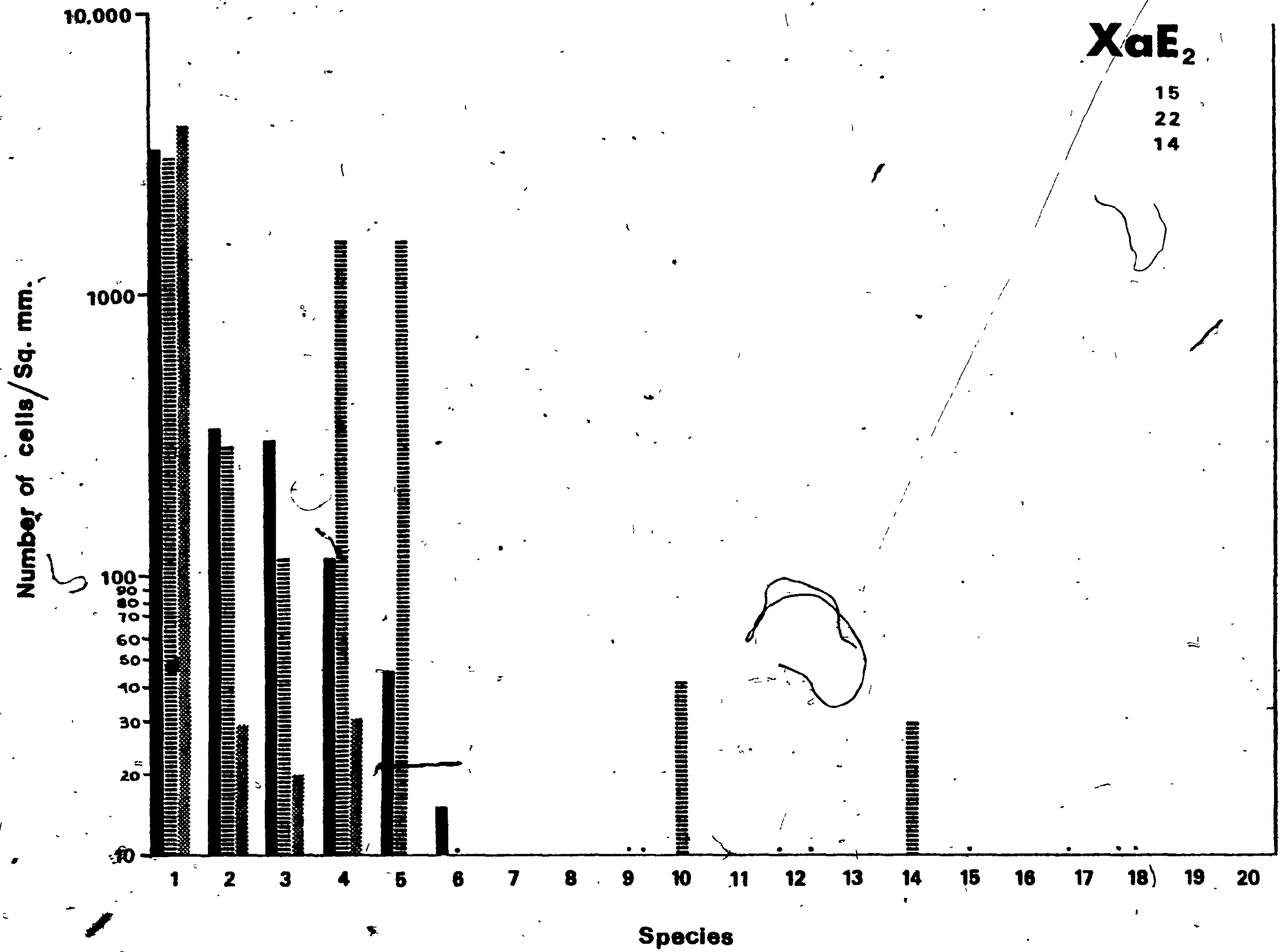
Species


XaE2
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22
14
Number of cells/Sq. mm.
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1000
100
90
80
70
60
50
40
30
20
10
1
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14
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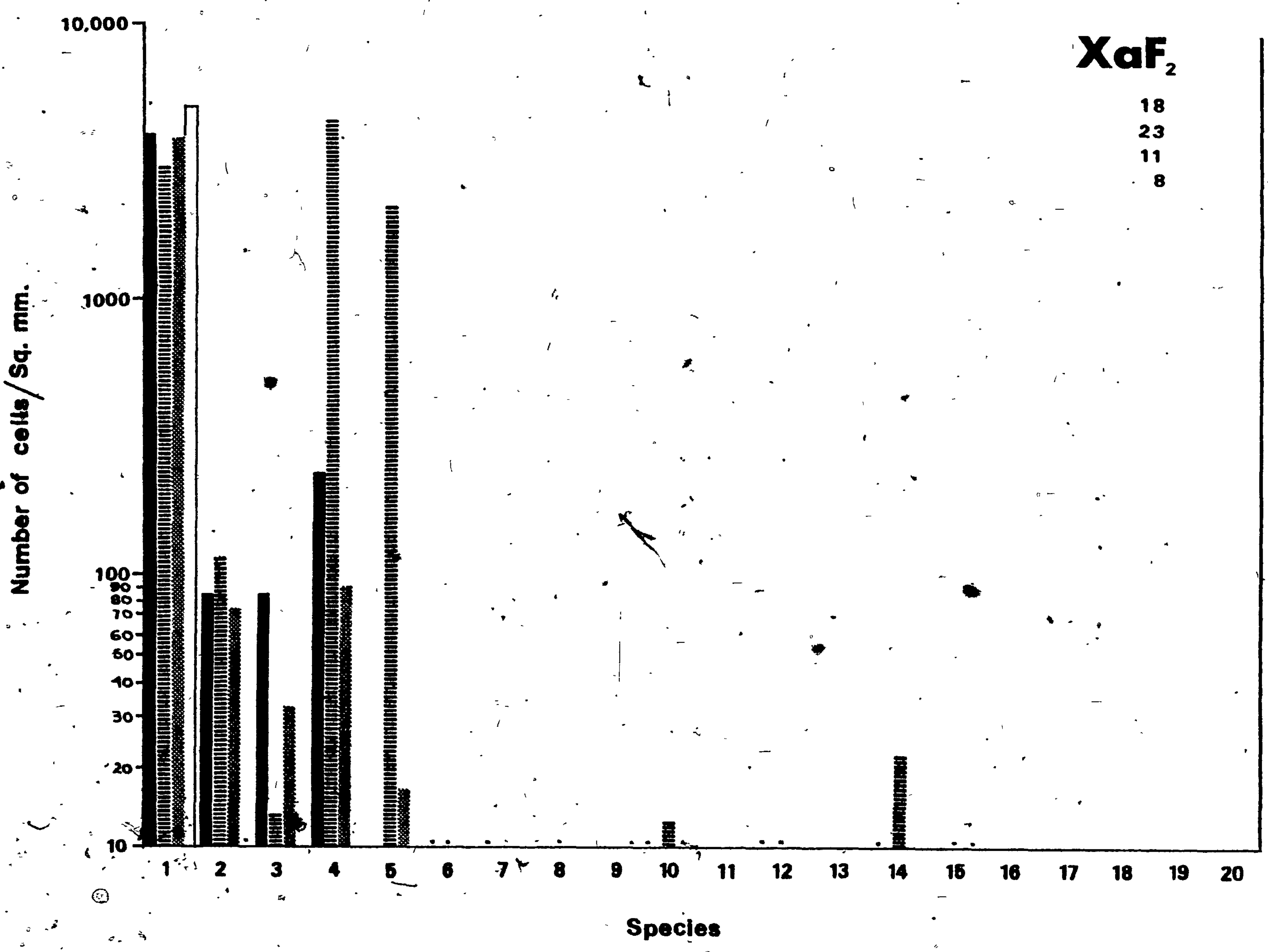
16
17
18
19
20
Species



XaF2
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23
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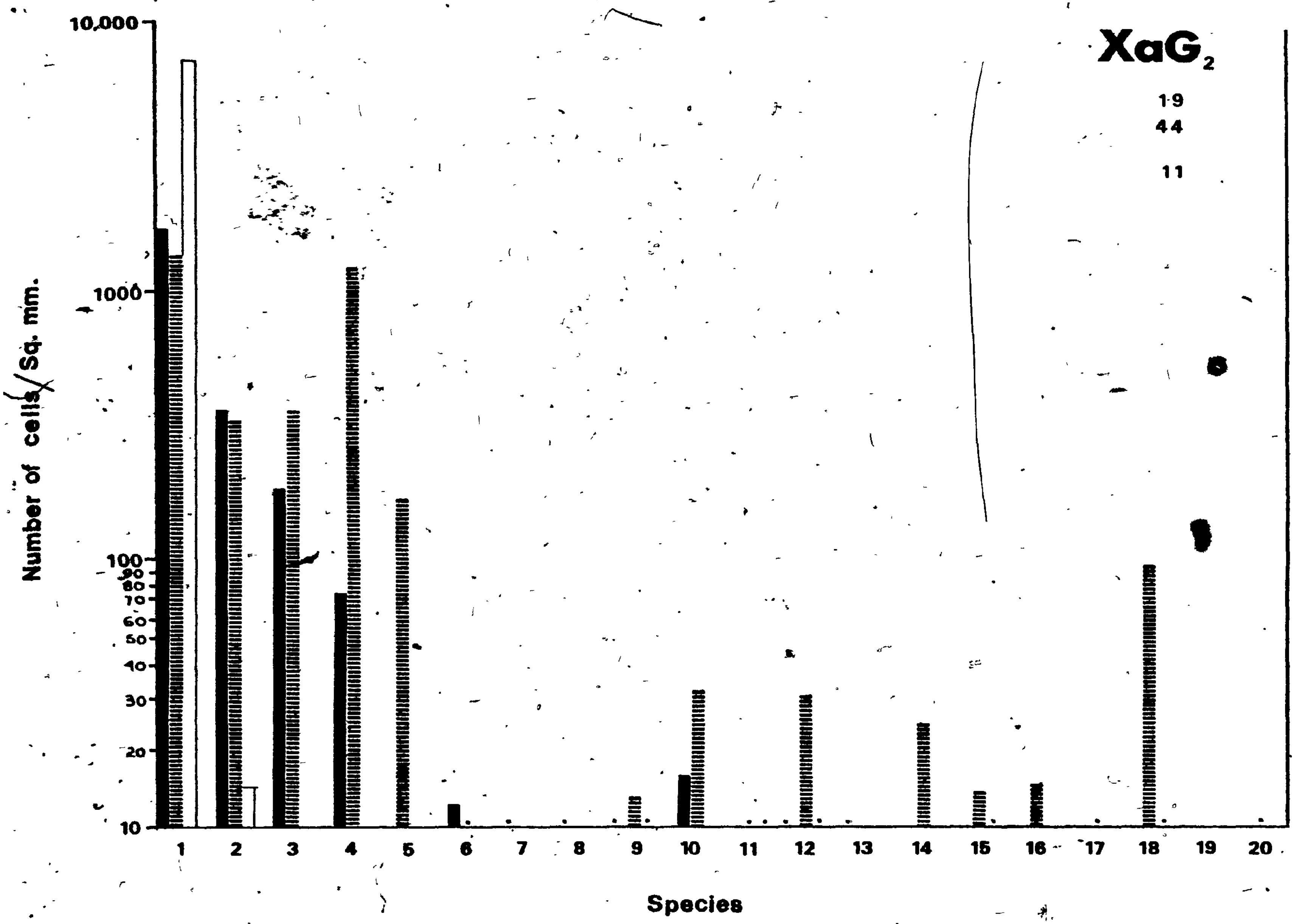
8
10,000
1000
100
90
80
70
60
50
40
30
20
10
Number of cells/Sq. mm.
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Species


XaG2
1·9
4·4
1·1
Number of cells/Sq. mm.
10,000
1000
100
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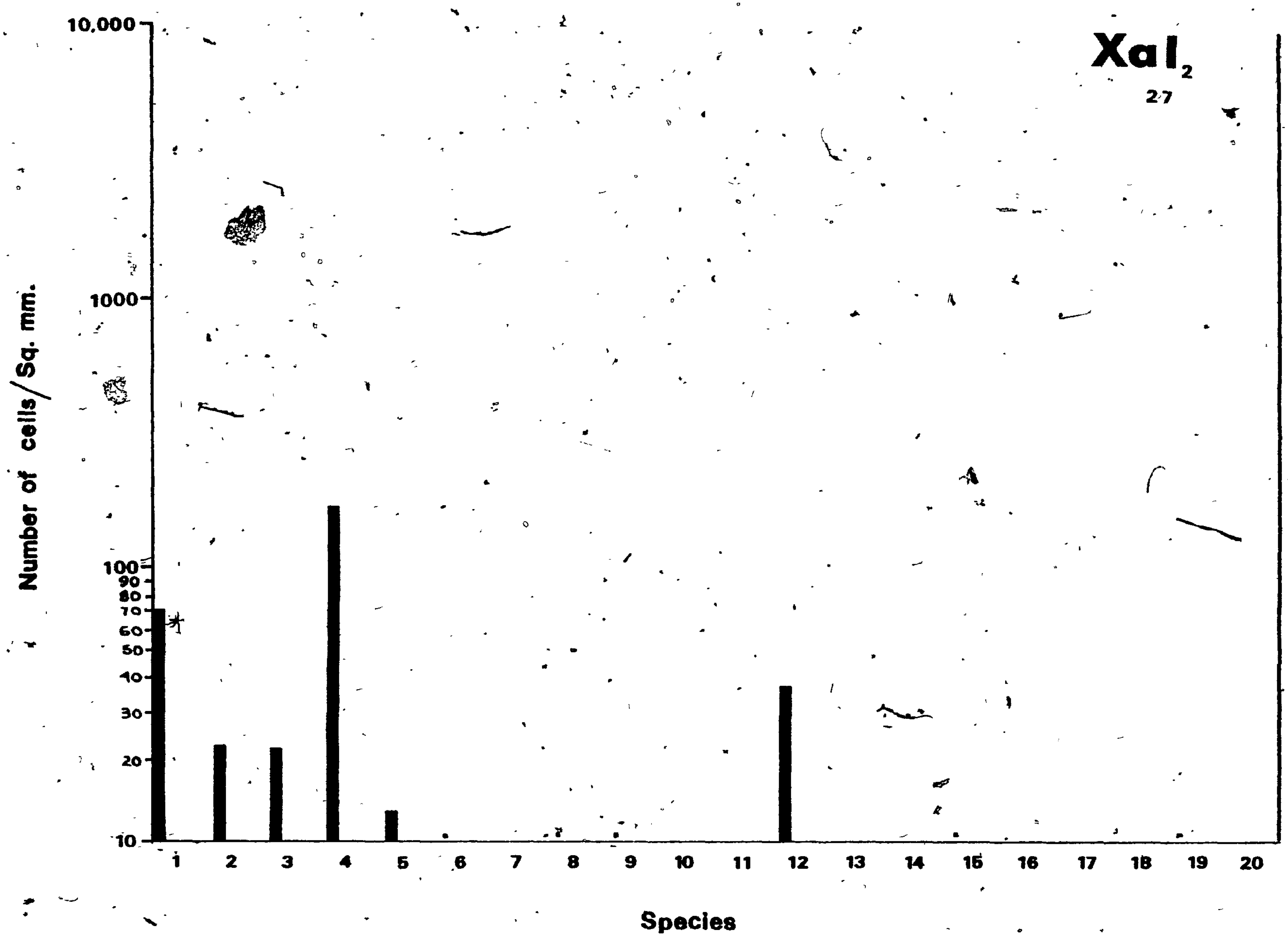
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Species


