The vegetation of the River Tweed

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THE VEGETATION OF THE RIVER TWEED

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Philosophy

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April, 1975

This thesis, which is entirely the result of my own work, has not been accepted for any degree, and is not being submitted concurrently in candidature for any other degree.

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ABSTRACT

A detailed account is given of the macrophytic vegetation of the major rivers within the Tweed Basin. Of these rivers, the Tweed and its largest tributary, the Teviot, have been studied in most detail, both being surveyed from source to mouth. Information brought together on the history and physiography of the Tweed Basin are summarized in this account, together with physical and water chemical data collected during the survey. The distribution of species is discussed in relation to changes in such parameters.

The method of survey involved recording the presence or absence of all macrophytic species within 0.5 km lengths of river, together with a subjective evaluation of their abundance. 570 such 0.5 km lengths were surveyed. All macroscopically visable species were recorded which were found completely submerged or at the immediate edge of the river. A total of 180 different macrophytic growths (usually species, but occasionally identified only to genus level) were present in the basin, including: 31 algae, 5 lichens, 83 bryophytes, 59 angiosperms, 2 macroscopic microbial communities. The identification and taxonomy of all species were studied critically.

Environmental parameters collected in most detail were the physical characteristics of each river, such as altitude, features of the substratum and flow regime. A water sampling programme was undertaken which involved the collection of 5 duplicate samples from sites in the main river and tributaries, and subsequent analysis for optical density, pH, conductivity, 10 cations and 6 anions.

The final discussion includes an appraisal of literature concerned with macrophytes in rivers, methods of study, and results obtained. Particular attention is paid to floristic accounts, especially those from the neighbourhood of the Tweed, the floras of these rivers being compared with the flora of the Tweed Basin. Comparison with data from these surveys would suggest that the Tweed is a river which is especially rich in macrophyte species.

The presence of historical data and herbarium specimens collected over the past two centuries has made it possible to suggest tentatively that the distribution of some species has changed markedly, whereas others appear to have changed little over 150 years. Cladophora glomerata is an example of a species which in recent years has become much less abundant. This is most probably due to a decrease in total phosphate content in the water, this in turn being due to a reduction in the use of synthetic detergents by the textile industry.

ACKNOWLEDGMENTS

I wish to thank Professor D. Boulter for the provision of research facilities in the Department of Botany, University of Durham for the duration of the project.

To all the staff of the Tweed River Purification Board, and in particular Mr J. C. Currie, sincere thanks are due for constant assistance in all spheres of my work throughout the three years of research, and also for supplying recent chemical and hydrological data. I should also like to thank Col. J. Ryan, Chairman of the Tweed Commissioners for hours of helpful discussions and access to Old Pollution and Fisheries Commissioners Reports. To the Biagi family, special thanks are due for allowing me and my samples to take over their home during survey periods.

Thanks are due to those who have helped in problems of taxonomy. The referees for particular taxa which are listed in 4.3 are thanked most sincerely: in particular, thanks are due to Rev. G. G. Graham for hours of helpful discussions and many critical identifications of bryophyte species: to Mr J. E. Dandy for verification of all Potamogeton identifications, and for supplying lists of all known records for that genus from the Tweed Basin: and Dr C. D. K. Cook for the difficult job of creating some semblance of order from the chaotic taxonomy of batrachium Ranunculus species.

I should also like to thank all colleagues and technical staff in the Department of Botany whose help, advice, and hours of soul searching discussions have been most appreciated. Thanks are also due to Mr W. B. Woodward and all staff of the Science Library for their constant assistance in obtaining reference literature. To Mrs V. Evans who had the unenviable task of typing this manuscript, I should like to offer my apologies and most sincere thanks.

In particular, I should like to thank my supervisor Dr B. A. Whitton for his helpful guidance and enthusiasm throughout the project.

Finally, I should like to thank the Tweed River Purification Board and also the University of Durham (Research Studentship) for the provision of financial assistance throughout the project.

1. INTRODUCTION

1.1 Aims

The macrophytic vegetation of many rivers in Britain and mainland Europe have been described in the literature. Despite this, comparisons of the vegetation of one river with another is often difficult, primarily because of differences in the methods of study and subsequent presentation of data. In reviewing literature concerning macrophytes in rivers, Westlake (1975) concluded "re-examination of the distribution of several genera in the light of modern taxonomy is badly needed". The present project was planned to provide a description of the macrophytic vegetation of a single river basin in considerable detail, making at the same time a critical appraisal of the taxonomy of the forms present, and relating their distribution to environmental parameters.

1.2 Literature referring to macrophyte surveys in rivers

The macrophytic vegetation found in several British rivers, and some of the factors affecting their distribution were described by Butcher (1933). The same author (Butcher, 1927, 1933a; Butcher et al., 1931, 1937) studied several other rivers, but similar surveys by other workers have been few. For instance, in the 930 page book "The British Isles and their vegetation" (Tansley, 1939), only 14 pages (pp. 622-633) referred to the vegetation of rivers, and almost the entire account was a summary of Butcher's work. At that time,however, much more information was already known about lake vegetation (West, 1910; Pearsall, 1920; Tansley, 1939). More recently, Spence (1964, 1967) and Seddon (1972) have described the vegetation of Scottish and Welsh lochs respectively. Few recent surveys have been carried out in rivers, the vegetation of most rivers and streams still remaining almost totally undescribed.

The paucity of data for rivers in comparison with lakes is also evident from algal studies in Britain. Whitton (1974) showed that prior to 1960, there were 24 river or stream sites with extensive algal lists; the comparable number for lake or reservoir sites was 56.

The Tyne, Wear, Tees and Wharfe are the four largest rivers in northern England, and in close proximity to the present authors study. The macrophytic vegetation of the Tees and Wharfe were described by Butcher (1933). The vegetation of the Tees and one of its tributaries the Skerne, were surveyed in more detail by Butcher et al. (1937), and more recently, Proctor (1971) resurveyed a natural, slow, deep stretch of river in the upper Tees known as the 'Wheel'. Whitton and Buckmaster (1970) surveyed the Wear from source to mouth, recording the presence or absence of all macrophytic species within 0.5 km lengths of river. A similar survey was carried out on the lower stretches of the N. Tyne and Tyne by Holmes et al. (1972).

In comparison with other areas, the vegetation of rivers in N-E. England is well documented. The authors of the surveys mentioned above made reference to the distribution of species in relation to physical and water chemistry characteristics. Since the river basin studied by the present author is in the same geographical region as these rivers, and the vegetation of each river will subsequently be closely compared, the characteristics of each river will be summarized briefly.

The Tyne and Wear fall gradually from source to mouth with the vertical drops per standard distance of river greatest in the upper stretches. In the upper stretches of both rivers there are no sudden drops due to water falls, and no stretches of deep, slow-flowing water. The upper stretches of the Tees has a greater vertical drop than the lower stretches, but the drop is less uniform than in the Tyne and Wear. There is High Force, a water fall with a considerable vertical drop, and prior to the construction of Cow Green Reservoir, was to be found the 'Wheel', described above.

The water chemistries of these rivers are also known. Butcher (1933) and Butcher *et al.* (1937) compared hardness figures of the Wharfe, Tees and Skerne. More recently independent surveys to ascertain the variety of water chemistries in rivers in N-E. England by the Botany Department, University of Durham, have provided further knowledge covering a wider range of chemical parameters. Data from six surveys are available for O.D., pH, conductivity, 10 cations and 6 anions. It was reported by Holmes *et al.* (1972) that the upper stretches of the Tyne and Wear are of similar water chemistry. On passing down the Wear, nutrient levels increase to high levels in the lower stretches (Snow and Whitton, 1971). The chemistry of the Tees suddenly changes at a point where the Skerne enters the river. This affluent increases levels of all elements which are correlated with increases in hardness: nutrient status and organic matter content also increase. Below the Skerne the Tees is moderately calcareous and nutrient rich, but above, it is soft and nutrient poor (Butcher *et al.*, 1937).

The chalk streams of southern England are the only other region in which detailed surveys of several rivers in close proximity to one another have been carried out. The first well documented surveys were the work of Butcher (1927, 1933) and Butcher *et al.* (1931). The Lark and Itchen were extensively surveyed, the exact distribution of individual plants being shown in several stretches. More recently, many experimental studies have been carried out on several other chalk streams (*e.g.* Westlake, 1965, 1968a; Ladle and Casey, 1971), including primary production studies.

Many macrophyte surveys have also been carried out on rivers from mainland Europe. Recent descriptive accounts include: Backhaus (1967) and Szemes (1967) for the Danube, Siedlecka-Binder (1967) for a torrent stretch of a Polish river; Sirjola (1969) for the Teuronjoki, Finland; Weber-Oldecop (1970, 1971) for rivers in lower Saxony; Krause (1971) for the upper Rhine; Kohler et al. (1970, 1973) for the Moosach, Germany; and Wølek (1971) for the Dunajec, Poland. Many smaller rivers and streams have also been surveyed. Several studies of European rivers used phyto-sociological techniques.

Other surveys that were concerned primarily with factors that affect the distribution of macrophytes have also been carried out. The aim of such studies was to relate the occurrence of species with one or more environmental factors, rather than descriptions of the vegetation found in the rivers studied. Many such surveys will be referred to later in the thesis.

1.3 Environmental parameters regarded as important in affecting the distribution of macrophytes in rivers

There are many experimental studies which attempt to show how environmental factors affect macrophytes in rivers; proving the existence of precise causal relationships between the distribution of a species and a single parameter are more difficult. The distribution of many species are often shown to be correlated with single factors, e.g. Ca levels; in such a case however, it is usually not known whether Ca is the causal factor, or whether it is one of several other related factors such as pH, conductivity and Mg, or the combined effects of all these factors. A few of the environmental factors regarded as important in affecting macrophyte distribution will now be briefly summarized.

One parameter which probably effects the distribution of species in rivers more than any other single factor is current velocity. The distribution of river macrophytes in relation to water velocity has been discussed by many authors, including: Butcher (1933), Roll (1938), Ackenheil (1944), Ruess (1954), Ruttner (1963), Sirjola (1969) and Haslam (1971). Current velocity is known to affect macrophyte species in a variety of ways. Direct effects include control of establishment, susceptibility to removal during floods, physical damage to tissues, and the physical uptake of ions and nutrients; the major indirect effect is the influence current velocity has on the nature of the substratum. When the distribution of a certain species is correlated with current velocity, it is usually not known whether a single, or a combination of the above factors are responsible.

Where water chemistry parameters remained constant, both Pearsall (1920) and Butcher (1933), for lakes and rivers respectively, reported that the distribution of species was primarily correlated with the nature of the substratum. For rivers, Westlake (1973) points out that although the distribution of many species can be correlated with the nature of the substratum, the main causal factor is probably the flow regime. This is well illustrated by Haslam (1971) who showed that for most species, correlation diagrams for substrata size and current velocity were usually the same shape. Substratum characteristics and flow regimes have frequently been correlated; the following are examples: Minnikin (1920), Butcher (1933), Tansley (1939), Sirjola (1969), Haslam (1971) and Hawkes (1975).

The effects exerted by the geology of the bedrock is still unresolved; however, Haslam (personal communication) regards this as a most important influence. The substratum may also be a source of nutrients, but there is still conflicting evidence as to whether the major source of rooted plant nutrients in rivers is supplied by the water, or by the substratum (Sculthorpe, 1967). Brown (1913) showed that the growth of *Elodea canadensis* was stimulated by increasing organic matter content in silt, and Chancellor (1958) reports that the chief cause of excessive weed growths is due to accumulation of nutrient organic matter in muds and silt.

Butcher (1933) indicated that rooted plants obtain minerals from the substratum and not the surrounding water. The exact proportion taken from the two sources usually depends on availability, and the individual species concerned (Hartog and Segal, 1964; Boyd, 1967).