Xal
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2.7
Number of cells/Sq. mm.
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1000
100
90
80
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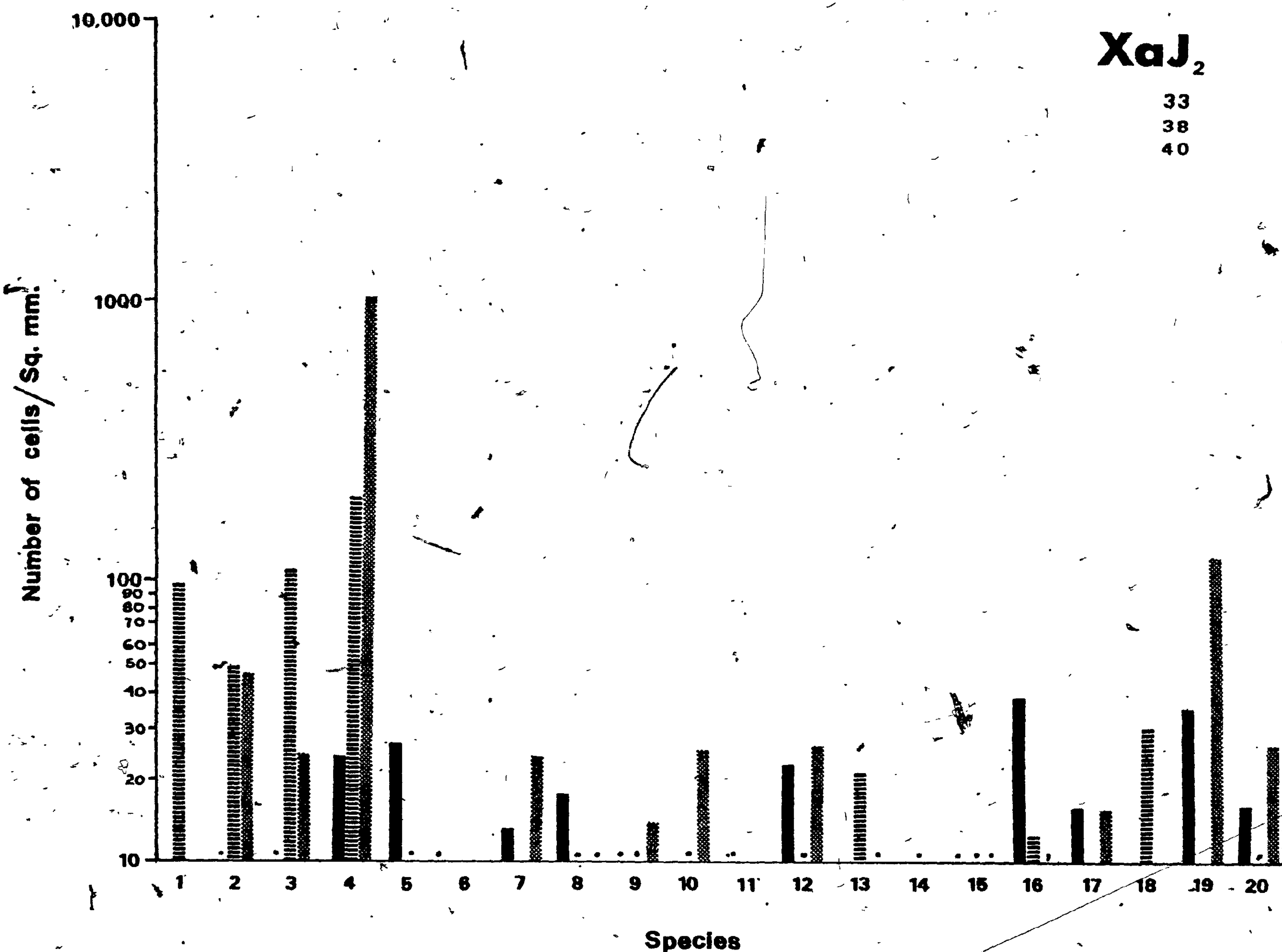
60
50
40
30
20
10
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
Species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Number of cells/Sq. mm.
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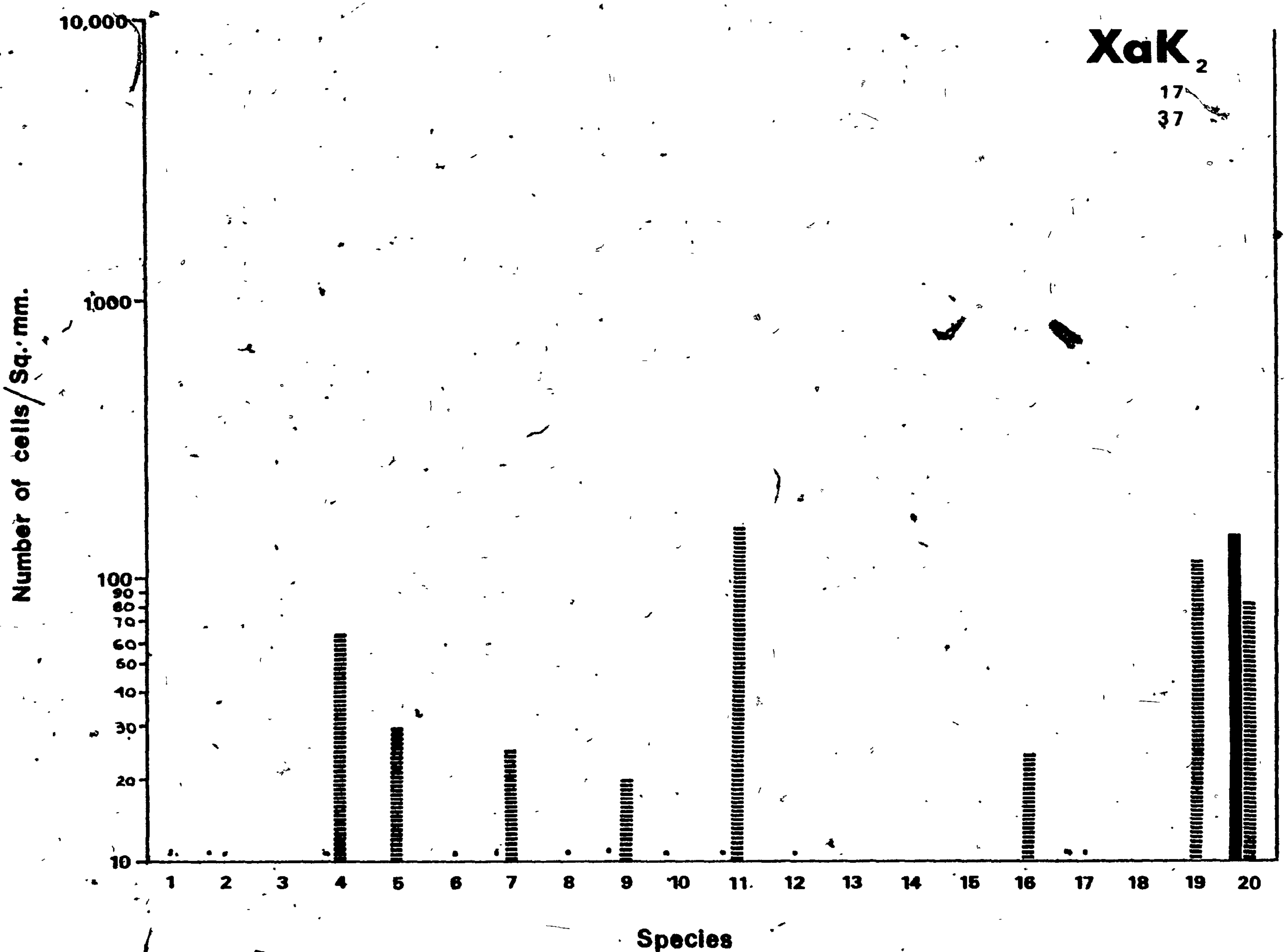
Species



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Number of cells/Sq.·mm.
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1000
100
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10
1
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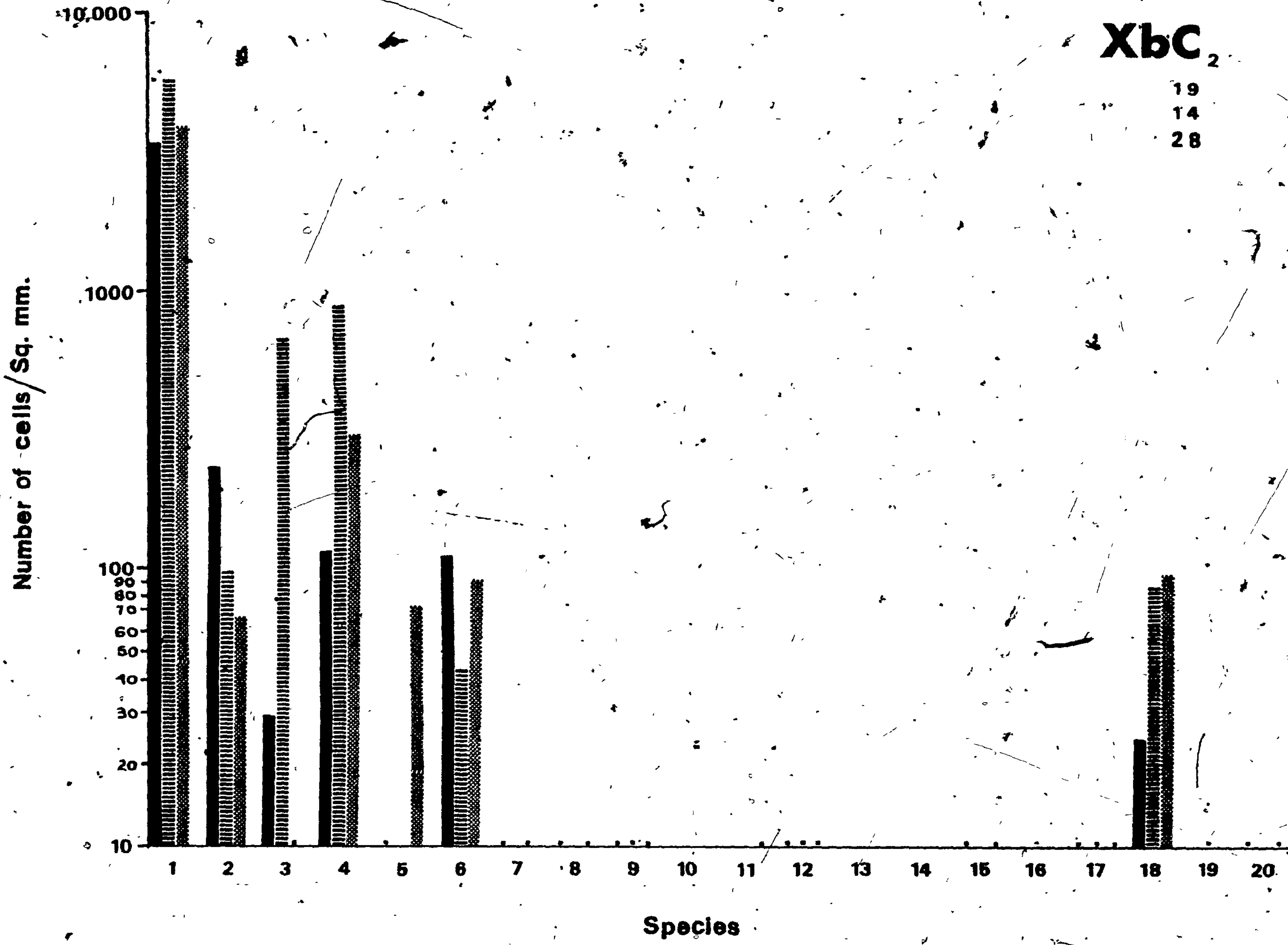
Species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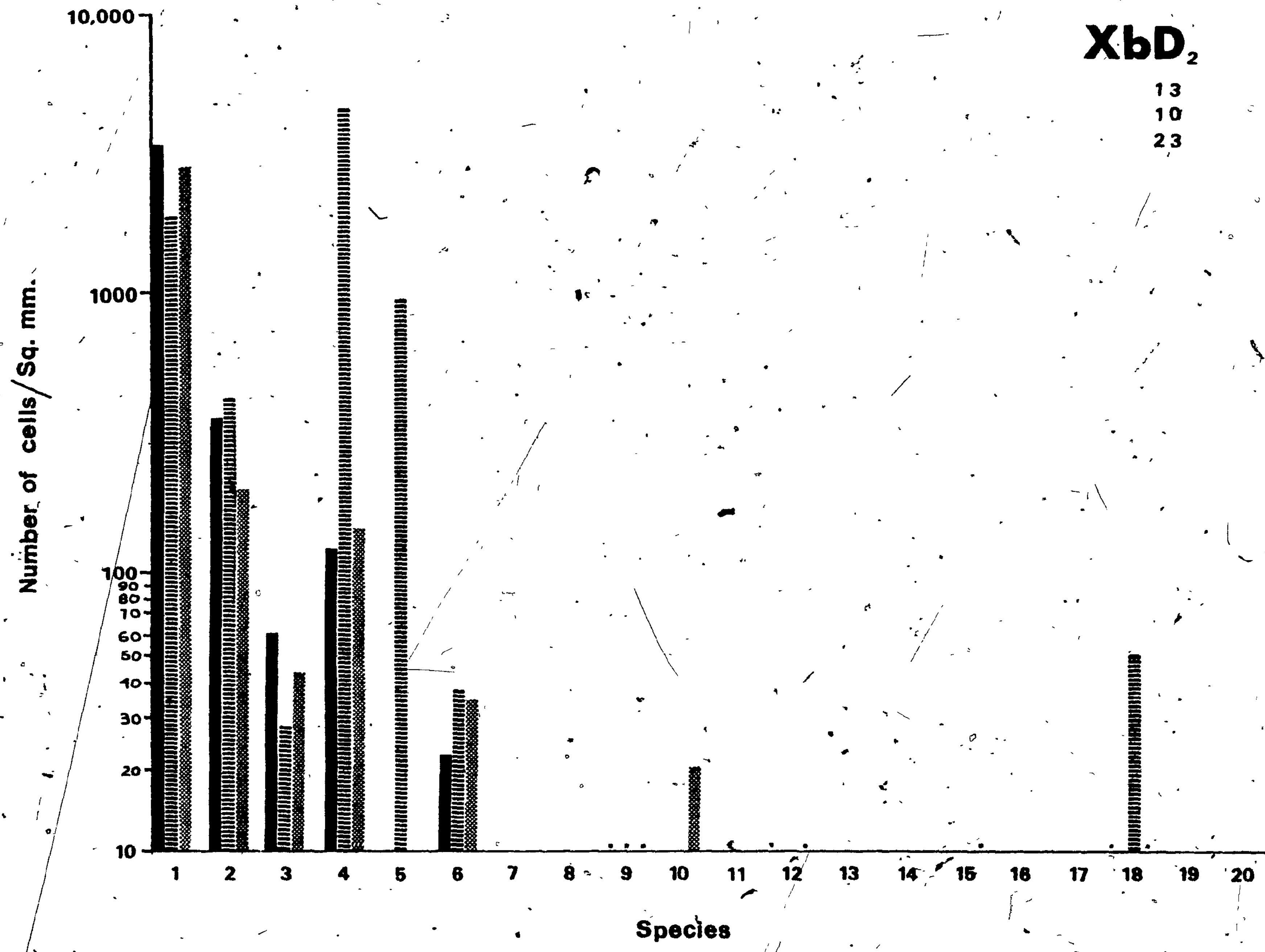
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Species



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10
1
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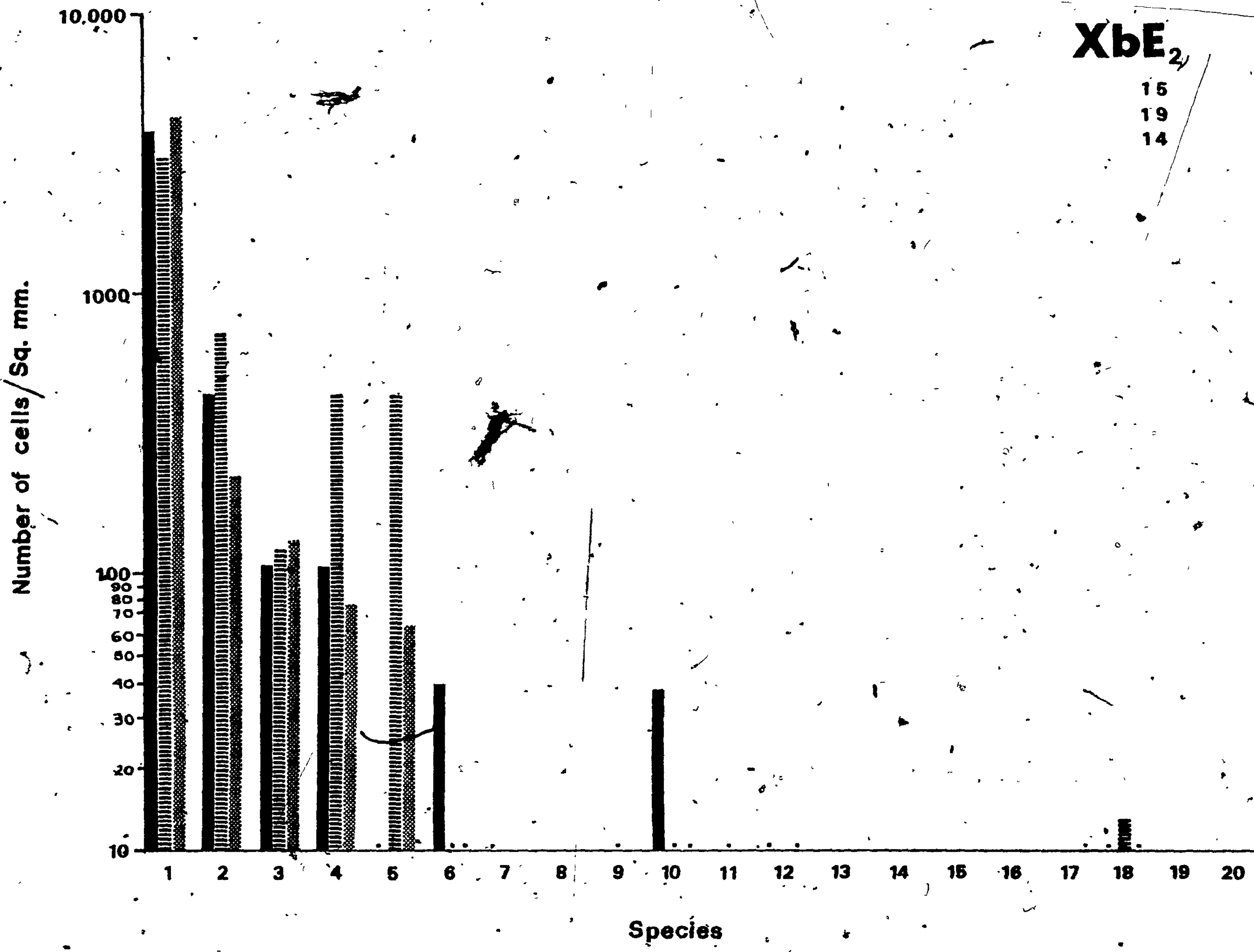
20
Species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Number of cells/Sq. mm.
1
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8
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10
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14
15
16
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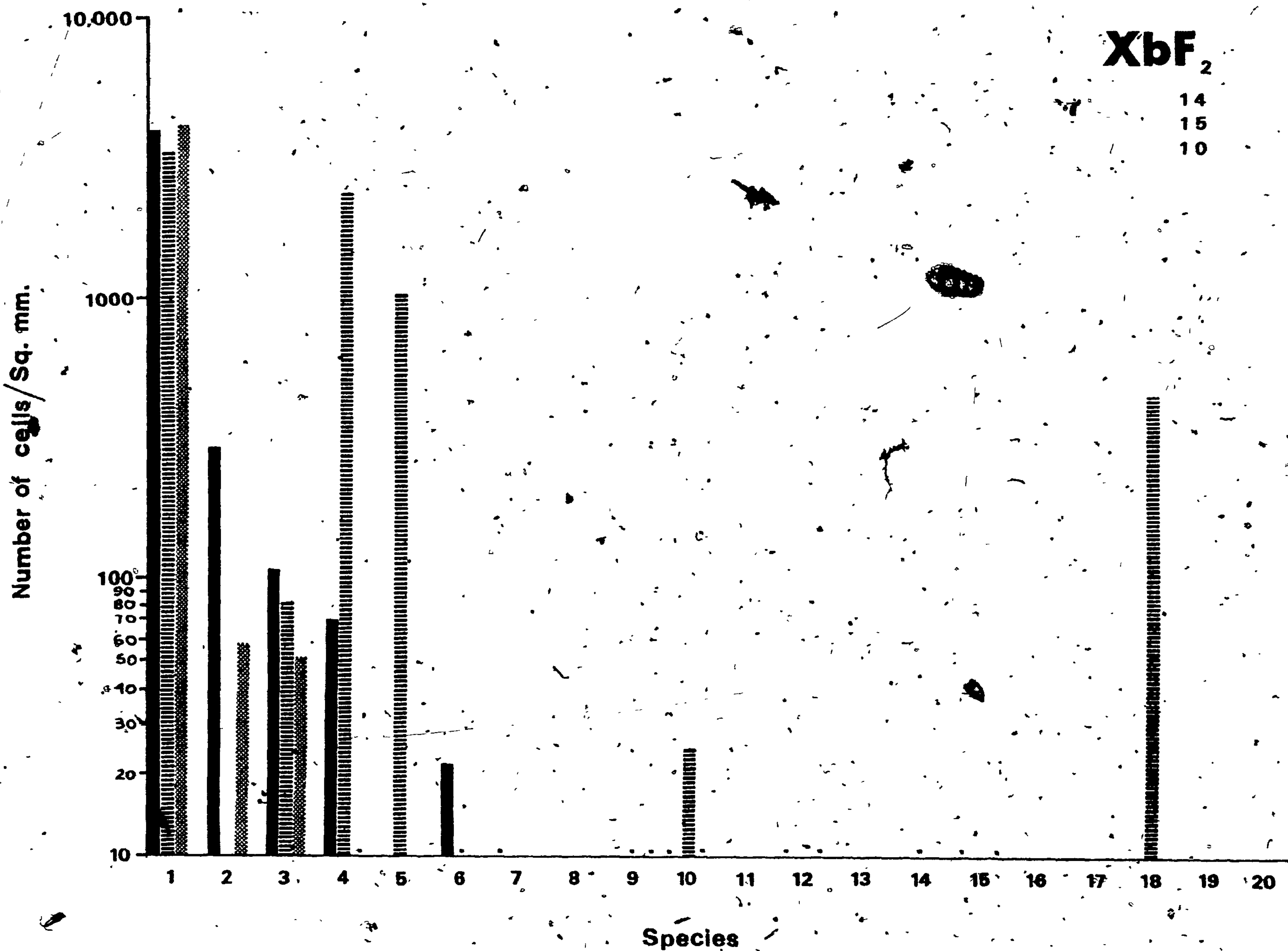
19
20
Species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Number of cells/Sq. mm.
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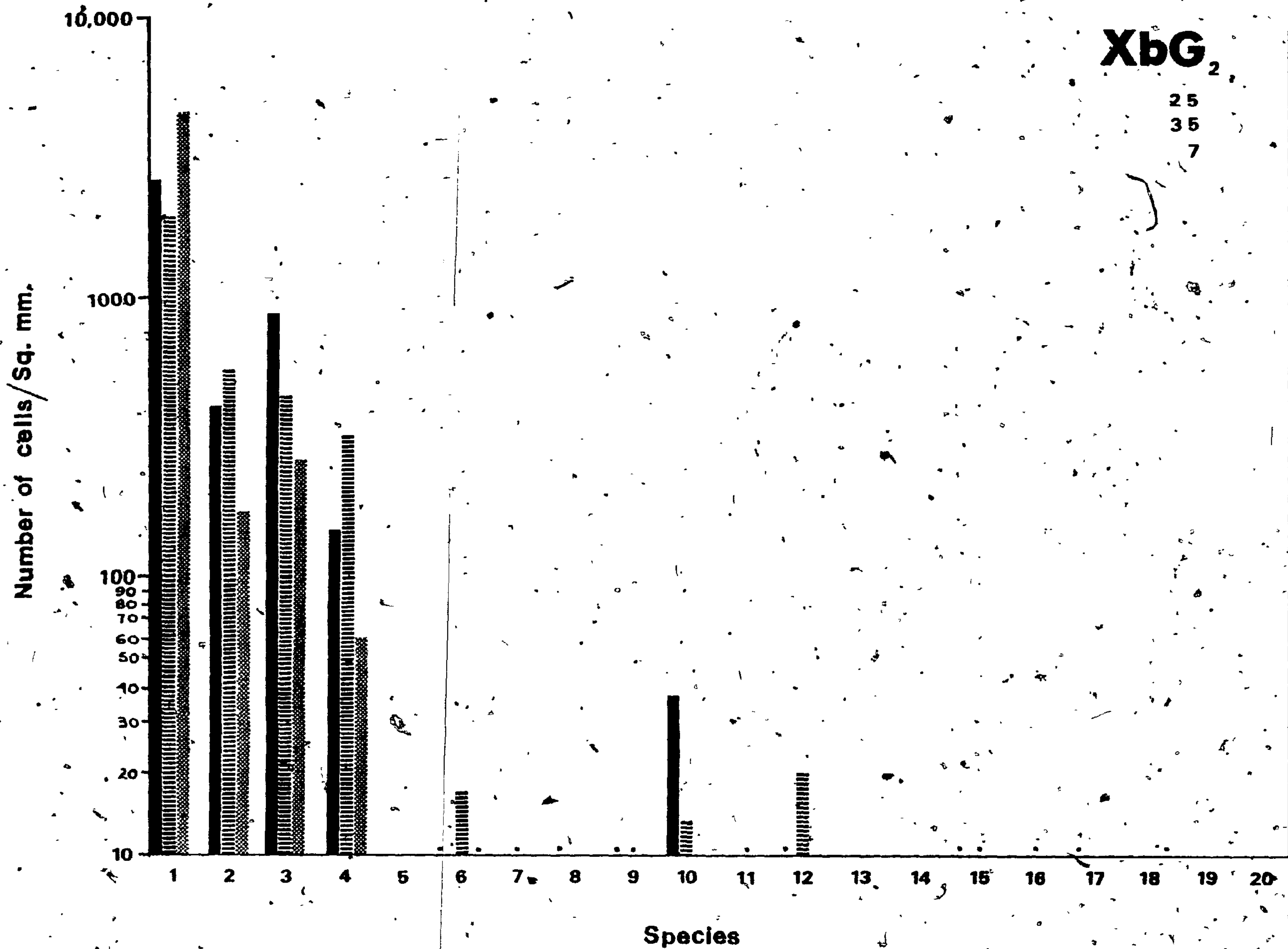
Species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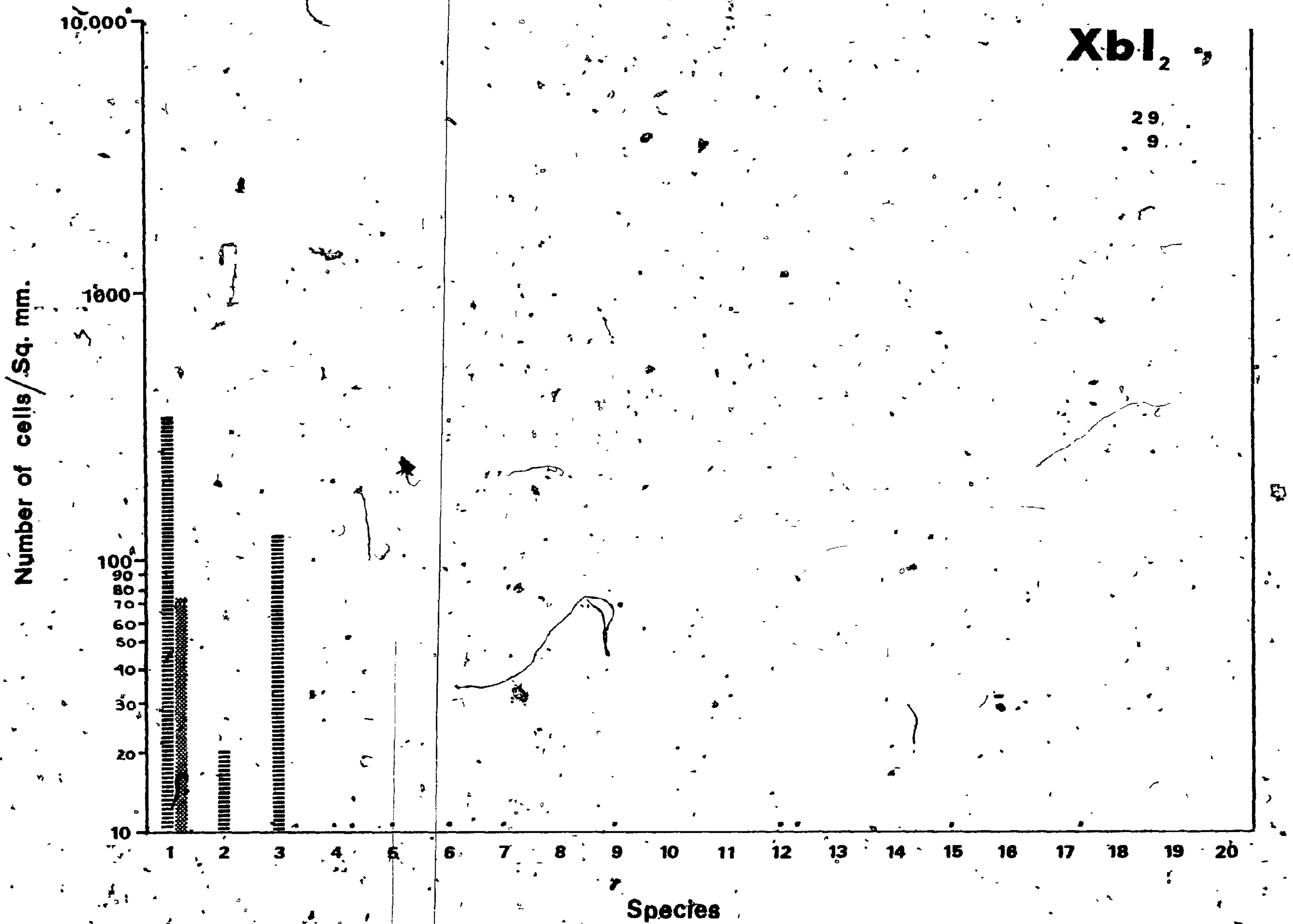
Species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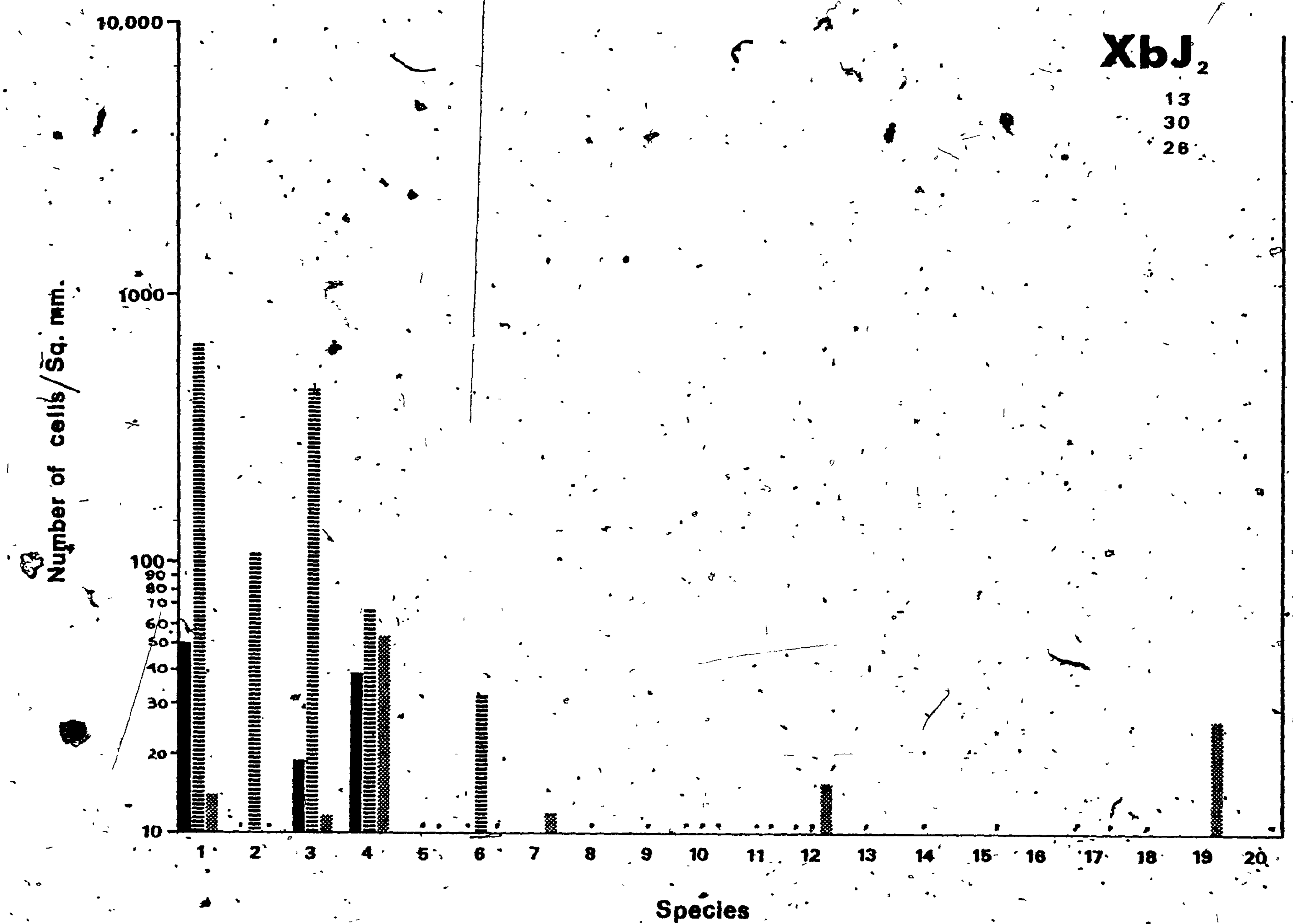
Species