Other parameters likely to influence the distribution of macrophytes in rivers are temperature, light, and the effects of man. Temperature is suggested as being the most important factor on a world-wide scale (Sculthorpe, 1967; Westlake, 1973). The latter author reports that "in general, temperature has no special effects in rivers". Due mainly to bank shading, surface reflection, water turbidity and absorbtion, the amount of light available to submerged plants is much less that that received by terrestrial species. The light climate of rivers in relation to vegetation has been summarized by Westlake (1966). Berrie (1972) and Mann _et al._ (1972) have shown the effects that shading can have on the distribution of plants in a river by taking transects across the Thames. Certain macrophytes are known to be characteristic of high light intensity _e.g._ members of the genus _Ranunculus_ (Cook, 1966), and others are characteristic of low light intensities _e.g._ _Hildenbrandia_ _rivularis_ (Zimmermann, 1927; Oberdorfer, 1928). The influence exerted by human activities on river conditions are widespread; probably the most documented effects are those resulting from pollution and river management. There have been numerous claims that aquatic macrophytes have increased due to eutrophication. Westlake (1975) points out that there is little evidence from "before and after" studies to support the popular theory that this is due to increases in both phosphorous and nitrogen. River management practises such as weed cutting and dredging will also affect macrophytes in a river; the extent to which species or rivers are affected will depend on the severity of treatment, season when carried out, and the characteristics of the individual macrophyte.

The distribution of many species has been correlated with water chemistry parameters; the most frequent correlations are made with either calcareous or non-calcareous waters, and eutrophic or oligotrophic waters (Westlake, 1973). He reports that there are few species that have "absolute requirements" for a particular type of water chemistry. Some of the factors affecting the distribution of aquatic macrophytes, including ion uptake, ionic balance, CO_2 requirements and its effect on membrane potential, and their ecological implications have been investigated by Denny (1966). Pearsall (1922), Spence (1967) and Seddon (1972) have shown that the distribution of species can be correlated with various water chemistry parameters in British lakes. Using four categories of water chemistry ranging from acid and non-calcareous, to alkaline and highly calcareous, Butcher (1933) had previously demonstrated the same for British rivers. It has been suggested by Westlake (1975) that C, N, K and P are the nutrients most likely to be limiting in rivers. The same author reports that the proportion of these elements within aquatic plants are usually 250 C: 4 N : 3 K : 1 P and the one that falls most below this proportion is likely to become limiting. This of course discounts any uptake from the substratum. The reported effects that changing water chemistry have on the distribution of macrophytes will not be included here, but will be compared with the findings of the present author, later.

1.4 Techniques of survey

From the brief review of literature concerning macrophyte surveys of rivers, it was obvious that a wide variety of techniques could be employed to describe vegetation of individual rivers. Methods range from casual observations made for particular genera, e.g. Heslop-Harrison (1942, 1944) and Dandy and Taylor (1946) for *Potamogeton* species, to the most exacting methods used in phytosociology. In these latter surveys, the composition and spatial arrangements of species within small areas of river (aufnahme) are described in detail, and then classified according to the communities recorded; examples include Weber-Oldecop (1970, 1971, 1974) and Kohler et al. (1971, 1973).

Useful approaches between these two extremes have been used by many authors. Butcher (1933) visited many sites in different rivers, and described the dominant vegetation found in a variety of river conditions. Several surveys on the Continent have employed the same method (Backhaus, 1967; Szemes, 1967; Siedlecka-Binder, 1967; Turala, 1970; Wølek, 1970). The methods usually involved a description of the vegetation from a representative number of sites; whole rivers were not surveyed. A similar approach was used by Butcher et al. (1937) for the Tees and Skerne.

Whitton and Buckmaster (1970) surveyed the whole length of the Wear, recording the presence or absence of species from consecutive 0.5 km lengths of river from source to mouth. A similar survey was carried out on the Tyne and N. Tyne by Holmes et al. (1972). The survey of the Tyne was less detailed than Whitton and Buckmaster's survey of the Wear, but the lowest 10 km of the N. Tyne was surveyed in greater detail. In this study, not only the presence or absence of species were recorded, but a subjective evaluation was also made of their abundance within each 0.5 km length, and was incorporated into the recording system.

The simplest method of survey is to record the presence or absence of species. If an evaluation of the abundance of each species is desired, the survey becomes more complicated. If the study area is large, it is impossible to make the method quantitative by recording the number of each species present within the area. However, this may still not be of great significance, for one plant of one species, may occupy 100 times the area of one plant, of another species. The usual compromise is a subjective evaluation of the abundance of each species, either in relation to each other, or on a recognised numerical scale of cover e.g. Tansley and Chip (1926). The former system is based on the creation of dominant, sub-dominant to rare species, and was used by Butcher (1933). The latter does not relate the abundance of one species with another, it can therefore distinguish between stretches of river with either sparse or thick vegetation; this method was used for the study of the N. Tyne by Holmes et al. (1972)

Many recent surveys of European rivers have included a consideration of the phytosociology of both species and communities. Some authors have just used phytosociology methods in their presentation of data; others have used rigorous techniques in the collection of data.

When phytosociological techniques are used from the outset, collection of data are complicated by the necessity to measure a further parameter; the spatial arrangement of species within the study area in relation to one another. Most surveys have followed the Zürich-Montpellier School (Braun-Blanquet et seq. 1921-1964; Braun-Blanquet and Tüxen, 1943, 1955; Tüxen, 1943). Prior to 1964 the classification of water plant communities was under-developed, and only two classes were recognised. More recently, the role of classifying water plant communities has received more attention e.g. Hartog and Segal (1964), who pointed out that water and land environments differ fundamentally, and that ecological concepts developed for terrestrial vegetation cannot be applied to aquatic vegetation. The generally accepted Zürich-Montpellier system is based on a single, yet complex factor, the floristic composition of the vegetation. Hartog and Segal regard floristic composition alone to be an insufficient character to classify plant communities in water. Their system proposed consideration of life form spectra, physignomy, stratification and ecology, in addition to the all important floristic composition.

Phytosociological methods can be used to illustrate specific points concerning vegetation surveys. One of the most frequently used techniques is the rearrangement of data into the format of an association table. Moore (1962) in a reassessment of the Braun-Blanquet system states "a good association table should allow one to read at a glance, the structure of the association, the diagnostic species of the association itself, and of its subunits, and a certain amount about their ecology". The same author stated that the hierarchical classification of communities makes no claim to be natural, but merely convenient. Several studies of rivers from mainland Europe have used association tables (or modified versions) to demonstrate the existance of different communities in different stretches of river. Two examples are: Backhaus (1967) for the headwaters of the Danube, and Kohler et al. (1971) for the Moosach. Kohler et al. concluded that correlations with chemical parameters were more reliable than phyto-sociological investigations. The more comprehensive phytosociological approaches of Weber-Oldecop (1971, 1973) could distinguish 12 plant communities in the Aller River System, and was regarded as a useful technique.

In order to show the effects that environmental parameters have on the distribution of macrophytes in a river, a variety of approaches are available. The choice of method is usually determined by the nature of the original, or concurrent survey of macrophyte distribution. In general, the smaller the area described, the more accurately the distribution of species can be correlated with external parameters. This is particularly true for small rivers which show obvious changes over very short distances. This aspect of macrophyte surveys will now be briefly considered.

Several studies, particularly in mainland Europe, have concentrated on describing the vegetation in small areas of uniform characteristics, using phytosociological methods. These include the surveys of Weber-Oldecop (1970, 1971) and Kohler et al. (1971, 1973), referred to earler. Others have been more concerned with the effects that environmental parameters have on individual plant species. In these cases, types of flow regime or substratum characteristics are often measured and categorised, and the distribution of species found in such stretches described. Examples of such studies include: Roll (1938), Ackenheil (1944), Sirjola (1969). Similar studies for water chemistry parameters have been employed. For instance, Iverson (1936) categorised 50 sites on the basis of pH, and described the presence or absence of species within those limits.

The main advantage of studying a small area is that the relationship of macrophytes and environmental parameters can be correlated more accurately. The study of small areas might allow precise measurements of each parameter at more or less the exact point where each species is present. Even in an area as small as 5 m^2 (a size of aufnahme frequently studied by phytosociologists), many characteristics are not uniform throughout. In addition, species growing within the area, merely by their presence, may cause changes in some parameters.

To obtain a true picture of a site's water chemistry would require taking a standard number of duplicate samples for a wide variety of flow regimes. If one regime is to be selected, it is possible that low flows may be biologically more meaningful than high flows. Although the amount of water passing through the river is less, and many elements may be concentrated, several others may be rapidly taken up from the water by the plants, and become limiting (Stake, 1967, 1968; Ahl, 1972).

When the vegetation of a whole river system is described, accurate correlation of the distribution of species with environmental parameters becomes more difficult. The description of Butcher (1933) of the vegetation of seven rivers in Britain attempted to relate the distribution of species to flow regimes (plus substratum), and water hardness characteristics. In order to do this, broad generalisations had to be made. The more systematic approach of describing the vegetation of the Wear by Whitton and Buckmaster (1970) also did the same. Although the primary aim of the latter authors was to describe the vegetation of the river, they also generalised that for survey purposes, the Wear could be regarded as a river that on passing downstream, had decreasing water velocity, and increasing nutrient levels.

It is inevitable therefore, that where the vegetation of a whole river is being described in detail, relating the distribution of species with environmental parameters is likely to be less accurate than when small areas are being studied. This means that several generalisations will have to be made. For instance, the vertical drop made by a river in a standard distance may be used to indicate the predominant current velocity and substratum characteristics of particular stretches, even though considerable variation will be shown. It could be presumed that the steeper the vertical drop, the faster the flow rate, and more rocky the substratum. Conversely, small vertical drops would indicate slow velocity rates, and a predominately muddy substratum with few rock surfaces. It is also almost impossible to collect water samples from every stretch of river surveyed. It is therefore important to choose strategic sites that can be used to represent the chemistry of a larger section of river. Samples should be collected at a time when most knowledge can be gained from the results, as indicated earlier.

1.5 Problems in collection and interpretation of macrophyte data from rivers

Many of the papers quoted in this introduction have pointed out that there are considerable problems associated with the collection and subsequent presentation of macrophyte data from rivers. For instance, Whitton and Buckmaster (1970) stated "recording of macrophytes in a river is complicated by various factors" and then outlined some of the problems. There are also difficulties in interpretation of data which often give rise to many apparent correlations or lack of correlations which are misleading, and which cannot be supported over a wide range of habitats (Westlake, 1975). A few of the problems involved will be summarized briefly.

The distribution of many species often varies greatly from one year to the next. The reasons for this are almost always environmentally controlled e.g. a heavy flood in early summer may uproot many large, slow-growing plants; their removal making room for quick growing, more transient species. On the other hand, a long spell of low flow conditions in early summer may result in larger plant species becoming established, and smaller more transient species excluded. For the same reasons as outlined above, the distribution of some species may be dependent on the size and/or frequency of floods prior to survey.

Both Butcher (1933) for the Lark, and Ruess (1954) for the Ischler Acher showed that populations of species in a river often 'move'. They showed that plants often spread to the side or downstream of their original position, and more upstream plants could be observed to advance downstream and take their place the following year.

Although some river species are obvious throughout the year, notably many bryophytes and members of the genus *Ranunculus*, many species are only obvious as macroscopic growths during certain seasons. Butcher (1933, 1933a) classified several river macrophytes according to whether they remained vegetative throughout the year, or whether they were 'die back' species. In other rivers, a succession of one dominant vegetation to another often occurs during the year. For example, in unmanaged southern chalk streams, *Ranunculus penicillatus* var. *calcareus* is replaced by *Rorippa nasturtium-*

aquatictum during mid-summer (Westlake, 1960, 1968, 1968a; Ladle and Casey 1971).

Another problem is that some species within the study area may be overlooked, and therefore excluded from the records. The extent to which this may occur is usually dependent on the method of survey. For instance, if small stretches are studied as representative of the vegetation of the whole river, the chance of a species being overlooked is greater than if the whole river was surveyed. Even when a whole river is surveyed, it is still possible that a rare or indistinct species may be overlooked.

For reasons outlined above, it is important that for comparative purposes, surveys should be carried out during a standard period of the year when; (a) most macrophytes are at their most obvious, and (b), when river flows can be expected to be low (unpredictable in Britain). It is suggested that the greatest number of macrophytes are at their most obvious from early June to late September. During this period, river flows usually allow work of a survey nature to be carried out during one day in two. In the presentation of data, it is important to stress the time and year of survey, and where possible, compare present day survey data with any previous records.

1.6 The present study

The Tweed River System was chosen for this particular study. Judging from surveys carried out on other rivers, and information already known about the Tweed, there were a wide variety of reasons why the Tweed was an ideal river to study. Some of the main reasons will be outlined below. As with all studies however, a major consideration has to be the financial feasibility of the project, and it is due to Tweed River Purification Board assistance that this work was possible.

In the Conservation Review compiled by Britton and Morgan (unpublished), the Tweed emerged as a nationally important, top category site (Grade 1) in the fresh water section. In practise, this meant that after surveying and evaluating all major semi-natural and natural ecosystems in Britain, the Tweed was one example of an ecosystem that should be safeguarded for nature conservation. The Nature Conservancy, Edinburgh (C. O. Badenoch, personal communication) stated that although a certain amount was known concerning the biology of the river, a critical survey of its vegetation was necessary.

The river has been investigated by many amateur botanists during the past two centuries, who showed it to contain a wide variety of submerged macrophytes (Thompson, 1807; Johnston, 1829, 1853; History of the Berwickshire Naturalist, from 1841). This was particularly evident for the genus Potamogeton. Herbarium specimens, some collected nearly two centuries ago, are still present in the British Museum (Natural History), and can be regarded as some indication of the vegetation during this period. Despite the many records, no clear patterns of distribution were evident; this was because only a few sites had been investigated, and critical surveys had not been carried out to show how isolated records from various parts of the catchment area could be related to one another.

Also available was considerable information concerning the past and present day characteristics of the rivers within the Basin. This background information was not readily available, but present in a wide variety of books primarily concerned with local history, natural history and fishing. Reports of the Tweed Commissioners and Pollution Commissions allow present-day conditions to be compared with those of one hundred years ago. When information from all sources were considered together, a vast amount of information could be gained from them, although singularly they would be of little value.

Judging from surveys from other rivers described in this chapter, and the problems involved in such studies, it was realised from the outset that certain restrictions would have to be imposed on the macrophyte surveys of the Tweed Basin. For instance, it would be impossible to survey the whole lengths of all rivers within the catchment; a system of priorities would therefore have to be adopted. The first priority was to survey the main river from source to mouth, and subsequent surveys would depend on the findings of the initial surveys, time available to survey, and the particular characteristics of individual tributaries. It was planned that the main river and at least its four largest tributaries would be surveyed. Other tributaries would be selected so that surveys were carried out from a wide variety of rivers with different physical and water chemistry characteristics.

A parallel, yet distinct survey of the micro-algae within the same river basin was also envisaged. The recording system, and an associated Fortran IV computer programme were drawn up with four main objectives. (i) A detailed record of the occurrence of attached algae (and other taxa) in the streams, their biological state, and the environmental characteristics of the sites where they occur. (ii) Presentation of data in a format in which a wide range of statistical tests could be applied to show the relationship between organism and environment. (iii) Availability of data in a form in which such methods as cluster analysis could be used where the occurrence of particular species might be related to one another. (iv) Comparison with data from other rivers which have been collected using a similar recording system.

The distribution of micro-algae would be related to factors such as altitude, stream width, mean flow and water chemistry. In addition, nine micro-environmental factors at the exact point where the samples were collected were considered: these included surface cover by the dominant growth form, substratum geology, substratum size, substratum topography, surface inclination, surface aspect, water depth, flow rate, and exposure to light.

Results of this study are not included in this thesis since the survey of the Tweed was an integrated part of a much larger research project which is still being carried out in the Department of Botany, University of Durham. It was felt that a treatment of the data that did not utilize the full potential of the envisaged, and almost completed computer programme would have been wasteful. The data will therefore be published at a future date when all four objectives of the survey can be fulfilled.

2. METHODS

2.1 Collection of background information on the Tweed and tributaries: physical parameters and water chemistry

2.11 Physical parameters

When macrophytes were recorded, notes were kept of the physical characteristics of every 0.5 km length surveyed. Changes in channel width, water depth, current speed, substrata and bank characteristics were noted. The data collected have been amalgamated, and the most characteristic features of each river given in 3.2.

2.12 Water chemistry - introduction

It was impracticable to obtain water chemistry data for the whole number of 0.5 km lengths surveyed. In order to collect data that could be related to all lengths surveyed, a main chemistry sampling programme was undertaken within a 12 month period that spanned two calendar years.

2.13 Sampling programme

Water samples were collected on five separate occasions from 29 sites on the Tweed and from 20 sites on 17 different tributaries (see 2.2b). Grid and kilometer references of all sampling points are tabulated in Table 2.1a. The sampling points on the Tweed were the same as used by the Tweed River Purification Board for their biennial chemistry survey of the river. The sites were most commonly above and below tributaries or effluent outflows. This allowed the causes of any changes to be identified. All large tributaries were sampled just above their confluence with the Tweed, the Teviot being sampled at two additional sites, and the Whiteadder at one site above its confluence with the Blackadder.

Five surveys were regarded as the minimum number that could be used to give a reliable comparison of water chemistries of the Tweed and its tributaries. It was intended that all surveys should be undertaken when

sample site	Grid ref.	km ref. point	sample representative for the following stretch of the Tweed
Tweed - Finglands	054194	3.0	0.0 - 3.0
Tweed - Tweedsmuir	097244	10.7	3.5 - 10.5
Tweed - Kingledors	109285	16.1	11.0 - 24.0
Tweed - Dawyck Bridge	164352	27.9	24.5 - 27.5
Tweed - Lyne Ford	206397	34.8	28.0 - 34.5
LYNE - FOOT	209401	-0.3	
Tweed - Manor Bridge	229393	37.7	35.0 - 38.0
MANOR - FOOT	229393	-0.0	
EDDLESTON - FOOT	251403	-0.0	
Tweed - Peebles gauge	257400	41.5	38.5 - 43.0
Tweed - Peebles dump	271395	43.4	43.5 - 46.0
Tweed - Horsburgh Ford	300392	46.5	
Tweed - Traguair Bridge	334359	52.5	46.5 - 52.0
Tweed - Walkerburn Bridge	361369	55.9	52.5 - 56.0
Tweed - Juniper Bank	405362	57.4	56.5 - 57.0
Tweed - Ashiestiel Bridge	439351	65.3	57.5 - 65.0
Tweed - Yair Bridge	458325	69.0	65.5 - 68.5
Tweed - Tweed Bridge	489322	72.3	69.0 - 72.0
MEGGET - FOOT	240226		
YARROW - PHILIP HAUGH	438278	-8.2	
ETTRICK - FOOT	489322	-0.0	
Tweed - Gala Ford	510348	75.5	72.5 - 76.0
GALA - FOOT	511349	-0.0	
Tweed - Lowood Bridge	529349	78.2	76.5 - 78.0
Tweed - Gattonside Bridge	345346	80.0	71.5 - 79.5
Tweed - Bridge above Leader	575347	83.5	80.0 - 83.0
LEADER - FOOT	578347	-0.1	
Tweed - Dryburgh Abbey	589318	88.8	83.5 - 88.5
Tweed - Mourton Bridge	610321	92.3	89.0 - 92.0
Tweed - Rutherford Lodge	648319	99.0	92.5 -108.0
TEVIOT - HAWICK	493144	-37.2	
ALE - FOOT	633246	-2.4	
TEVIOT - ANCRUM	639238	-19.2	
JED - FOOT	661241	-0.3	
TEVIOT - FOOT	720335	-0.2	
Tweed - Kelso Bridge	730335	108.9	
Tweed - Sprouston Gauge	752354	112.3	108.5 - 112.0
EDEN - FOOT (bridge)	765375	-0.2	
Tweed - Below Birgham	808393	120.7	112.5 - 120.5
LAMBDEN - SPRINGWELLS	767432		
LEET - FOOT	844396	0.0	
Tweed - Coldstream Bridge	849401	127.8	121.0 - 132.0
TILL - FOOT (Bridge)	884434	-1.5	
Tweed - Norham Bridge	890473	137.7	132.5 - 137.5
Tweed - Fishwick Mains	918497	142.3	138.0 - 142.0
Tweed - Union Bridge	933510	145.4	142.5 - 149.5
WHITEADDER - ABOVE CHURNSIDE	849564	21.6	
BLACKADDER - FOOT	863545	17.5	
WHITEADDER - FOOT	857526	-2.0	

Table 2.1a Chemistry sampling points

river flows were low. Because of organizational problems, this could not, however, be guaranteed. Three of the surveys were during low flows when levels in the rivers were in the 10% lowest ever recorded. On the other two occasions flows were either just above, or just below levels experienced 50% of the time. Further data are summarized in 5.1.

At the same time as the final samples were collected for the main programme (22.V.73), 20 additional samples were taken. These new sites had been chosen in consultation with the Tweed River Purification Board in order to ascertain if there were any streams with unusual water chemistries within the Tweed Basin.

In addition to this, samples were also collected at intermittent intervals over three years from 10 sites on the Tweed and its tributaries. These samples were not analysed for anions, but other analyses served to show that the data furnished from the main survey of five duplicates were representative of the water chemistry of the rivers over a longer period than 12 months.

2.14 Collection and storage of samples

Prior to sampling, all bottles and filters were soaked in 6% HCl for a minimum period of 24 hours to remove any heavy metals bound to their surfaces, and also to kill any living cells. All traces of the acid were subsequently removed by washing six times in distilled water. 'Pyrex' glass bottles were used for the collection of water used in cation, Cl and Si analysis, and polythene bottles for PO_4-P, NH_4-N, NO_2-N and NO_3-N.

Samples were collected from the main current of the river from just below the surface of the water, and filtered directly. A 'Sinta' glass No. 2 funnel which had a pore size not exceeding 45 μm (manufacturer's catalogue) was chosen as a compromise between effectiveness in removing particulate matter, and speed of filtration. In practice, particles as small as 10 μm were screened, including some bacteria. The removal of bacteria was desirable in order to minimise any biological changes taking place between the time of collection and time of analysis.

All samples were collected on the same day, returned to the laboratory, and stored prior to analysis at as low a temperature as possible without actually freezing ($3^{o}C$). Apart from cations, all other analyses were completed within 36 hours of collection.

2.15 Analyses

Laboratory analytical methods were as follows:

Cl	argentometric titration	methods recommended by the American Public Health Association (1971)
Si	hetero-poly blue	
PO_4-P	stannous chloride	
NH_4-N	distillation and nesslerization	
NO_2-N	method of Crosby (1967)	
NO_3-N	method of Hammond (1959)	

pH and conductivity were measured using standard laboratory meters, and optical density was measured using a Hilger and Watts Uvispek photo-electric spectrophotometer Mk 9 (H 700) and 40 mm cells. The same equipment was used for all colorimetric readings.

Detection limits of each element were as recommended by the authors quoted, and within the limits of the particular apparatus in use. In the case of NO_3-N however, it was found that the detection limit of 0.5 mg l^{-1} was a little conservative. Since the waters analysed had little interference from high background levels of other elements, the method on all occasions produced results that were accurate to 0.2 mg l^{-1}. The use of 40 mm cells for this and other methods facilitated more accurate results.

Results of the main chemistry survey are tabulated in 5.2 and summarized in text, in 5.3 and 5.4.