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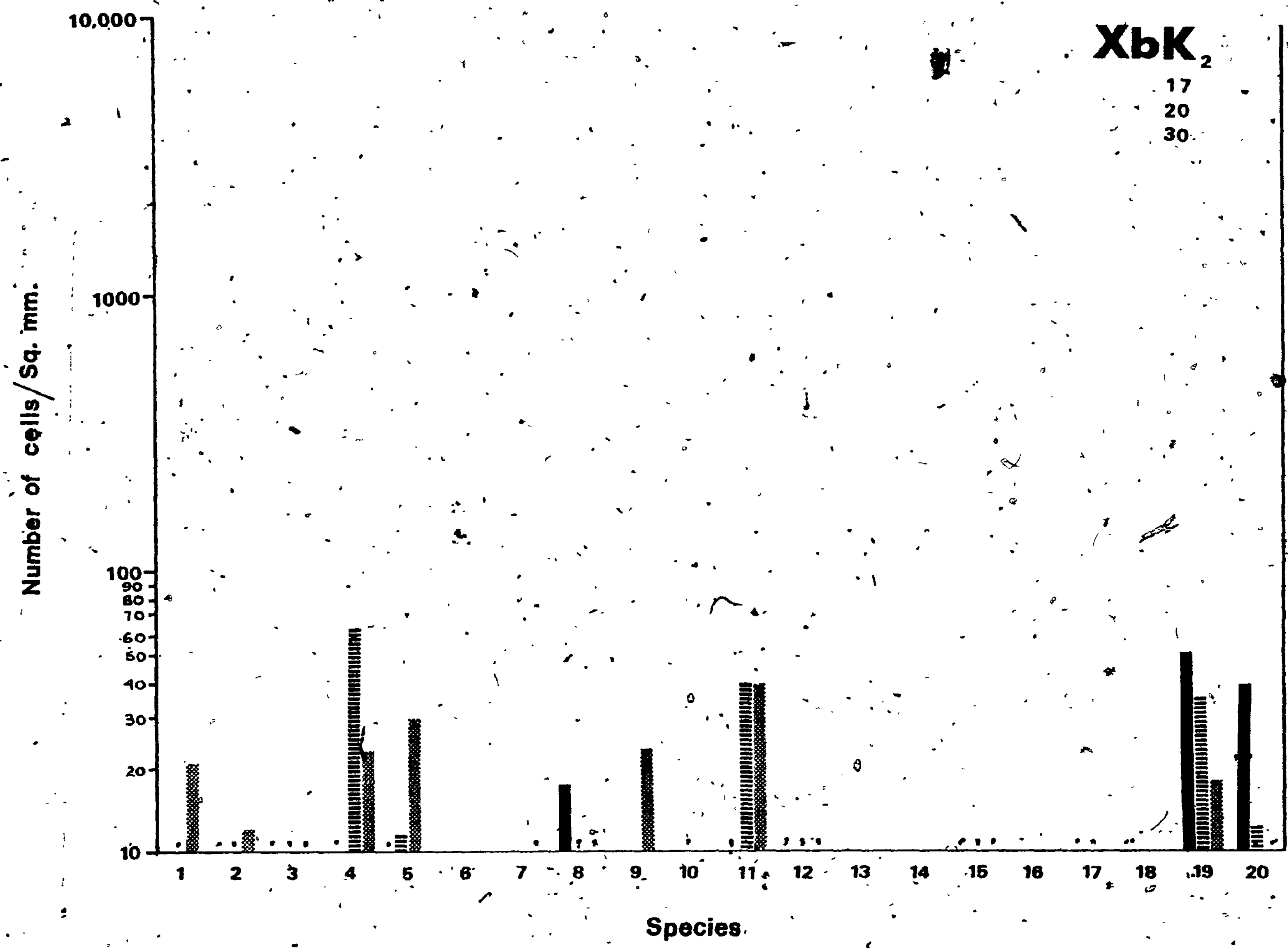
20
Species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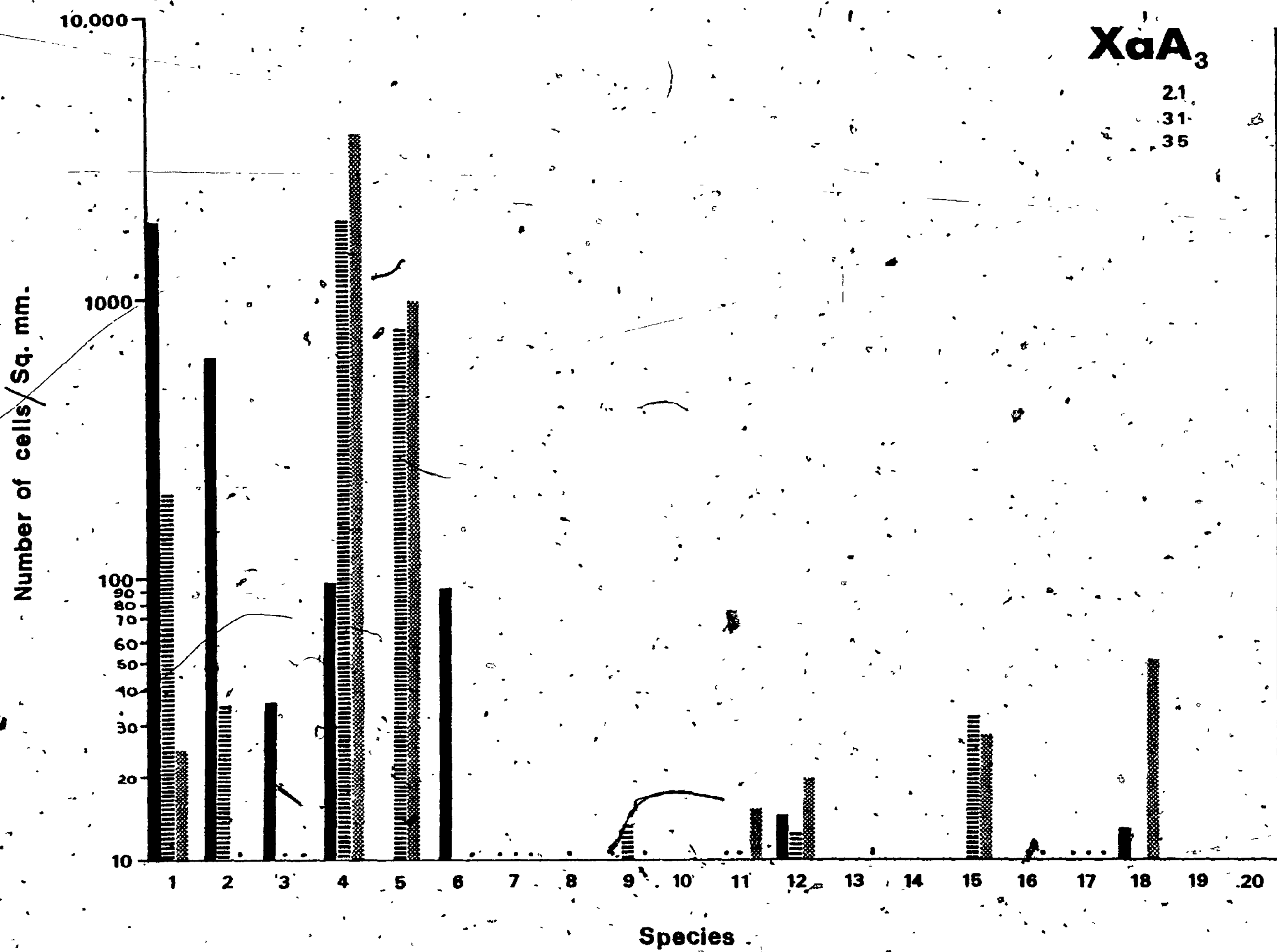
Species



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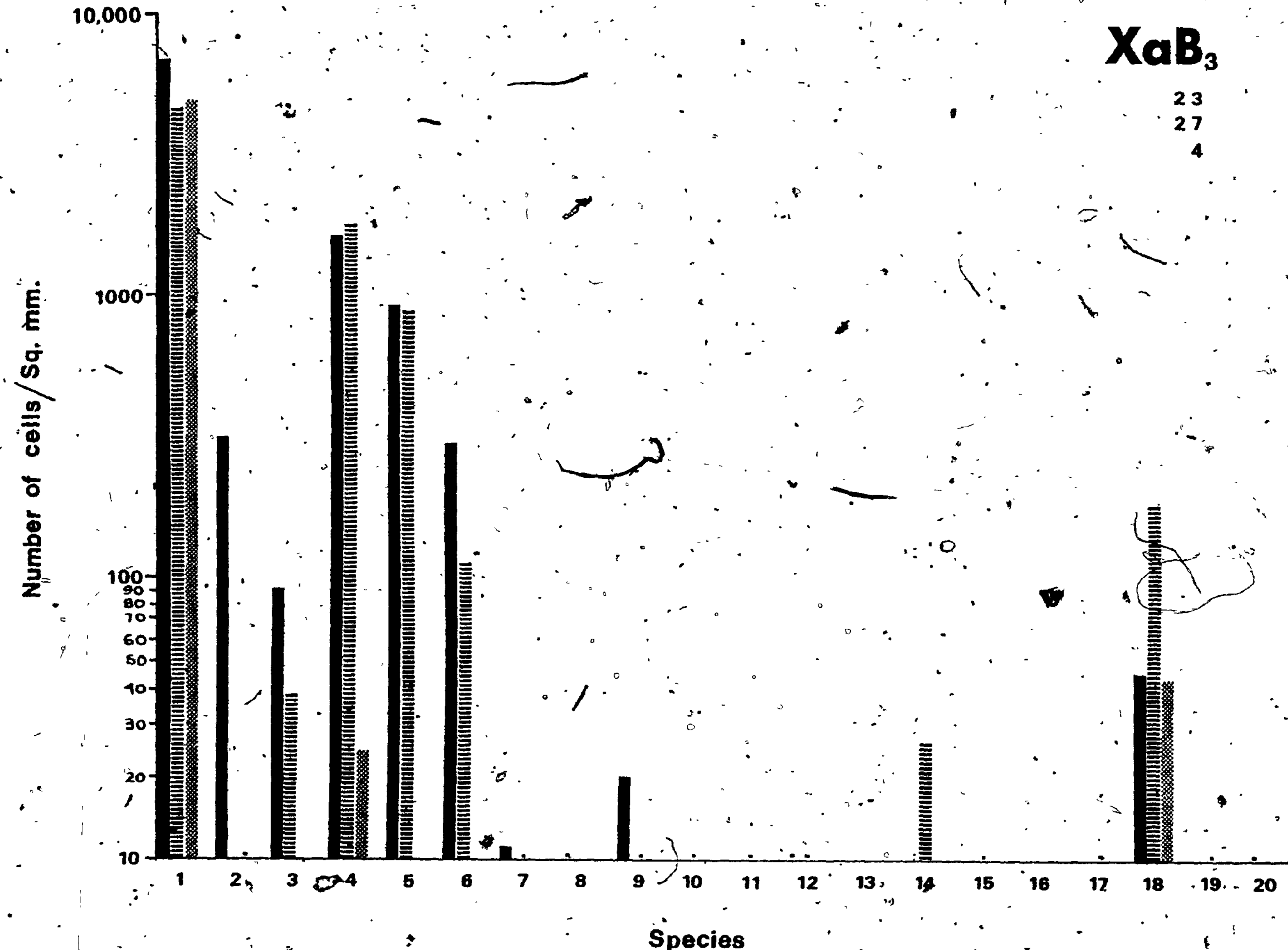
Species