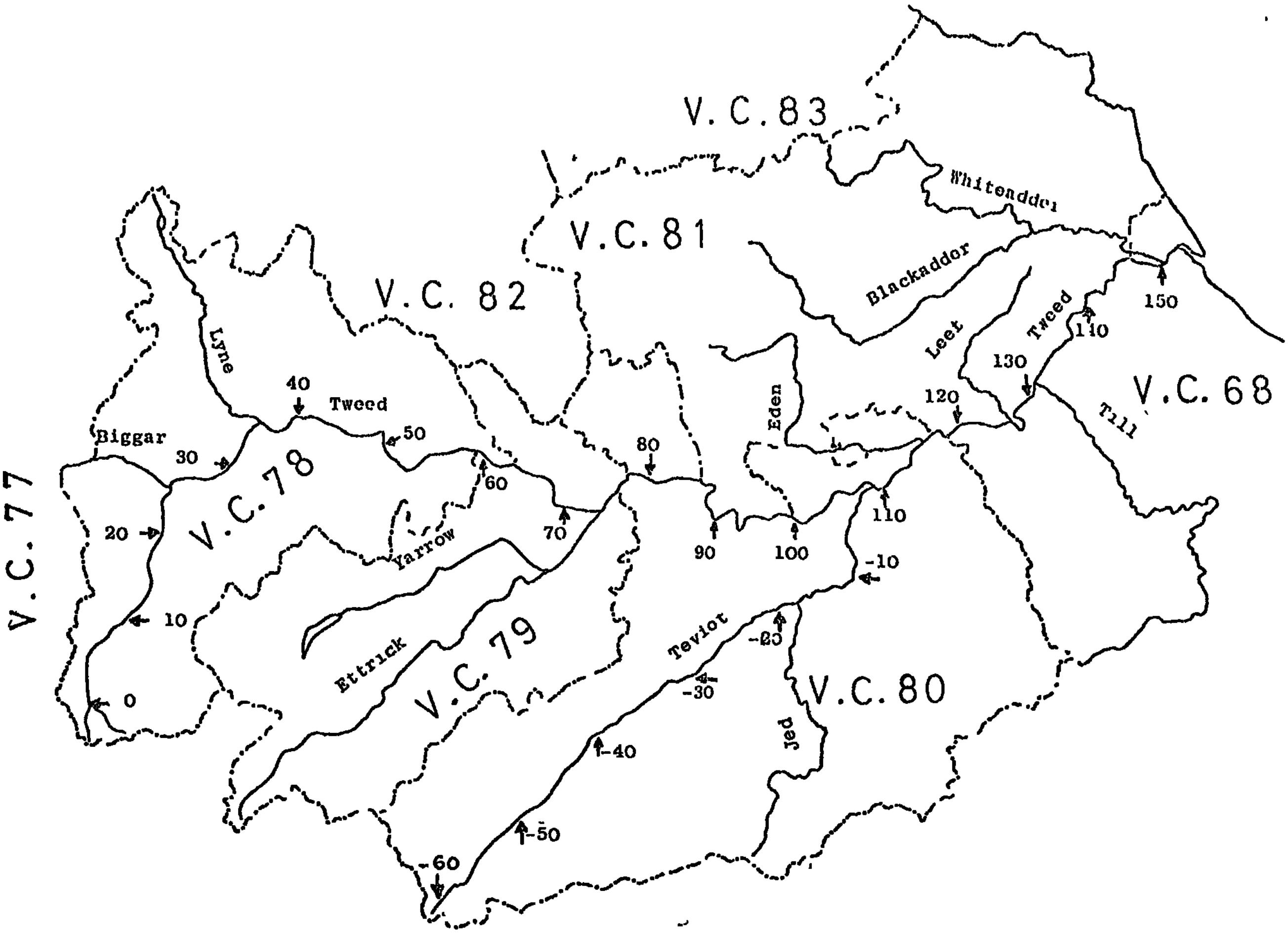


Fig. 2.2a Rivers on which macrophyte surveys were carried out, showing km reference points for the Tweed and Teviot. Vice-counties (V.C.) are also shown.

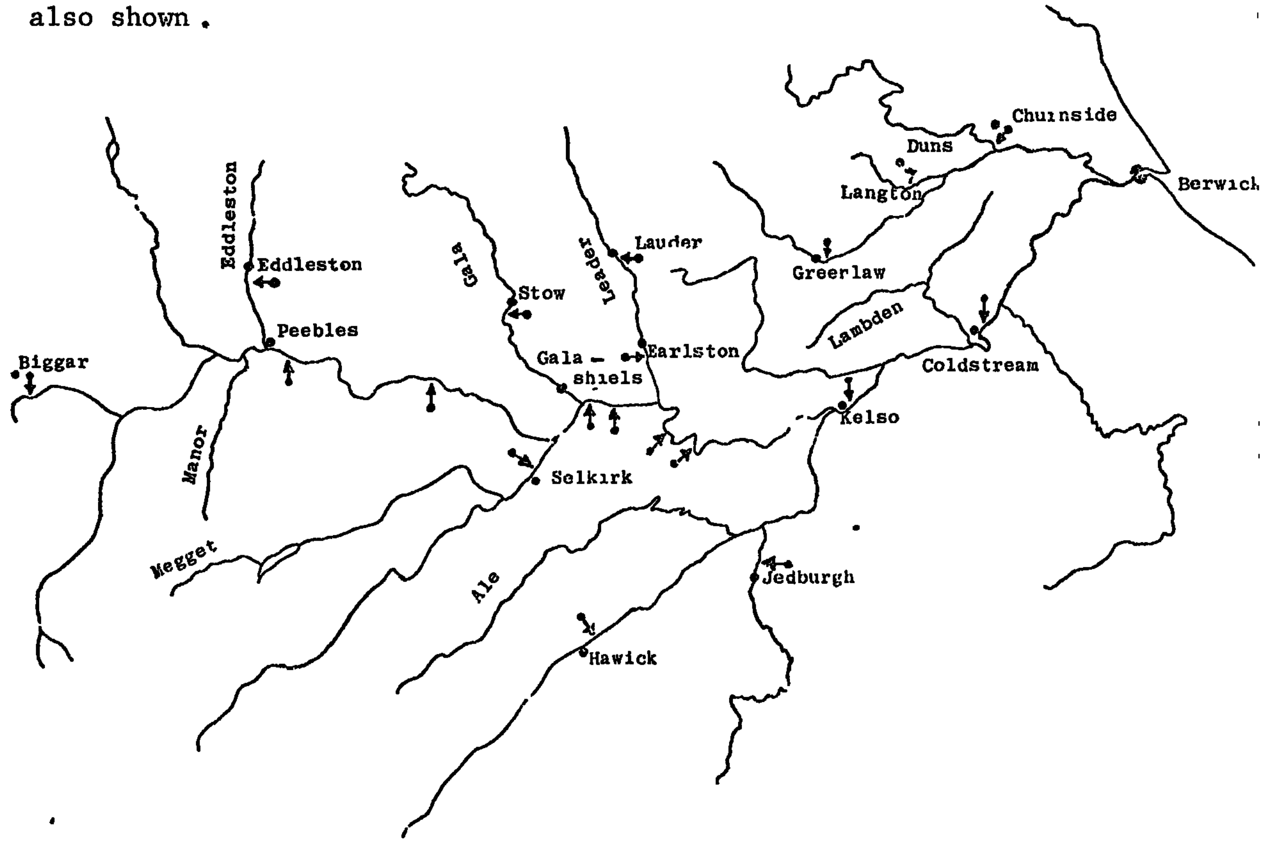


Fig 2.2b Additional tributaries sampled during the main chemistry survey. Main towns (●) and sewage effluents (♆) are also shown.

2.2 Macrophyte surveys

Prior to surveying, six inch to the mile Ordnance Survey maps of the rivers were obtained, and reference 0.5 km lengths marked upon them. These maps are at present held at the Department of Botany, University of Durham.

The main river was marked off into continuous 0.5 km lengths from source to mouth. The confluence of the small trickle of water from Tweed Well, and the much larger Cor Water was designated the uppermost point of the survey, and thus referred to as km 0.0. From this point, the Tweed was divided into 0.5 km lengths down its entire length to well into the brackish region at Berwick (km 154.0). Fig. 2.2a shows the kilometer points down the Tweed in relation to its main tributaries.

Tributaries have their zero points at their junction with the main river, and 0.5 km lengths successively marked off from mouth to source. Reference points of tributaries are preceded by a minus sign e.g. the Teviot which is the largest tributary of the Tweed; Teviot Foot was thus km -0.0, and 0.5 km lengths were marked up its entire length to km -62.0, where the small trickle of the Teviot Water was joined by the larger Rams Cleugh. This was the uppermost point surveyed in this tributary.

Table 2.2a summarizes when, and to what extent, rivers in the Tweed Basin were surveyed. As the whole length of the Tweed was surveyed, in many ways the river resembled a giant 'transect', 150 km in length, and divided for the efficient description of its vegetation into 300 non-random, continuous 'quadrats' of varying width, but a standard length of 0.5 km. The Teviot was also surveyed throughout its entire length, the 'transect' being only 62 km long.

Partial surveys were carried out on 10 tributaries, those selected being chosen for the reasons outlined in 6.1. Because of the limited time

rivers surveyed from source to mouth	number of 0.5 km lengths surveyed	year of survey
Tweed	300	1971
Teviot	124	1972
rivers receiving only partial surveys		
Biggar	6	1973-74
Lyne	5	1973
Yarrow	13	1972
Ettrick	14	1973
Jed	8	1972
Eden	5	1973
Leet	8	1973
Till	37	1972-74
Blackadder	22	1973
Whiteadder	28	1973-74
Total number of lengths lengths surveyed	570	

All surveys were carried out between the months of june to september.

Table 2.2a Summary of macrophyte surveys carried out for rivers within the Tweed Basin.

available to carry out macrophyte surveys, (see 1.5), it was found impossible to survey the whole lengths of these tributaries. Selective 0.5 km lengths were thus chosen as representative of the vegetation of the whole river. The choice of particular lengths involved the study of the Ordnance Survey maps to ascertain 0.5 km lengths where access to the river was easy. Points on the river where changes in vegetation might reasonably be expected to take place, e.g. where a tributary enters the river, were also marked as important points to survey. Final selection of 0.5 km lengths ensured that a representative number of sites were recorded from within 10 km stretches of river. After the initial study, if data from two adjacent sites were very different, a few reaches between the two different sites were surveyed to ascertain the point at which the change occurred, and the possible cause of such a change.

For the majority of 0.5 km lengths surveyed, the presence of any macrophyte (see 2.4) was recorded whilst wading. However in deep water, boats were used. It was not possible to cover every small area of river, and there was thus the possibility that a species might be overlooked from any particular length. In such instances the species would at least be very rare.

Surveys were carried out by recording the presence of macrophyte species within the 0.5 km lengths as described by Whitton and Buckmaster (1970) for the Wear, and by Holmes et al. (1972) for the North Tyne. When a species was present within a 0.5 km length, its abundance was estimated using a scale of one to five related to that used for terrestrial vegetation by Tansley and Crisp (1926) and Hanson (1934). This method was also comparable to the subjective method using descriptive terms employed for rivers by Butcher (1927, 1933, 1933a). The definition of the numerical scale used in the survey is tabulated below.

abundance scale	description
1	rare
2	occasional
3	frequent
4	abundant
5	very abundant

Although the aim of the survey was to record all macrophytes that were visable and easily identifiable in the field, critical identification to species level was often impossible. In such instances, plants were collected and brought back to the laboratory where microscopes could be used, and floras consulted.

In certain instances, identification could not be achieved by collection and subsequent close examination. This applied to those plants that flowered early in the season, and can only be identified with certainty when flowers or fruits are available, e.g. Carex and Ranunculus species. The complex taxonomy of the latter genus necessitated many sites on the Tweed being revisited during the flowering season of May and June in subsequent years. Slight changes to the original data were made in the light of new knowledge. Also, many of the first 0.5 km lengths surveyed were checked in order to validate information collected before experience was gained.

With the exception of the cases mentioned above, survey data given in Chapter 6 are representative for the vegetation of the rivers during the months and year of survey indicated in Table 2.2a. Any seasonal differences in the presence or frequency of any species are summarized in Chapter 7.

Since most plant records are catalogued according to vice-counties, the distribution of every species in each vice-county in the Tweed Basin are given in (i), Chapter 6. The boundaries are those given in the Atlas of the British Flora by Perring and Walters (1962). For rare species from the Tweed, it was important to know from which bank the species was nearest, since the Tweed frequently formed the boundary between one vice-county and another (see Fig. 2.2a).

2.3 Erection of "association tables"

Primary data of rivers which received complete surveys have been rearranged into a format akin to an association table frequently used to demonstrate plant communities by phytosociologists of the Zürich-Montpellier School of Braun-Blanquet (see 1.3). The final outcome is the grouping and boxing off of species with similar distribution patterns into macrophyte communities. The collection of data and final presentation are, however, slightly different from that of the phytosociologist.

The main difference in the collection of data, is the study area used. The phytosociologist studies an area called an 'aufnahme' which should be of uniform physical and chemical characteristics. Species found within the 'aufnahme' are recorded using a subjective abundance scale similar to that used in the macrophyte survey described. The phytosociologist includes a second figure which refers to the species sociability, i.e. its spatial behaviour within the area. Since the size of area studied in this macrophyte survey was much larger than that normally used by phytosociologists, and the areas investigated were never uniform in physical or chemical characteristics, a sociability figure could not be included. The data thus furnished from 0.5 km lengths could not be treated in exactly the same way a phytosociologist may use data from an 'aufnahme'.