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40
30
20
10
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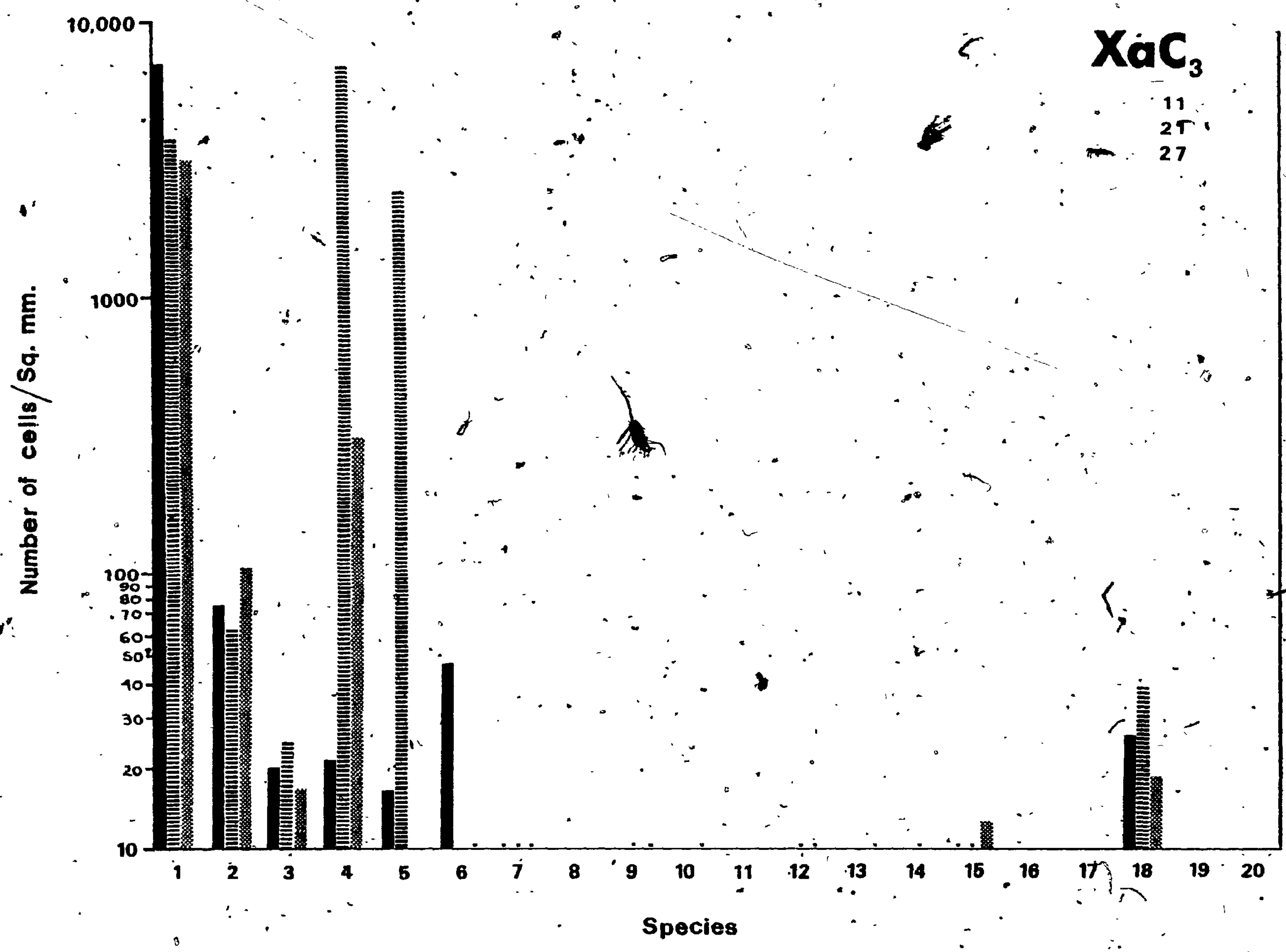
Species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Number of cells/Sq. mm.
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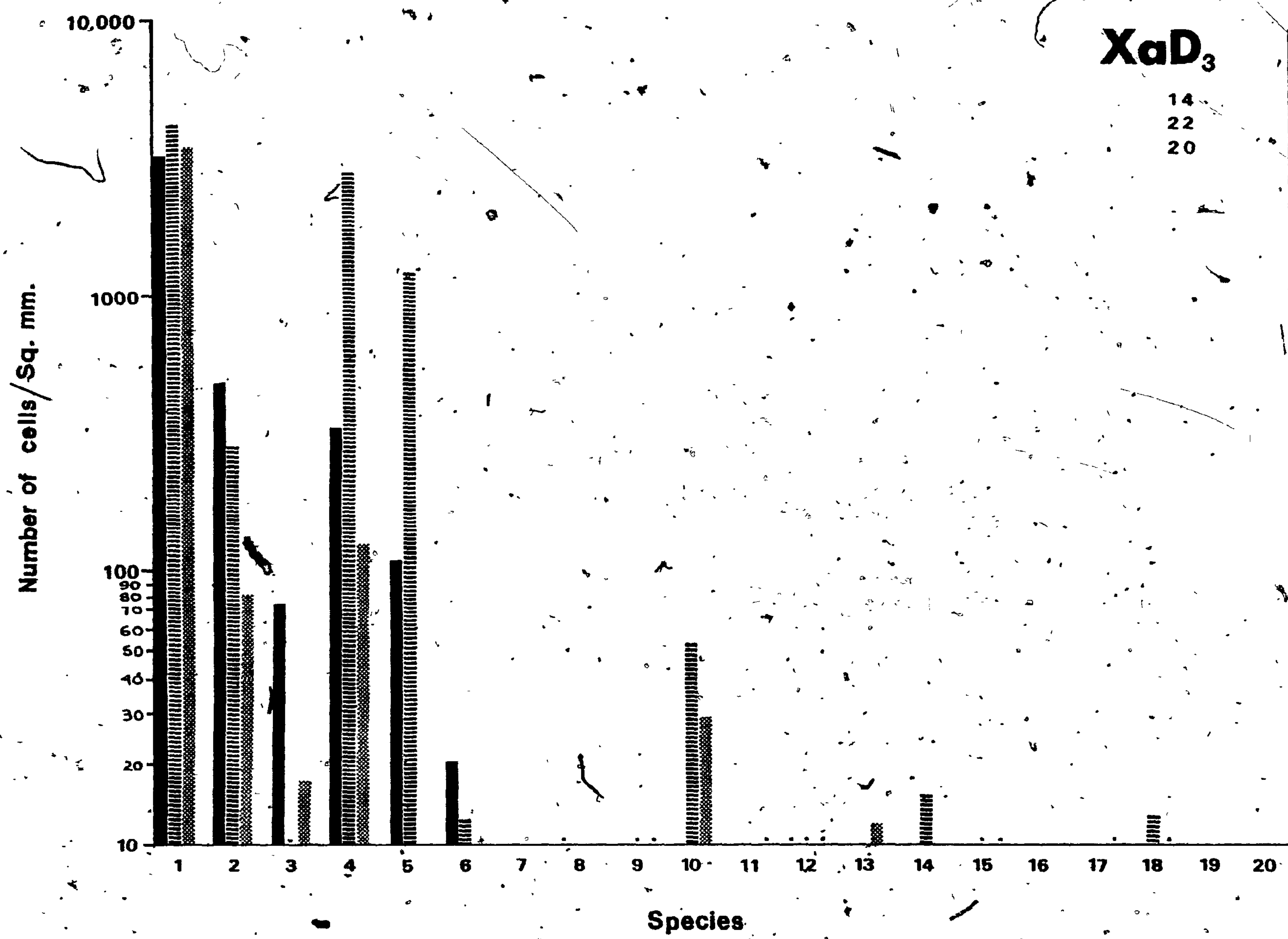
Species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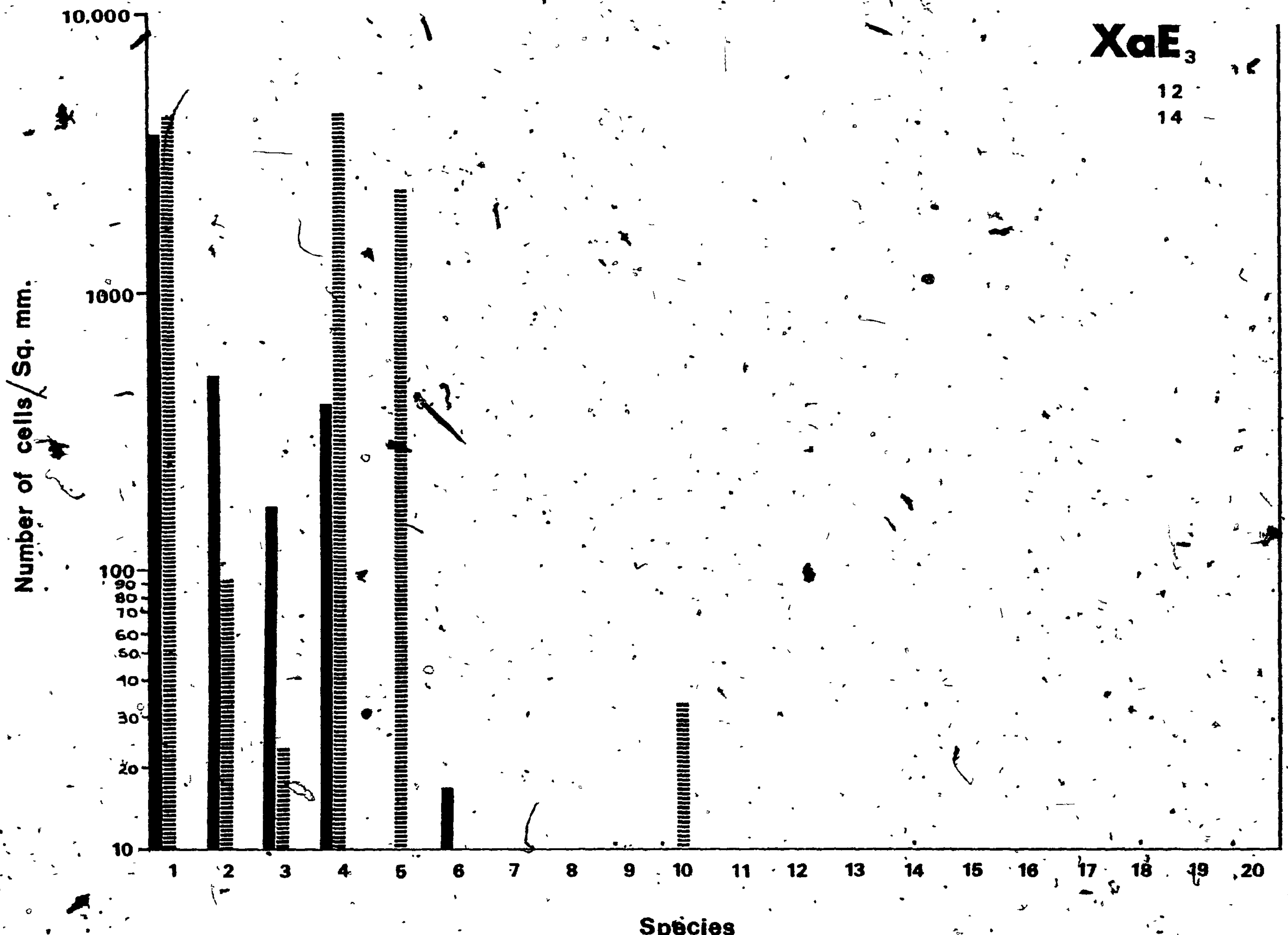
Species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Number of cells/Sq. mm.
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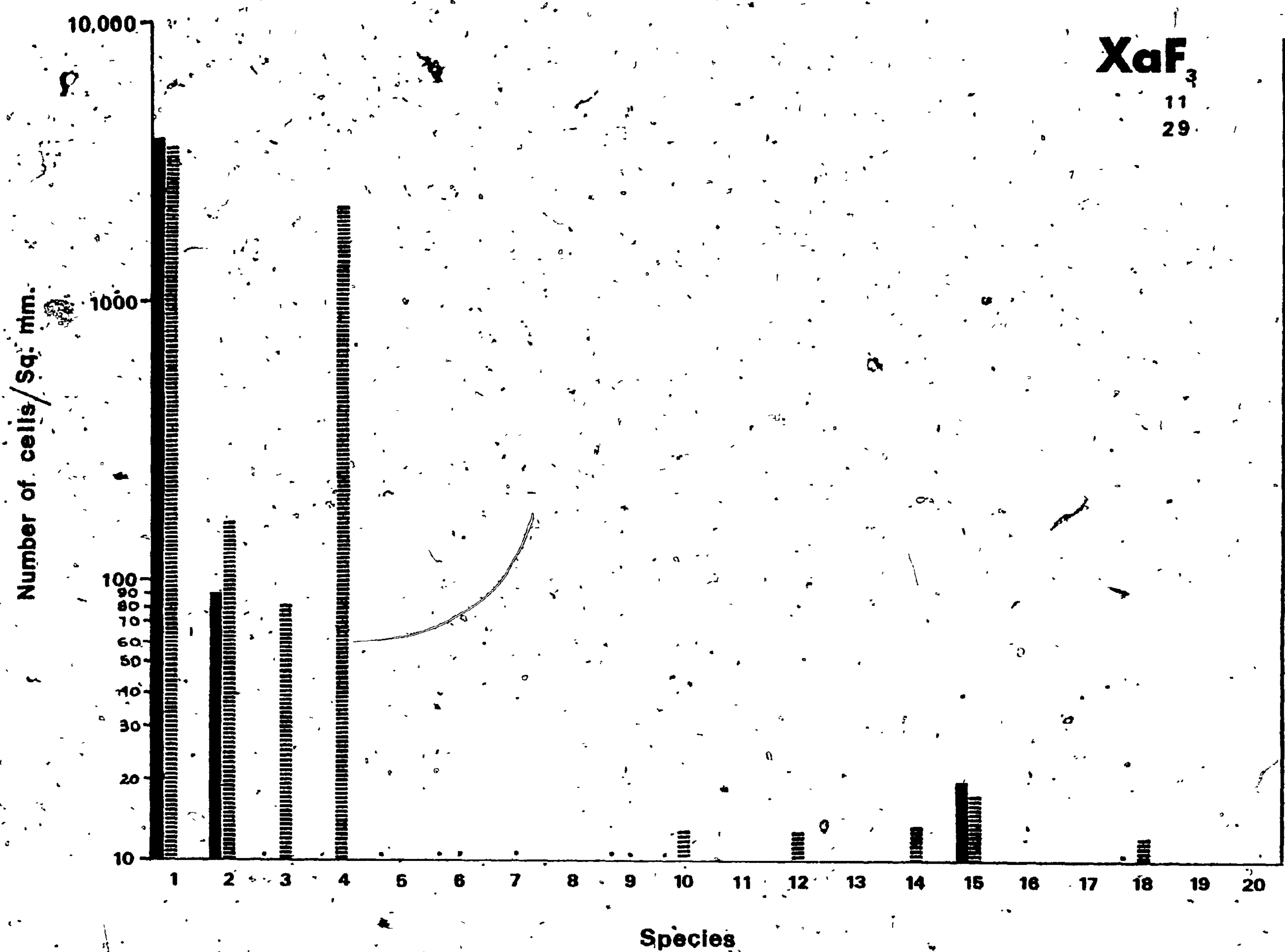
20
Species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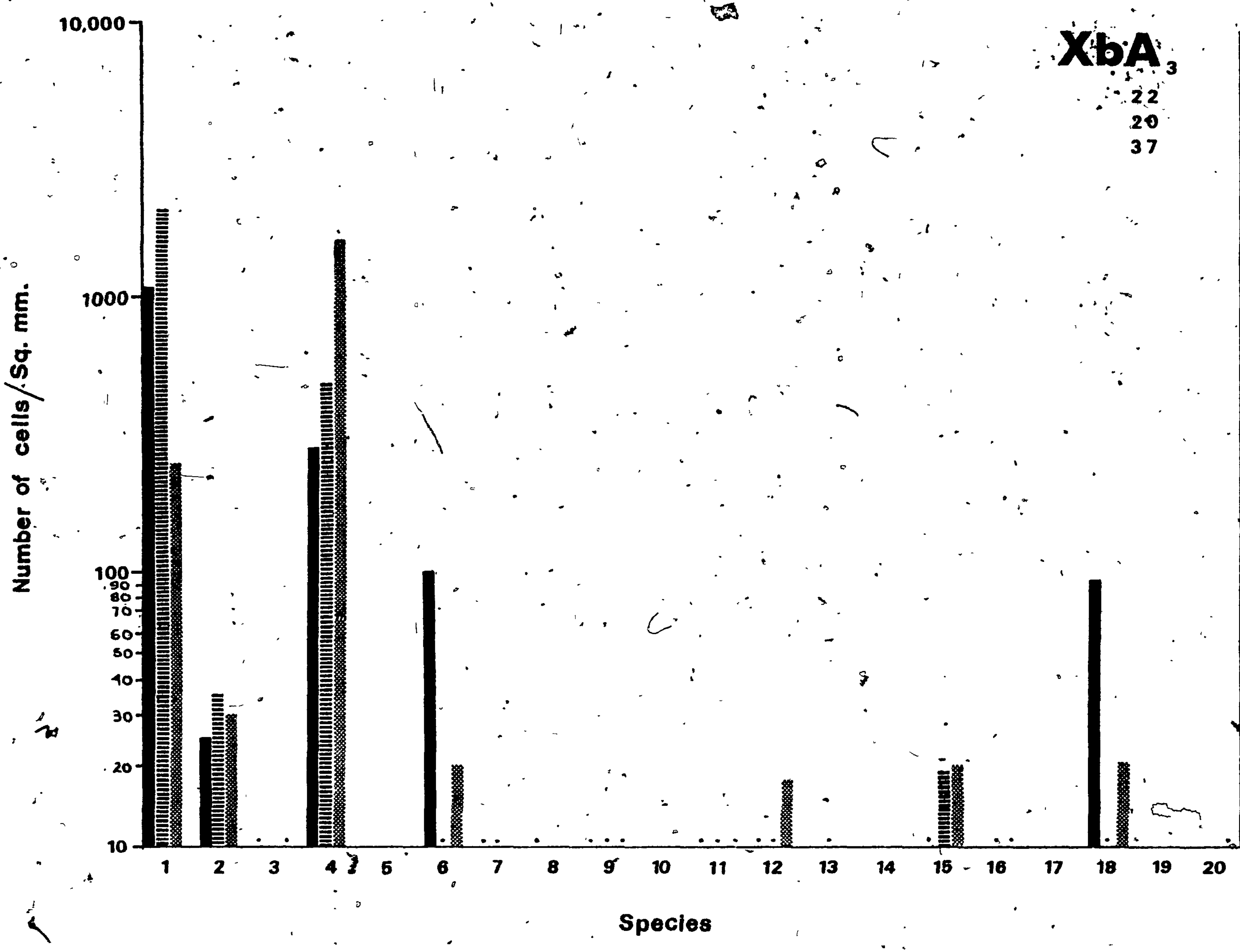
Species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Number of cells/Sq. mm.
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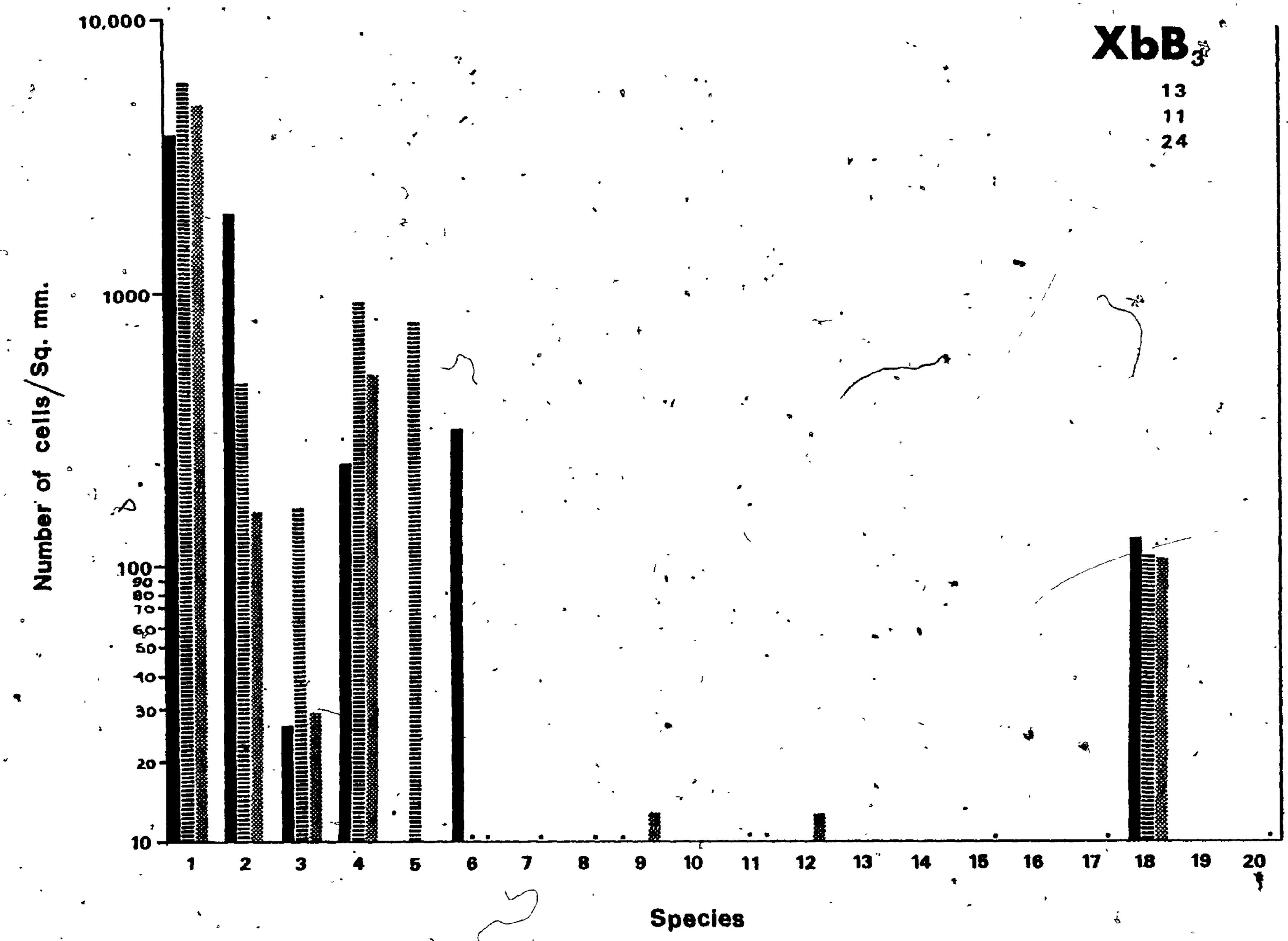
Species