The initial step in the erection of an "association table" (see 8.64) from the primary data given in Chapter 6 was to amalgamate data from five consecutive 0.5 km lengths, and so reduce the number of figures to a fifth of the original number. Each point on the table thus represents a distance of 2.5 km of river.

The formation of the "association table" followed that given by Shimwell (1971, pp. 189-193). In the 'raw table' in which species were listed in taxonomic order, it was noticed that certain combinations of species recurred again and again, and it was these species which had restricted occurrences that were grouped together. The groups of species were then arranged so that those species restricted to the upper reaches of the river were at the top left, and those present only in the lower reaches, at the bottom right of the Table. Species that occurred throughout the river were placed in the middle, and those with intermediate distributions placed either side. The macrophytes with similar occurrences were then boxed together to give an annotated, or outlined raw association table (Shimwell, 1971).

The original ordering of species into groups was done by recording whether a species was present or absent in each 2.5 km stretch of river. A second table was drawn up using the aggregate of the subjective abundance scores for the five 0.5 km lengths in each 2.5 km stretch. Since for each 0.5 km length the maximum abundance value for any species was five (see 2.2), the maximum value for any point on the table could be 25. In order to make the table clearer, a system of dots, plusses and numbers has been used. Numbers have been used when a total abundance value was five or more. To be recorded as five or above indicates that a species was either present (albeit rare) in all 0.5 km lengths, or if absent from one or more, to be at least recorded as occasional or frequent in others, so as to bring the aggregate total to at least five. A total of 10 could thus mean that the species was recorded as two from five 0.5 km lengths, or as five from only two 0.5 km lengths. A plus is used when the total abundance value for 2.5 km is less than five. Dots indicate the distribution span along the river, but the absence of the species within that particular 2.5 km length.

It was noted that in the table originally drawn up using presence and absence alone, '+' signs substituted for the actual abundance total for each 2.5 km given in the published tables. Since the table using abundance values provided more information, the former are not included.

The arrangement of species within each boxed off community was determined by comparing the relative abundances of each species in different stretches of the river. Those highest in the box had higher abundances in the upper stretches than in the lower stretches, and vice-versa for species in the bottom of the box.

The horizontal lines in the tables were the separating boundary between one community and another. The vertical lines of each box were drawn where the member species of each community ceased to be recorded from more than half the 2.5 km lengths.

The differences between this and a phytosociologist's association table are: (i) the horizontal axis had a predetermined order related to the linear arrangements of 0.5 km lengths down the river; (ii) in true association tables, only indicator or 'type' species of a community are kept, while others are disregarded; (iii) a sociability figure is not included.

2.4 Terminology

All macrophyte species recorded from the Tweed Basin are listed in Chapter 4. Their full name, followed by the appropriate authority is given there only. Elsewhere in the text, the author is omitted except when reference is made to a species not present in the Tweed.

Data are expressed in S.I units as recommended by the British Standard Institution, BS 3763 (1970).

Abbreviations: in some instances where long chemical, place or biological names are frequently used, the full name, followed by an abbreviated form in parenthesis is used when first quoted in each Chapter. Subsequent citations use the abbreviated form only.

Macrophyte: this term is used as by Butcher *et al*. (1937) to "include all the larger plants and those algae which are both easily visable individually, and may usually be identified in the field". Four main groups of plants contribute to this vegetation; certain large algae, obvious lichens, and all bryophytes and angiosperms.

Submerged macrophyte(S): includes the definitions of 'hydrophytes' by Raunkiaer (1934) and Iverson (1936), that of a 'water plant' by Hartog and Segal (1964) and under more general terminology, that of Sculthorpe (1967). Submerged macrophytes are those plants which have their vegetative parts submerged or floating, but not projecting into the air. For the most part, these plants are able to develop vegetatively and generatively with all but their floral parts submerged. This group therefore includes most algae, bryophytes such as *Fontinalis antipyretica* and *Eurhynchium riparioides* which thrive most below water but occasionally occur above the surface, and angiosperms such as *Myriophyllum*, *Potamogeton* and *Ranunculus* species.

Bank macrophytes (B): includes all species that are either partially submerged, or at least kept moist by river water during periods of average flow. The group includes such species as *Prasiola crispa* found growing on large boulders even if in mid-stream, and all lichens, bryophytes and angiosperms found growing at the immediate waters edge. Examples are *Collema flaccidum*, *Cinclidotus fontinaliodes* and *Phalaris arundinacea*. This group also includes emergent bank species that may occasionally occur totally submerged in the main current of the river *e.g.* *Butomus umbellatus* and *Sparganium erectum*.

Association: regarded by several synsystematic schools as the 'basic unit' of plant communities and has been defined in several different ways. In this thesis the word is used as by Butcher et al. (1931) in the general sense of the word only. It does not imply any Braun-Blanquet phytosociological union of species as described for rivers by Roll (1938), Weber-Oldecop (1970, 1971, 1974), Kohler (1971) and Kohler et al. (1973).

Community: as used by Becking (1957) to describe a group of individual plant species, "the composition of which is determined by environmental conditions, and to a lesser known degree the mutual relation and interactions of these species, i.e. composition, abundance, dominance, sociability and competition".

For terminology referring to water chemistry, see 5.1.

3. AREA DESCRIPTION

3.1 Introduction

This chapter is a comprehensive description of the Tweed Basin. Most of the data are included because of their direct effect, or combined effects in governing the distribution of macrophyte species, (see chapters 7, 8 and 9). Others, such as mention of the dominant forms of agriculture in different catchment areas are included since these can give a good guide to the topography of the river's surroundings, and hence the river's characteristics. Population size and pastimes are discussed too, since rivers are frequently the receptacles of their waste products.

The expanded historical and natural history information given is not only included because of the effects they had in influencing the present day distribution of some macrophytes, but also for the interest of local biologists.

The Tweed Basin is defined in 3.2, and the physical characteristics of the Tweed and its tributaries described. Particular reference is made to altitude, current velocity and flow regimes, geology, substratum characteristics and river size. The information given is an amalgamation of personal observations (see 2.11), personal communications with Mr J. C. Currie, and descriptions of the area given by the following authors: Angus (1884), Ettrick and Yarrow; Bogg (1898), Borders; Burnett (1938), Tweed; Eyre-Todd (N.D.), Borders; Fraser (1907), anglers songs from the Tweed; Groome (1887), Borders; Lang and Lang (1923) Borders; Lauder (1890), Tweed and tributaries; Maxwell (1905), Tweed; McMichael (N.D.), Borders; Russell (1885), Yarrow; Thomson (N.D.), Lauderdale; Wilson (1924), Gala; Scottish Development Department (1968), Borders; Steven (1916), Yarrow.

The geology of the Tweed Basin is summarized in 3.3. The map (Fig. 3.3a) was drawn from Ordnance Survey (geology survey maps) and the text taken from: Gunn and Clough (1895), Fowler (1926), Pringle (1935), Scottish Development Department (1968), Greig (1971).

Climate is discussed briefly in 3.4. All information was derived from: Scottish Development Department (1968) and the Tweed River Purification Board (1973). Temperature data given by the former have been converted from fahrenheit to centigrade.

3.5 gives some historical background of the Tweed Basin over the last 200 years, and gives some insight into the conditions of its rivers during that period. Population, industry and sewage disposal are discussed since they had the most influence in causing 'unnatural' changes in river conditions. Some attempt is made to relate present day river conditions with those described from over a century ago.

For obvious reasons, none of the data are from personal observations; however some of the generalizations expressed are. Only particularly important, or specialised facts are followed by a reference author, the general text being obtained from the following sources: Curphey (1896), Department of Health for Scotland (1931, 1950), Government White Paper (1966), Home (1874), Nicoll (1972), Rivers Pollution Commission of 1868 (1872), Royal Commission on Sewage Disposal (1912), Royal Commission on Tweed and Solway Fisheries (1896), Scottish Advisory Committee (1931), Scottish Development Department (1968, 1972), Scottish Water Advisory Committee (1950), Tweed Fisheries Commission (1866) Walpole and Young (1874, 1875), Wheaton and Curphey, (1906).

Thanks are due to Mr J. C. Currie, Inspector and Chemist, Tweed River Purification Board (T.R.P.B.) for making all the Boards records available, and for supplying information on the present state of sewage works; and also to Colonel J. Ryan, Chairman of the Tweed Commissioners for the loan of the Commissioner's reports, and helpful discussions.

Information of the river's hydrology, and data available from a continuous water monitor recorder on the Tweed at Boleside (km 74.5) are given in 3.6. Again thanks are due to the T.R.P.B.

3.2 Physical characters of the Tweed and its tributaries

The basin of the Tweed is well defined. Fig. 3.2a shows that it is bound on the west by elevated moorlands reaching 810 m, which separate the sources of the Tweed and Clyde. To the north it is bound by the Moorfoot and Lammermuir Hills, the former to the north-west, reaching 705 m, and the latter to the north-east, reaching a height of 572 m. In the south-west, Annandale and Eskdale are separated from Tweed, Ettrick and Teviot sources by the Tweedsmuir Hills, reaching a maximum elevation of 890 m. The Cheviot Hills in the mid-south are a bounding range of hills reaching 882 m, but they do not extend to the south-east where a gap is left to admit the River Till. To the east the Tweed discharges its water into the North Sea.

The names of the counties, their vice county (v.c.) numbers, and the proportion of each within the Tweed Basin are tabulated in Table 3.2a (see 2.1).

v.c. number	county	Percentage within the Tweed Basin
77	Lanarkshire	0.7%
78	Peebleshire	100.0%
79	Selkirkshire	100.0%
80	Roxburghshire	99.9%
82	Midlothian	25.0%
83	Eastlothian	25.0%
81	Berwickshire	75.0%
68	Northumberland	16.0%

Table 3.2a Percentage of each county drained by the Tweed.

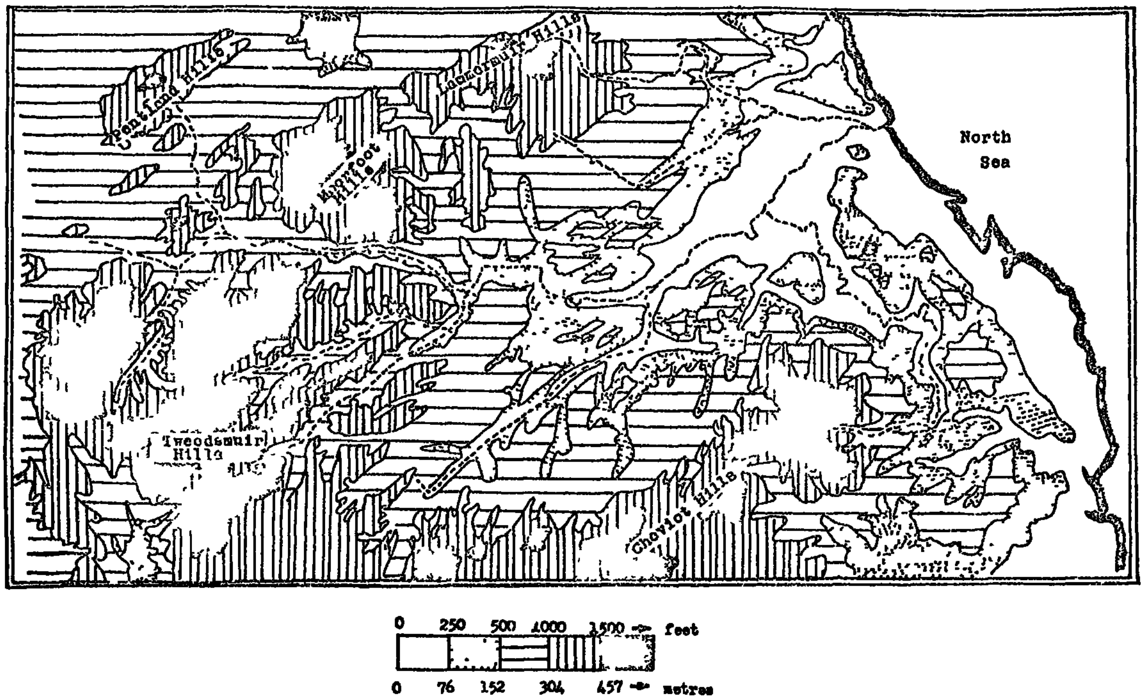


Fig. 3.2a Releif map of River Tweed Basin.

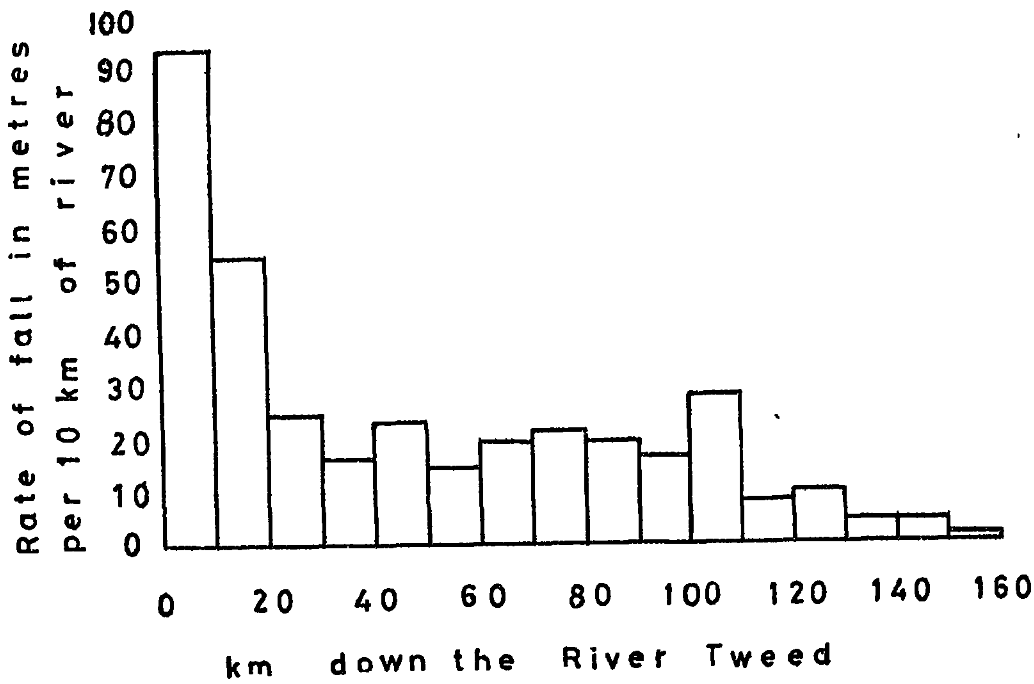


Fig 3.2b Vertical drop shown by the Tweed per 10 km from source to mouth.

The Tweed rises in the extreme south-west of the county of Peebles at about 500 m. Two kilometers away the Clyde takes its rise to the west, and the Annan 0.5 km to the south. Tweed Burn flows east for several kilometers, and is joined by the larger Cor Water at a height of 330 m. For survey purposes, this point represents the head of the Tweed and has been designated km 0.0 (see 2.2).

Fig. 3.2b represents in histogram form the rate of fall per 10 km down the Tweed from km 0.0 to the sea beyond Berwick (km 155.0). Three distinct zones are obvious.

In the upper 20 km, the river drops very rapidly, particularly so in the first 10. Within that area however, the fall is uniform and gradual with no waterfalls of any size, such as seen at High Force in upper Teesdale. The largest sudden drop is Tweedsmuir Falls (km 10.5) which has a vertical drop not exceeding 1.5 m. These upper stretches are characterised by rapid currents flowing over substrates of rock sheets, boulders or large stones incorporated into a stable substratum. There is no stretch of the upper Tweed which is comparable to the deep, slow flowing, former 'Wheel' of the Tees described in 1.2 (see Fig. 3.2d).

From km 20 to 110 the rate of fall varies little from one 10 km to another. A large weir and cauld exaggerate figures for the stretch 100.0 to 109.5. In this mid-river section, the flow characteristics very markedly from reach to reach with all types from fast and shallow, to deep and vary slow. Substratum characteristics also show great variation associated with the change in flow. Generally, sheet-rock, boulders and large rocks are more common in the upper reaches, but here too, fine silt accumulates in quieter alcoves. On passing downstream, rocks of the largest dimensions become less common while mixed smaller stones and gravel dominate. Shading by trees is at its maximum in this section (see Fig. 3.2d).

Below Teviot Foot (km 108.5) the physical characteristics of the Tweed again change. The effect of this tributary on the major river cannot be more aptly described than by Thomas Lauder (1874), "Like a gentleman of large fortune who has just received a great accession to it, the Tweed having been joined by the Teviot leaves Kelso with an air of dignity and importance". From Kelso to Berwick the flow rate is greatly reduced, with many stretches of deep water, slow current velocity and thick deposits of mud and fine silt. The estuary extends up the river to km 137.5 but is never deep enough to be navigatable. At high tide, it is brackish at km 146.0 (see Fig. 3.2d).

The upper one third of the Tweed flows through the county of Peebleshire, and in this county a large number of streams enter the main river. The principal ones are the Fruid and Talla, upon which large reservoirs have been built, the former only within the last decade and the latter at the end of the last century. The others, in order passing downstream are the Biggar, Lyne, Manor and Eddleston (see Figs 2.2a and 2.2b).

The first major tributary is the Fruid, from which the Tweed receives a minimum compensation flow of 0.2 $m^3 s^{-1}$ during the summer, which is reduced to half that level during the winter. 4.5 km downstream of the Fruid, and again entering the rivers from the south, the Talla flows into the Tweed just below Tweedsmuir at km 10.5. Both the Fruid and the Talla previous to impoundment had the characteristics of fast flowing highland streams. The Silurian bedrock drained by the two tributaries is unproductive and supports only fell sheep farming. In recent years, much of the surrounding hills have been taken over by the Forestry Commission who have been responsible for extensive reafforestation.

At km 24.5 the Biggar drains into the Tweed from the left. The name is derived from the word bygg-barley field, for even in primitive times the area was famous for its agriculture. The valley is a flat alluvial plain that links the rich Lanarkshire farming area with the valley of the Tweed. Because the valley is so flat, the river in pre-war times constantly overflowed its banks. Between 1914-18, Italian war prisoners dug a new straight channel for the river, however, this proved inadequate in 1948 when the valley was seriously flooded. Consequent straightening and deepening has produced a tributary which is slow flowing and canal like. Large boulders are absent, the bottom being predominately soft mud, although gravel is present in the relatively faster, shallower stretches. The drainage area is predominately one of Silurian rocks, thickly overlaid by glacial deposits (see Fig. 3.2e).

The largest of the Peebleshire tributaries is the Lyne, which flows into the Tweed at km 35.5. The Lyne rises in mountainous country at a height of 530 m. In 1924 Baddinsgill Reservoir was built, and the catchment area above 330 m impounded. In the Lyne's journey of 30 km it receives several tributaries, the most important being the Tarth. This tributary and the lower stretches of the Lyne flow through cultivated land in a fairly deep and uniform manner. The upper half of the catchment area flows on Old Red Sandstone and Limestone, while the lower half flows on Silurian rock (see Fig. 3.2e).

Between the Lyne and Eddleston, and flowing from the south is the Manor. It rises at 450 m and drops steeply, receiving many streams from steep and lofty surroundings. The catchment area is particularly unproductive supporting only hill farming, although the lower stretches are forested.

Entering the Tweed from the north, and splitting the town of Peebles in two, is the Eddleston. This tributary rises at only 300 m, and on its journey of 18 km traverses only Silurian rocks. The bed of the river is mainly pebbles and small boulders, with large rocks being rare. The upper half of the river above the town of Eddleston flows in a flat cultivated valley where the growing of crops has been practiced for many centuries. Conversely, the lower stretches flow in a deep sided valley suitable only for fell sheep.

The first major tributary to enter the Tweed is the Ettrick, which has its own large affluent the Yarrow. The total area drained exceeds 500 km^2 and the mean yearly flow of the Ettrick is 15 $m^3\ s^{-1}$ (i.e. three-quarters that of the Tweed above its confluence).

The Yarrow rises at 530 m from hills that separate it from the Moffat. The Yarrow initially flows into a small lake, the Loch of the Lowes, and then into the much larger St. Mary's Loch. This loch receives another affluent, the Megget from the north. In general, the whole Yarrow Valley below the lochs is narrow and steep sided, supporting only hill farming. In a few localities however, glacial till has been deposited on the otherwise unproductive Silurian rocks, and here the valley flattens out. In one such area the course of the river changed during a flood in 1962. The bed of the river is rocky and stony, and no silt accumulates. Coarse gravels occur between stones and at the waters edge (see Fig. 3.2e).

The Ettrick rises at a similar height and is similar in most characteristics. The valley of the Ettrick is however wider, and more suitable for cultivation than that of the Yarrow. In the lowest stretches of both rivers, forests are common and the banks of the rivers shaded. Below the confluence of the two rivers and more particularly below Selkirk, fine silt accumulates in slower deep stretches, and the amount of large rock surfaces decreases (see Fig. 3.2f).

At km 75.5, having passed through the middle of Galashiels, the Gala enters the Tweed. This tributary rises at 380 m and bisects the Moorfoot and Lammermuir Hills on its passage to the Tweed. The Gala is a fast flowing river. A century and a half ago, the valley was predominately pastoral, but rapidly the whole surrounding country became hedged and the land cultivated. Today there is only pastoral farming on the surrounding hills.

Arising from the west of the Lammermuir Hills at 500 m and entering the Tweed at km 83.5 is the Leader. To the west of its valley lie the most easterly extension of the Silurian sediments, and to the east is Upper Old Red Sandstone. The Leader Valley, like the Gala, yielded to the plough several centuries ago.

The Tweed receives no major tributaries for 25 km until just above Kelso at km 108.5 where its largest affluent, the Teviot joins it. The Teviot rises at a height of only 365 m and flows for 67 km and drains almost the entire county of Roxburghshire. At Ormiston Mill, 8.0 km above the confluence with the Tweed, the mean daily flow of the Teviot is just under 20 $m^3 s^{-1}$, and the area drained 1100 km^2.

Even in the upper 20 km, the Teviot does not have the characteristics of a mountain stream. Generally, the flow alternates between swift or slow, but the substratum is composed predominately of loose large pebbles that do not form a firm base. There are few 'mountain flush' stretches characterized by torrential flow over large solid rock surfaces. In scenery, land surface and geology, upper Teviotdale and Tweeddale are similar, the sole industry of both being sheep farming.

At Hawick the characteristically very rapid Slitrig enters the river. On passing downstream from Hawick, the Teviot valley widens, the surrounding area having been cultivated for centuries. The current velocity of the river is reduced as it passes over Old Red Sandstone, the rate of fall being equivalent to the lowest 40 km of the Tweed (see Fig. 32c). Many stretches in the lowest 20 km of the Teviot are deep and slow flowing, however these are frequently interrupted by short stretches of shallow, fast flowing water. In the lowest 5 km the river flows upon hard Basaltic Igneous rocks, and then upon Carboniferous Limestone (see Fig. 3.2f).

The Jed is the only tributary of the Teviot that flows through a major town, namely Jedburgh. The river drains an area in excess of 140 km^2, and has a daily mean flow of below 2 $m^3 s^{-1}$. It drains a well cultivated valley and flows predominately on Old Red Sandstone, into which in many areas it has cut deep channels. The bed of the river is predominately rocky.

A little downstream of Kelso at km 115.0 the Eden discharges its rather small volume of water into the Tweed. It takes its rise in the moorlands between the Leader and Blackadder, and flows through a rich and heavily cultivated valley. The current velocity is characteristically swift, and the substratum rocky. In the most downstream stretches however, fine shingle and pebbles predominate. From source to Tweed, the Eden traverse Old Red Sandstone, Basaltic Igneous and Carboniferous Limestone.