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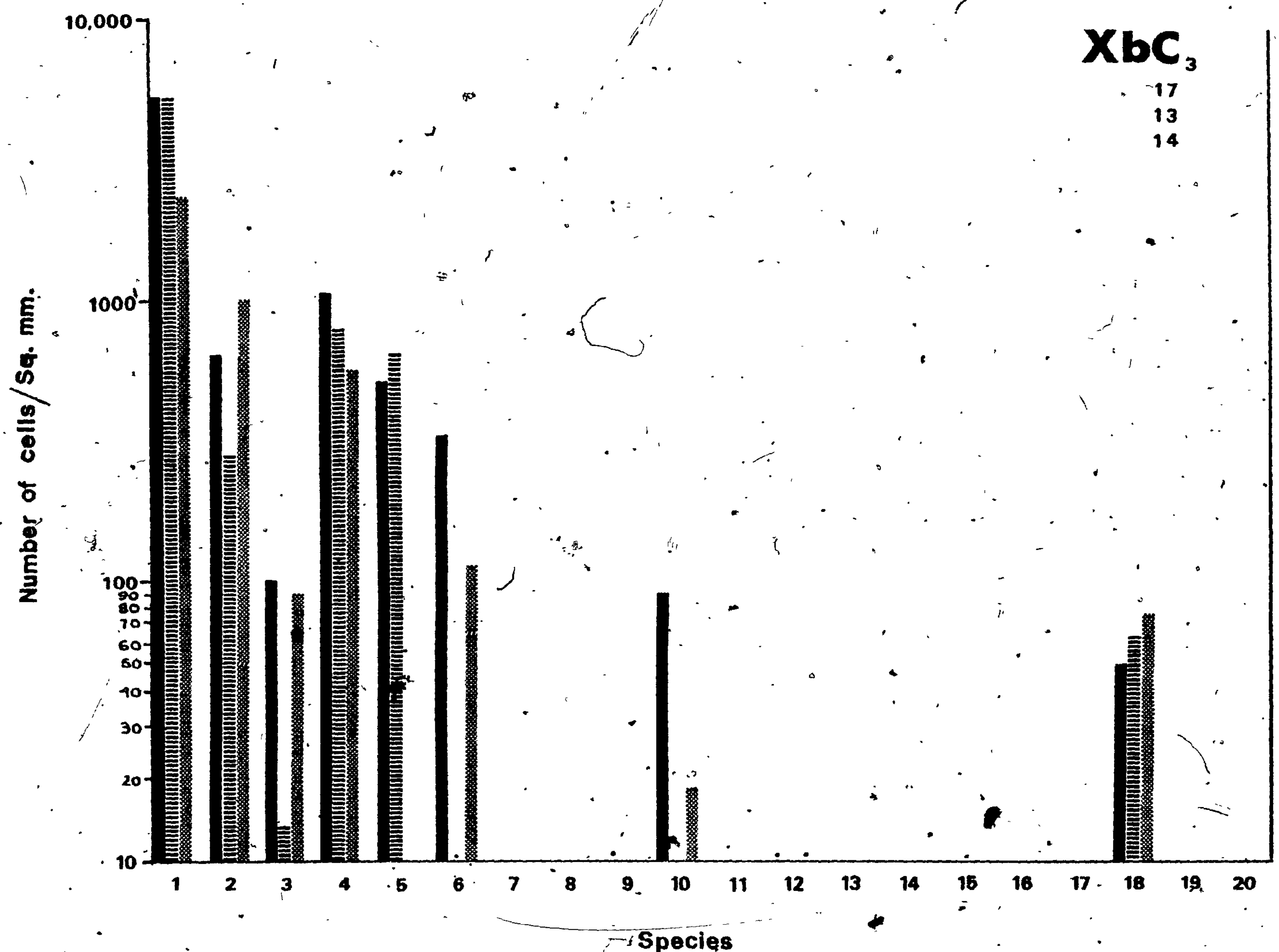
Species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Number of cells/Sq. mm.
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1000
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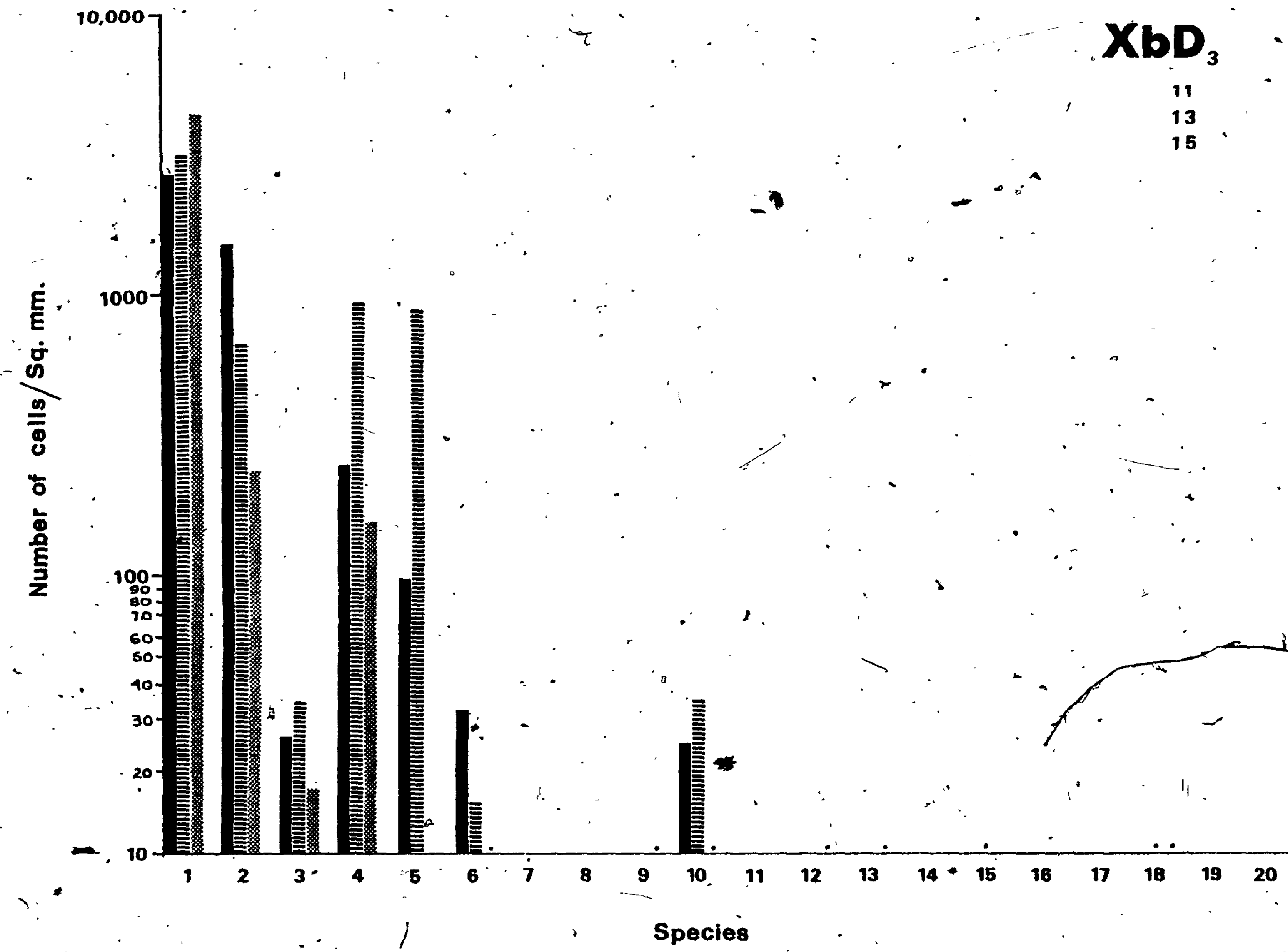
Species


XbD3
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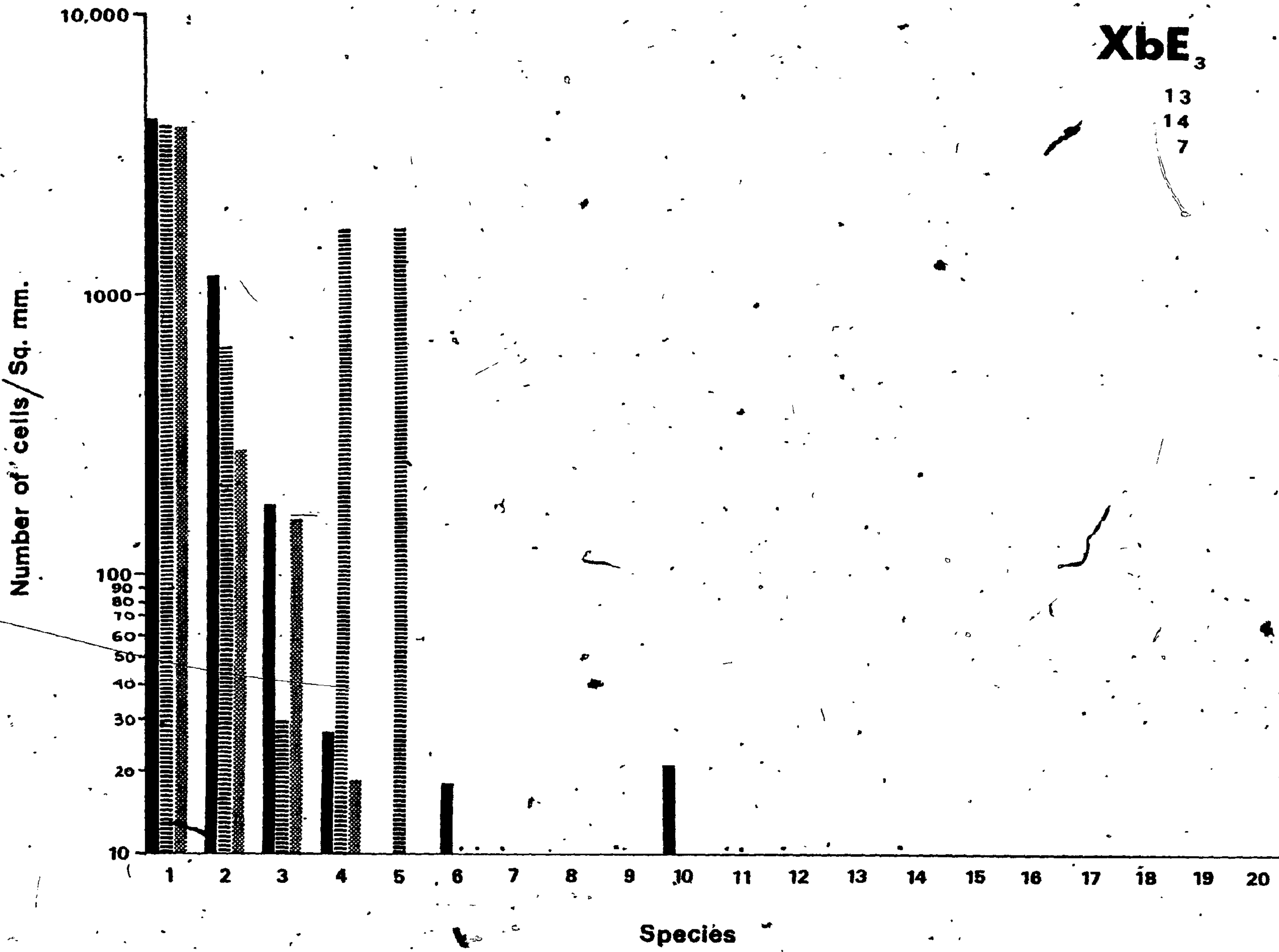
Species


XbE3
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Number of cells/Sq. mm.
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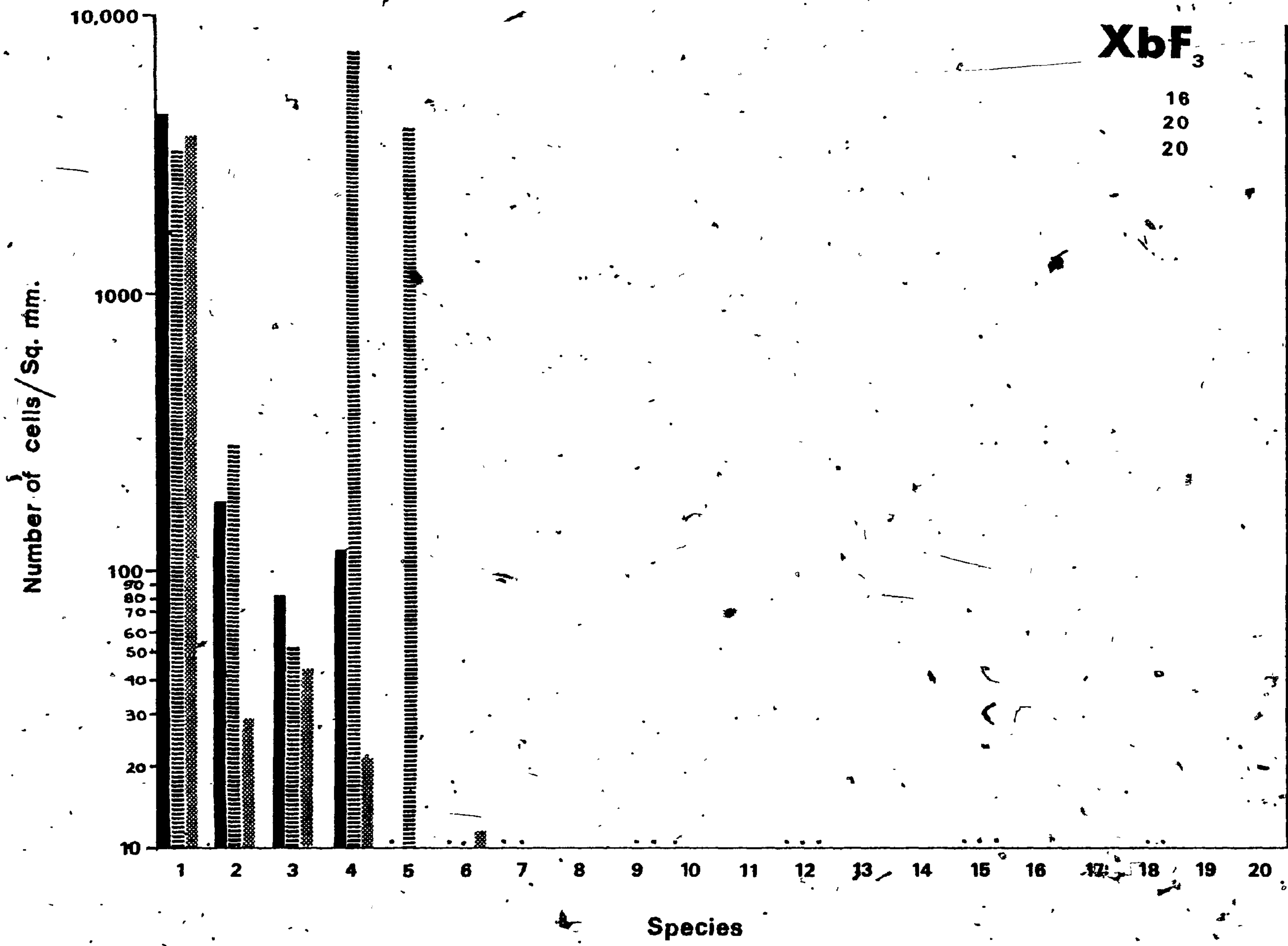
Species



XbF3
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Number of cells/Sq. mm.
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1000
100
90
80
70
60
50
40
30
20
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Species

APPENDIX III: Statistical Analysis. See text for details.