Also draining an area on the north bank of the Tweed, and between the Eden and Whiteadder is the Leet. In the summer this tributary was the characteristics of a ditch, frequently less than a metre wide. Commonly the stream takes the form of deep pools connected by shallow, narrower stretches. On its twisting journey of 21 km across a very fertile, and heavily manured alluvial plain, the vertical drop is only 33 m. 200 m before discharging its water into the Tweed at Coldstream (km 127.5), the Leet is swelled by water from the recipient river via a mill lade (see Fig. 3.2g).

5 km below Coldstream, the slow flowing Till enters the Tweed. The Till is the longest tributary of the Tweed, and flows for 86 km being characteristically deep, with a sluggish flow. The river takes its rise on

the eastern slopes of the Cheviots under the name of the Breamish, and receives several other streams on its left bank. The principle one is the Glen, which is formed by the junction of the Bowment and College Burns. For the first 25 km, the river flows first on granite where the flow is swift and the substratum rocky, and then less swiftly on Carboniferous Limestone. In the lower 60 km, and now under the name of the Till, the river is slow, deep and drains an intensly cultivated, large, flat plain. The Till has a rate of fall that is less than 0.7 m km^{-1}. The mean daily flow is approximately 10 m^3 s^{-1}, and the total drainage area 673 km^2. Since the flow of the river is so slight, and the substratum so soft, periodic dredging is required to keep the flow of the Till to the same channel. The geology of the Till catchment area is entirely composed of Carboniferous deposits of Sandstone, Limestone and Scremerston Coal Groups which commonly are thickly overlaid by more recent deposits. Between km-20 and-30 the river has cut deeply into the glacial alluvium to expose an extensive deposit of an interglacial peat. In this area, the bed of the river is either soft sand, or compacted black peat. In places raised mounds of peat extend up from the surface and mimick large rock boulders. In other stretches, the bed of the river is sandy, or less commonly muddy. Rocks and boulders are rare, but evenly scattered except in the area described above (see Fig.3.2g).

The Tweed's largest northern tributary, the Whiteadder, and the latter's affluent the Blackadder, enter the Tweed in the brackish tidal reaches 4 km above Berwick. The Whiteadder is itself tidal for 1 km. Both the Blackadder and the Whiteadder rise high in the Lammermuir Hills. The former emerges from peaty uplands which imparts to its water a high organic matter content, as well as a distinct dark colour from which its name is derived. The Whiteadder on the other hand is much clearer.

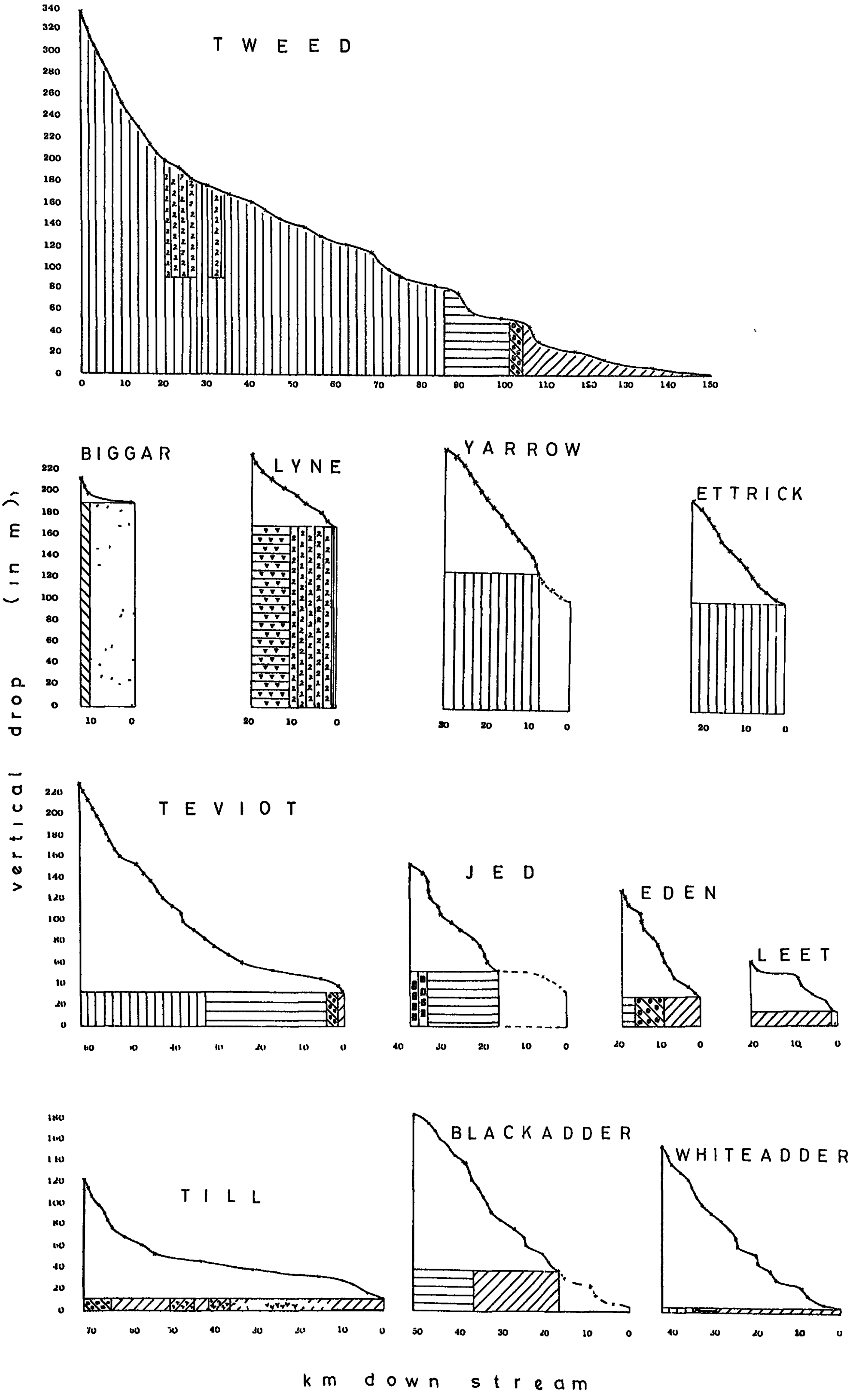
The Blackadder rises at a height of 400 m and runs east at right angles to the Whiteadder and bisects the town of Greenlaw. Even here the characteristics of the river are evident. The flow is predominately slow and the river often deep but rarely wide. The deepest stretches have soft substratum of thick mud, while the shallower stretches have shingle beds. The edges of the river give way to flat muddy banks which back directly onto rich, often richly cultivated land. The bedrock is Old Red Sandstone that gives way in the lowest 20 km to Carboniferous Limestone.

The Whiteadder rises to the east of the Blackadder, but at a similar height. The flow rate in the upper reaches is very fast and many sandstone rocks are exposed. From just above Blackadder Foot downstream to the Tweed, the Whiteadder flows through flat country and it has been necessary to restrain it by embankments so as to keep it to one regular channel. As a result, numerous slow stretches with deep muddy stretches exist. The area drained is principally Calciferous Sandstone, which is intensively farmed.

Fig. 3.2c compares the vertical drop and bedrock geology down the River Tweed and those tributaries which were surveyed for macrophytes (For key to geology see Fig. 3.3a). The height at which each particular tributary enters the Tweed is indicated by the depth of geology plotted.

The steepness of the upper Tweed is not equalled by any of the tributaries plotted, but the Yarrow and the Ettrick above their confluence, upper Teviot, Jed and Eden come close to it. The Lyne, mid Teviot, upper Till and the majority of the Blackadder and Whiteadder have vertical drops intermediate between the upper and mid sections of the Tweed. The Biggar (although the highest tributary), lower Teviot, Leet, Till and lower stretches of the Blackadder and Whiteadder have small vertical drops which are comparable with the lowest stretches of the Tweed. The characteristics of nine rivers are shown in Figs 3.2d-g.

Fig 3.2c (overleaf) Comparative vertical drops down the length of the Tweed and the 11 tributaries on which macrophyte surveys were carried out. The geology of each river is also shown, the depth of geology plotted indicating the height at which the tributary enters the Tweed.



TWEED
BIGGAR
LYNE
YARROW
ETTRICK
TEVIOT
JED
EDEN
LEET
TILL
BLACKADDER
WHITEADDER
vertical drop (in m)
km down stream

3.3 Geology

The whole of the Tweed Basin is composed of Palaeozoic rocks which are often overlaid by more recent deposits. These Ancient Life Rocks in general form parallel bands stretching across the river basin in a south-west to north-east direction.

The earliest rocks are the Silurian deposits which formed under marine conditions 450 m years ago. After being elevated they were subjected to erosion and subsidence, the resultant depressions subsequently becoming covered by Old Red Sandstone. During this period of volcanic activity and deposition, land area increased at the expense of the sea. The following Carboniferous period (350×10^6 years ago) began with characteristic clear shallow seas, but gradually the sea beds began to rise to expose great flat stretches of land in the lowest lying areas of the present day basin. The resultant brackish swamps built the present-day Carboniferous deposits. During the Pleistocene Ice Age of 1×10^6 years ago. Ice sheets covered the whole of the southern uplands and moved across the area in an easterly direction, rounding off hills, scouring valleys and transporting and then depositing ground up rocks as the ice melted.

In the N-W. of the basin in the neighbourhood of the upper Biggar and Lyne, Andesetic Igneous Lavas are interspersed with Silurian rocks, Old Red Sandstone and Carboniferous Limestone. To the south and east of here, and composing by far the larger part of the basin of the river are the Silurian Llandeilo, Tarannon, Wandovery and Wenlock beds. These greywackes and shales which are hard and resistant to erosion occupy the major part of the area which lies west of a line drawn from north to south through the Leader Valley, St. Boswells and Denholm (east of Hawick). To the east of the massive Silurian belt is a band of

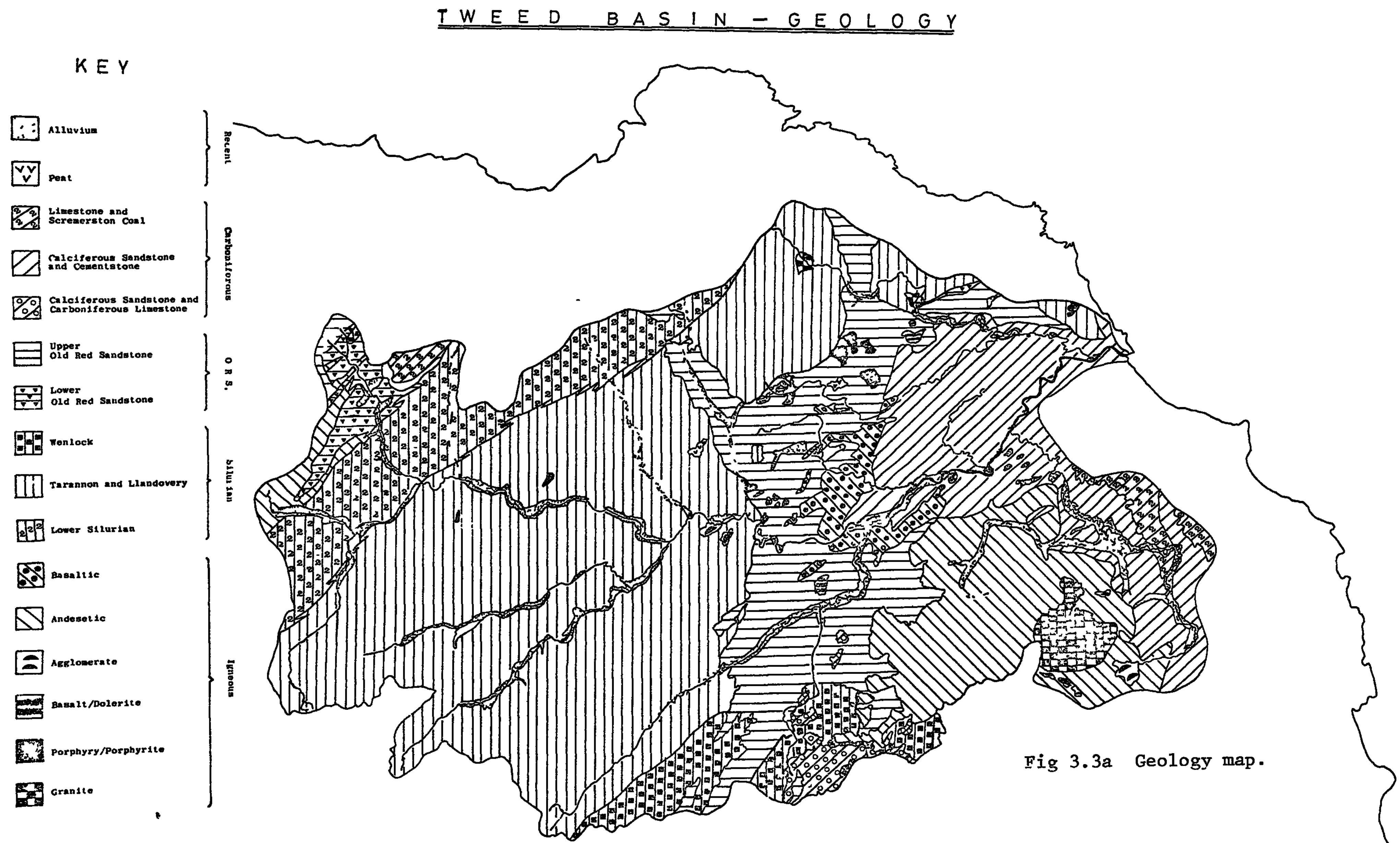


Fig 3.3a Geology map.