TABLE 1: Paired comparisons of slide replicates and replicate counts of the same slide from randomly chosen samples using the Wilcoxon Signed Ranks Test. Species 1 to 20 from Table 3, Appendix II were used.

| SLIDE | SOURCE OF VARIATION | n | TWO-TAILED P | DECISION AT 95% CONFIDENCE LEVEL |
|---|---|---|---|---|
| $2aE_1$ | slide replicates | 15 | 0.4 | $H_o$ accepted |
| $2aD_2$ | slide replicates | 14 | 0.4 | $H_o$ accepted |
| $1bD_3$ | slide replicates | 9 | 0.2 | $H_o$ accepted |
| $3aD_3$ | comparison with 3 month slide sampled same date | 12 | 0.05 | $H_o$ rejected |
| $3bF_2$ | replicate counts | 10 | 0.10 | $H_o$ accepted |
| $1aG_2$ | replicate counts | 14 | 0.01 | $H_o$ rejected |
| $3bG_2$ | slide replicates | 5 | $>0.5$ | $H_o$ accepted |

TABLE 2: Abundance differences of the 20 dominant diatoms among the 3 major stations Probability that observed differences are due to chance alone appears directly to the right of each sign associated with it. P is calculated by the Wilcoxon Signed Ranks Test; n varied from 9 to 20.

| | ROCKY | | | MUDDY | | | |
|---|---|---|---|---|---|---|---|
| SLIDE | Site 1 | Site 2 | Site 3 | Site 1 | Site 2 | Site 3 | Site 1 |
| $A_1$ | | < .01 | | > .20 | | | < .01 |
| $A_2$ | | < .05 | | | > .30 | > .10 | |
| $A_3$ | | | < .20 | | < .05 | < .10 | |
| $B_1$ | | < .05 | | | < .10 | < .05 | < .30 |
| $B_2$ | | < .30 | < .20 | | < .10 | < .001 | > .20 |
| $B_3$ | | > .30 | > .005 | < .001 | < .05 | > .30 | > .05 |
| $C_1$ | | < .025 | < .10 | > .20 | | < .05 | > .01 |
| $C_2$ | | < .005 | < .30 | > .005 | < .30 | < .05 | |
| $C_3$ | | < .30 | > .005 | | > .025 | | < .05 |
| $D_1$ | | < .001 | < .005 | > .20 | < .10 | > .025 | < .30 |
| $D_2$ | | | | | < .20 | | |
| $D_3$ | | < .20 | > .10 | < .30 | < .20 | > .20 | < .20 |
| $E_1$ | | < .025 | | > .10 | > .05 | > .30 | < .20 |
| $E_2$ | | | > .10 | < .20 | | > .20 | < .20 |
| $E_3$ | | | | | > .30 | > .10 | < .005 |
| $F_1$ | | < .20 | > .10 | > .10 | | > .30 | |
| $F_2$ | | < .20 | | | | | .20 |
| $F_3$ | | < .10 | | | | > .20 | .025 |
| $G_1$ | | < .005 | > .05 | > .005 | | > .05 | < .025 |
| $G_2$ | | < .005 | | | | .005 | |
| $H_1$ | | < .005 | | | | | |
| $I_2$ | | | | | | .005 | |
| $J_2$ | | < .05 | < .30 | > .05 | < .005 | > .30 | > .05 |
| $K_2$ | | < .025 | | | < .10 | | > .05 |

TABLE 3: Two-way analysis of variance for diversity data using series and stations as independant variables done for the three colonization ages at rocky and muddy subsites.

| SOURCE OF VARIATION | SUMS OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARES | F-value | PROBABILITY ASSOCIATED WITH F-value | SUBSITE (AGE) |
|---|---|---|---|---|---|---|
| Series | 7.321 | 6 | 1.220 | 4.265 | 0.0006 | ROCKY |
| Sites | 1.363 | 2 | 0.682 | 5.174 | 0.024 | 2 wk. |
| Residual | 1.581 | 12 | 0.132 | | | |
| Total | 10.265 | 20 | | | | |
| Series | 2.165 | 5 | 0.433 | 3.026 | 0.064 | ROCKY |
| Sites | 0.755 | 2 | 0.377 | 2.637 | 0.120 | 4 wk. |
| Residual | 1.431 | 10 | 0.143 | | | |
| Total | 4.351 | 17 | | | | |
| Series | 0.024 | 3 | 0.008 | 0.081 | 0.908 | ROCKY |
| Sites | 0.702 | 2 | 0.351 | 3.539 | 0.097 | 6 wk. |
| Residual | 0.595 | 6 | 0.099 | | | |
| Total | 1.320 | 11 | | | | |
| Series | 6.422 | 5 | 1.284 | 2.902 | 0.0713 | MUDDY |
| Sites | 0.732 | 2 | 0.366 | 0.827 | 0.465 | 2 wk. |
| Residual | 4.426 | 10 | 0.443 | | | |
| Total | 11.579 | 17 | | | | |
| Series | 1.837 | 5 | 0.367 | 1.233 | 0.363 | MUDDY |
| Sites | 0.022 | 2 | 0.011 | 0.037 | 0.963 | 4 wk. |
| Residual | 2.981 | 10 | 0.298 | | | |
| Total | 4.841 | 17 | | | | |
| Series | 1.792 | 4 | 0.448 | 1.093 | 0.422 | MUDDY |
| Sites | 0.102 | 2 | 0.051 | 0.125 | 0.884 | 6 wk. |
| Residual | 3.279 | 8 | 0.409 | | | |
| Total | 5.174 | 14 | | | | |

TABLE 4: Two-way analysis of variance for total number of individuals on slides using series and stations as independant variables done for the three colonization ages at rocky and muddy subsites.

| SOURCE OF VARIATION | SUMS OF SQUARES | DEGREES OF FREEDOM | MEAN SQUARES | F-value | PROBABILITY ASSOCIATED WITH F-value | SUBSITE (AGE) |
|---|---|---|---|---|---|---|
| Series | 1.808 | 6 | 0.301 | 0.362 | 0.889 | ROCKY |
| Stations | 6.822 | 2 | 3.411 | 4.100 | 0.044 | 2 wk. |
| Residual | 9.083 | 12 | 0.832 | | | |
| Total | 18.614 | 20 | | | | |
| Series | 5.819 | 5 | 1.163 | 2.590 | 0.013 | ROCKY |
| Stations | 2.135 | 2 | 1.068 | 2.376 | 0.143 | 4 wk. |
| Residual | 4.493 | 10 | 0.449 | | | |
| Total | 12.448 | 17 | | | | |
| Series | 1.593 | 5 | 0.319 | 1.301 | 0.337 | ROCKY |
| Stations | 0.647 | 2 | 0.323 | 1.319 | 0.310 | 6 wk. |
| Residual | 2.449 | 10 | 0.245 | | | |
| Total | 4.688 | 17 | | | | |
| Series | 11.385 | 6 | 1.898 | 5.073 | 0.008 | MUDDY |
| Stations | 1.239 | 2 | 0.620 | 1.657 | 0.232 | 2 wk. |
| Residual | 4.488 | 12 | 0.374 | | | |
| Total | 17.113 | 20 | | | | |
| Series | 6.202 | 6 | 1.034 | 3.572 | 0.029 | MUDDY |
| Stations | 1.392 | 2 | 0.696 | 2.405 | 0.132 | 4 wk. |
| Residual | 3.473 | 12 | 0.289 | | | |
| Total | 11.067 | 20 | | | | |
| Series | 2.976 | 5 | 0.595 | 6.337 | 0.007 | MUDDY |
| Stations | 0.681 | 2 | 0.340 | 3.622 | 0.066 | 6 wk. |
| Residual | 0.939 | 10 | 0.093 | | | |
| Total | 4.596 | 17 | | | | |

TABLE 5: Comparison of numbers for each of the 20 dominant diatoms of rocky and muddy subsites at the three stations of Bishop's Stream. One-tailed P (probability that difference is due to chance) was calculated using the Wilcoxon Signed Ranks Test. Asterisks indicate significant differences; n=20.

| SLIDE | STATIONS 1 | STATIONS 2 | STATIONS 3 |
|---|---|---|---|
| $A_1$ | M > R (P=10%) | R > M (P=.5%)*** | R > M (P=10%) |
| $A_2$ | M R (P=5%)* | R M (P=20%) | R M (P=20%) |
| $A_3$ | R M (P=30%) | R M (P=10%) | R M (P=20%) |
| $B_1$ | R M (P=30%) | R M (P=30%) | R M (P=.5%)*** |
| $B_2$ | R M (P=10%) | R M (P=40%) | M R (P=.5%)*** |
| $B_3$ | R M (P=5%)* | R M (P=30%) | M R (P=.5%)*** |
| $C_1$ | R M (P=5%)* | R M (P=30%) | R M (P=5%)* |
| $C_2$ | M R (P=.5%)*** | R M (P=10%) | R M (P=5%)* |
| $C_3$ | M R (P=10%) | R M (P=20%) | M R (P=30%) |
| $D_1$ | R M (P=30%) | R M (P=10%) | M R (P=40%) |
| $D_2$ | M R (P=5%)* | M R (P=20%) | R M (P=10%) |
| $D_3$ | R M (P=30%) | R M (P=20%) | R M (P=1%)** |
| $E_1$ | M R (P=5%)* | R M (P=20%) | R M (P=2.5%)* |
| $E_2$ | M R (P=20%) | R M (P=20%) | M R (P=2.5%)* |
| $E_3$ | M R (P=1%)** | R M (P=30%) | |
| $F_1$ | M R (P=20%) | R M (P=30%) | M R (P=10%) |
| $F_2$ | R M (P=20%) | | |

TABLE 6: F-values from analysis of variance performed on diversity of slide communites aged from 2 weeks to 6 weeks for series A to G. Probabilities associated with the F-values are given as P. A high F-value indicates significant variation between the diversity of the three aged communities. Stations are pooled in the analysis.

| SERIES | F-values (d.f. 2,4) ROCKY SUBSITE | MUDDY SUBSITE |
|---|---|---|
| A | 20.80669 (P=.007) | 10.51411 (P=.025) |
| B | 12.86666 (P=.018) | 4.31893 (P=.100) |
| C | 244.89760 (P=.001) | 4.44640 (P=.100) |
| D | 4.80187 (P=.087) | 11.07240 (P=.023) |
| E | 0.81965 (P=.503) | 2.35510 (P=.210) |
| F | | 0.18375 (P=.839) |
| G | 0.09404 (P=.788) | 0.03588 (P=.123) |

TABLE 7: F-values from analysis of variance performed on log-transformed data for total numbers of diatoms on slides aged from 2 weeks to 6 weeks for series A to F. Probabilities and F-values as in Table 6 of this Appendix. Stations are pooled.

| SERIES | F-values (d.f. 2,4) ROCKY SUBSITE | MUDDY SUBSITE |
|---|---|---|
| A | 5.16429 (P=.078) | 2.46133 (P=.201) |
| B | 8.29923 (P=.038) | 9.46059 (P=.030) |
| C | 5.65148 (P=.068) | 36.64105 (P=.003) |
| D | 16.06851 (P=.012) | 35.59655 (P=.003) |
| E | 38.86226 (P=.002) | 29.86410 (P=.004) |
| F | 4.66923 (P=.090) | 2.98871 (P=.161) |

TABLE 8: Comparison of total diatom population of edges with middle of slide using Wilcoxon Signed Ranks Test. The probability that the differences are chance occurrences is given by P.

| STATION | AGE OF COLONY (in weeks) | AREAS COMPARED | DIFFERENCE ( a plus sign indicates higher numbers in first area; a negative sign=no difference) |
|---|---|---|---|
| 1 | 2 | Upstream/Middle | + (P=1%) |
| 1 | 2 | Downstream/Middle | + (P=5%) |
| 1 | 2 | Upstream/Downstream | + (P=5%) |
| 2 | 2 | Upstream/Middle | + (P=5%) |
| 2 | 2 | Downstream/Middle | + |
| 1 | 4 | Upstream/Middle | + (P=10%) |
| 1 | 4 | Downstream/Middle | + (P=5%) |
| 2 | 4 | Upstream/Middle | − |
| 2 | 4 | Downstream/Middle | − |

TABLE 9: Distribution of diatoms from top to bottom of slide. The probability that the phenomenon observed occurred by chance is given by P, calculated using the Wilcoxon Signed Ranks Test after pairs were arranged according to the Cox & Stuart Test for Trend; n=5.

| DATE OF COLLECTION | TWO WEEK OLD COLONIES | | FOUR WEEK COLONIES | | SIX WEEK COLONIES | |
|---|---|---|---|---|---|---|
| | slide | trend | slide | trend | slide | trend |
| 18/05/77 | $2aA_1$ | + (P 10%) | | | | |
| 2/06/77 | | | $2aA_2$ | + (P=1%) | | |
| 2/06/77 | | | $2bA_2$ | + (P=10%) | | |
| 15/06/77 | | | $2aB_2$ | + (P=10%) | $2aA_3$ | + (P=1%) |
| 15/06/77 | $2bC_1$ | − (P=15%) | $2bB_2$ | ± | | |
| 29/06/77 | $2aD_1$ | − (P=40%) | $2aC_2$ | + (P=10%) | $2aB_3$ | − (P=40%) |
| 29/06/77 | $2bD_1$ | ± | $2bC_2$ | ± | | |
| 13/07/77 | $2aE_1$ | − (P=30%) | $2aD_2$ | + (P=5%) | $2aC_3$ | ± |
| 13/07/77 | $2bE_1$ | + (P=10%) | $2bD_2$ | ± | $2bC_3$ | ± |
| 14/07/77 | $1aE_1$ | + (P=1%) | | | | |
| 14/07/77 | $1bE_1$ | + (P=10%) | | | | |
| 27/07/77 | $2aF_1$ | ± | $2aE_2$ | + | $2aD_3$ | + (P=1%) |
| 27/07/77 | $2bF_1$ | + (P=5%) | $2bE_2$ | − (P=5%) | $2bD_3$ | − (P=20%) |
| 28/07/77 | $1aF_1$ | − (P=40%) | $1aE_2$ | + (P=1%) | | |
| 10/08/77 | | | $2aF_2$ | ± | $2aE_3$ | + (P=1%) |
| 10/08/77 | | | $2bF_2$ | + (P=5%) | $2bE_3$ | + (P=20%) |
| | | | | | $2aF_3$ | + (P=5%) |
| | | | | | $2bF_3$ | ± |

+ : Preference of diatoms for top of slide
± : No preference
− : Preference for bottom of slide

TABLE 10: Paired comparisons of slide replicates taken from the edge and the middle of the slide chamber using Wilcoxon Signed Ranks Test. Species 1 to 20 of Table 3, Appendix II, were used. Incubation time of all slides was 4 weeks. Slides were sampled August 9 and 10.

| STATION | SOURCE OF VARIATION | n | TEST STATISTIC | TWO-TAILED P | DECISION AT 95% CONFIDENCE LEVEL |
|---|---|---|---|---|---|
| 1a | edge vs. middle | 12 | 29.0 | .4 | $H_o$ accepted |
| 1a | middle vs. middle | 9 | 14.0 | .2 | $H_o$ accepted |
| 2b | edge vs. middle | 11 | 29.0 | .7 | $H_o$ accepted |
| 2b | middle vs. middle | 7 | 5.0 | .2 | $H_o$ accepted |
| 3b | edge vs. middle | 10 | 18.0 | .4 | $H_o$ accepted |
| 3b | middle vs. middle | 8 | 17.5 | .5 | $H_o$ accepted |

TABLE 11. Paired comparisons of communities on frosted and clear surfaces of slides. Mean numbers of Species 1 to 20 are used. Probabilities are calculated by the Wilcoxon Signed Ranks Test. Slides were sampled August 10 and represent 4 week exposures.

| SITE | SOURCE OF VARIATION | n | TEST STATISTIC | TWO-TAILED P | DECISION AT 95% CONFIDENCE LEVEL |
|---|---|---|---|---|---|
| 2b | clear/frosted top/bottom same slide | 10 | 24 | >.5 | $H_o$ accepted |
| 2b | clear/frosted top/top different slides | 8 | 14 | .6 | $H_o$ accepted |
| 2b | clear/frosted bottom/bottom diff. slides | 11 | 11 | .05 | $H_o$ rejected |
| 2b | clear/frosted bottom/top same slide | 11 | 7 | .02 | $H_o$ rejected |
| 2a | clear/frosted bottom/top same slide | 13 | 42.5 | >.5 | $H_o$ accepted |