Old Red Sandstone which extends as far east as Kelso and as far south as the Cheviots. This rock is softer, and imparts a gentler type of relief and often distinctive red colour to the landscape. To the east of Kelso and the Cheviots, and extending to the sea, lie the Lower Carboniferous rocks; the Calciferous Sandstone and Carboniferous Limestone respectively. Apart from small scattered volcanic plugs, the only other main rock masses are the Calciferous Sandstone sediments that occur in a small area south and east of Jedburgh, and the more extensive laval sheets of Basaltic Igneous rock north west of Kelso. In the south east of the basin, and in particular the area drained by the R. Till, boulder clay covers a great proportion of the area, and elsewhere glacial drift and river gravels cover up the older rocks.

3.4 Climate

The climate of the Borders is transitional between that of west and east Scotland. The uplands are generally cloudy and rainy, and the lowlands to the east, sunnier and drier. As altitude increases, more northerly traits such as coldness and snow increase. The Moorfoot and Lammermuir Hills are credited with a sheltering influence from northern, arctic air.

Table 3.4a summarizes monthly and yearly air temperature means from four sites from within the Tweed Basin during the period 1931-1961. The climate is cool, with annual temperatures in the highlands below 7.5^{o}C, and in the valleys one or more degrees higher e.g. (Kelso 8.3^{o}C). Above 300 m the climate is described as sub-arctic. July is the warmest month, with maximum temperatures of only 16.7 - 19.5^{o}C in the summer months of June, July and August. The mean temperatures for these months are however only just above 10^{o}C. January and February in all districts show minimum temperatures below freezing, and ground frosts are liable to

station	monthly means (1931-1961)												annual means		
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	max.	min.	mean
Stanhope	1.5	2.2	4.2	6.2	9.2	12.1	13.8	13.3	11.3	8.2	4.9	3.2	11.3	3.7	7.5
Selkirk	2.2	2.5	4.4	6.9	9.8	12.8	14.4	14.0	12.0	8.4	5.1	3.2	11.6	4.2	7.9
Hawick	1.6	2.3	4.3	6.6	9.8	12.5	14.3	13.8	12.0	8.5	5.2	3.4	11.8	3.9	7.8
Kelso	2.3	2.9	4.9	7.3	10.0	13.0	14.8	14.2	12.1	8.7	5.4	3.4	12.4	4.3	8.3

Stanhope (245 m)   Selkirk (198-m)   Hawick (185 m)   Kelso (65 m)

Table 3.4a Long term temperature data for four stations within the Tweed Basin.

occur from September to May.

Daily air temperatures show a much greater diurnal range during the summer months than during the winter. The mean daily range during May, June and July is 10°C while less than half this in November, December, January and February. This is reflected in water temperatures as shown by the continuous recorder at Boleside on the Tweed (see 3.6). During late spring, summer and early autumn, water temperatues in the years 1972 and 1973 showed great daily fluctuations of almost 5°C, and monthly variations of 14.5°C. During the winter, however, daily rhythmic fluctuations were very rare, and limited to less than 1°C and monthly ranges to 7°C.

Data concerning diurnal fluctuations in sunlight hours are limited. The Scottish Development Department (1968) published long term averages (1931 - 1960) for one station in the Tweed Basin. This was at Marchmont House, 3 km below Greenlaw, on the banks of the Blackadder. June is the sunniest month, with an average of six hours sunshine per day, compared with an average of just over one hour in December. The combined influence of sun and temperature on river characteristics is discussed in 3.5 and 3.6.

There are no wind gauges in the area, however, the prevailing winds are west and south-west, which causes considerable funnelling because of the orientation of the valleys.

Rainfall, and its significance in being the principal factor influencing river flows will be discussed under hydrology (3.6). Table 3.4b gives details of rainfall from two stations on the Tweed, and 12 stations on nine different tributaries for the period 1971-73, compared with the long term averages (from meterological office). At every station, the three years were below average, the latter particularly so.

The western part of the catchment area where the Tweed, Ettrick and Teviot take their rise, is a high lying plain which collects most precipitation. In this region, long term averages range from 1000 mm to 2000mm per annum. On the leeward middle and eastern parts of the basin where the land is flatter and lower, rainfall does not exceed 1000 mm per year, and in the Merse of the Tweed, annual means are below 500 mm.

catchment	station	grid ref. NT	ht. (m)	yearly totals (mm) 1971	1972	1973	L.T.A.
BIGGAR	SKIRLING	079396	223	779.8	596.6	549.4	1016
JARROW	CAPPERCLEUGH	239233	250	1037.1	1160.1	846.0	1524
YARROW	GORDON ARMS	308249	229	798.4	901.8	635.5	1007
ETTRICK	ETTRICK SCHOOL	266145	232	1301.0	1371.8	989.7	1505
ETTRICK	SELKIRK	475286	183	633.6	674.5	537.5	782
GALA	BROTHERSHIELS	420558	294	776.4	730.6	616.2	965
Tweed	Dingleton Hosp.	542332	146	613.9	601.9	527.6	762
Tweed	Newtown	581317	88	552.3	528.4	503.7	711
TEVIOT	HAWICK	512156	96	627.6	692.5	533.2	822
JED	EDGERSTON TOFTS	700109	241	587.0	692.5	595.4	1003
TEVIOT	ECKFORD	711271	61	492.0	405.7	438.2	699
EDEN	GORDON HOSPITAL	658343	157	590.4	529.0	515.5	706
TILL	YETHOLM	818284	99	597.2	542.8	498.5	737
WHITEADDER	CHIRNSIDE	875566	126	568.1	477.6	462.9	660

Table 3.4b Rainfall data for 1971, 1972, 1973, compared with the long term average.

3.5 Population, industry and sewerage

3.51 Introduction

These three topics are inter-linked since a population must have work, and the waste products furnished by the population and its industries inevitably find their way into the rivers, in a treated or untreated condition. Generally, the distribution of industry follows that of the population, although this does not necessarily mean that for all communities, the pollution load from trade effluent is proportional to that of domestic sources.

Fig. 3.51a shows the changing total population of the Border counties during the past 160 years. It clearly demonstrates the increase in

year of census	1801	1851	1911	1961
total population	78,050	108,486	116,694	100,828
% population of Scotland	4.9%	3.7%	2.4%	2.0%

Fig.3.51a total population of the Border Counties 1801-1961

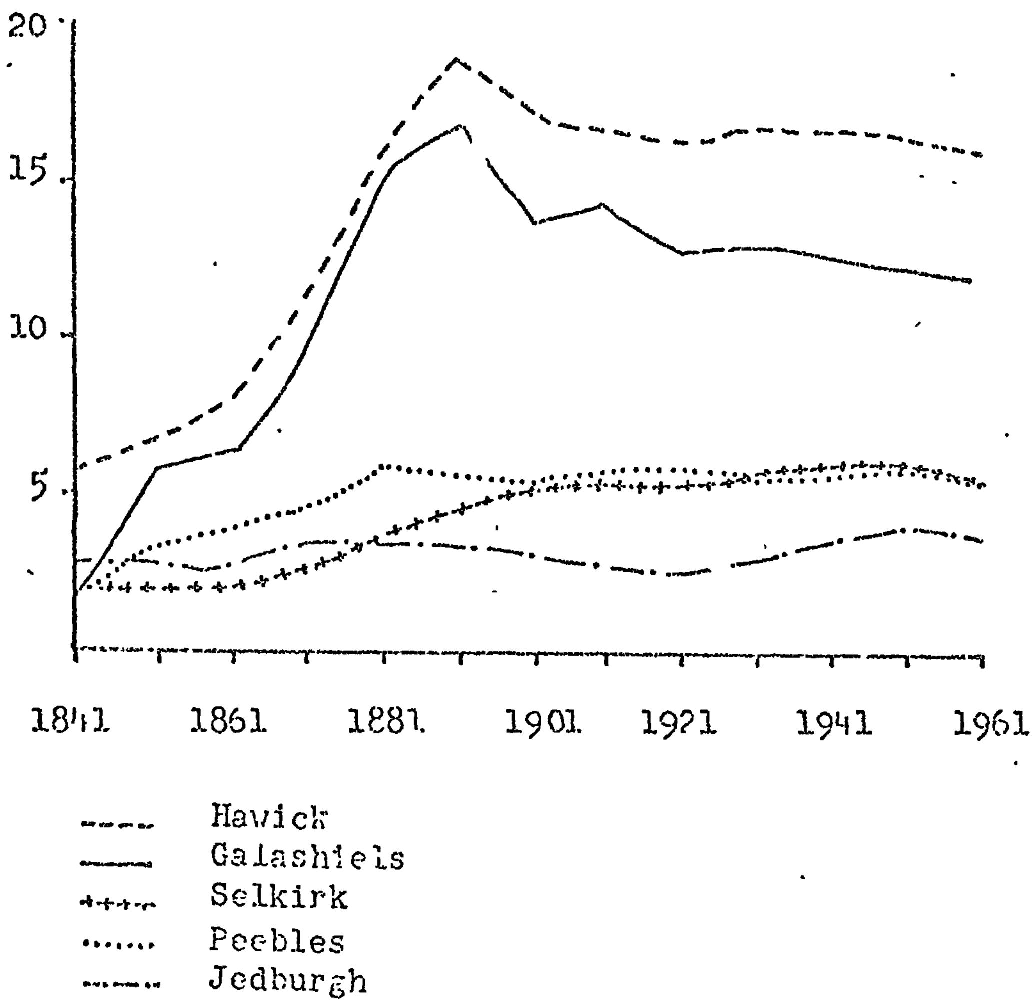


Fig. 3.51b population of the Mill Burghs 1801-1961

population through the nineteenth century, and the decrease during the last fifty years.

The Central Borders, defined as the counties of Peebleshire, Selkirkshire and Roxburghshire (Scottish Development Department, 1968), has most of the total population, and has shown the greatest changes through the past 200 years. The Central Border towns began to grow in the middle of the nineteenth century and expanded rapidly in the following 40 years. This was concomitant with the increase in the textile industry.

Fig. 3.51b shows the population changes in the five main textile burghs over the period 1801-1961. The populations of both Hawick and Galashiels rose rapidly to peak totals in 1891. In the whole of the Borders, the population rose from 43,000 in 1801 to 92,500 in 1891. Since that date, a drop has occurred, and in 1966 the figure was 73,000 (Scottish Development Department, 1968).

Throughout the last two centuries, the population has chiefly been engaged in the woollen trade. The chief centres in the beginning, as now, were Hawick, Galashiels, Jedburgh, Selkirk, Peebles, Innerleithen and Walkerburn. The numerous flocks of sheep kept on the surrounding areas provide the primary factor of the industry, to which was added the abundance of pure water furnished by the Tweed and its tributaries. The mills of Peebles, Innerleithen and Walkerburn use water from the Tweed, while others take theirs from tributaries.

The wool trade has managed to remain the most important industry in the area because of a series of successful adaptations to the present day. First the power was provided by water, and then with the advent of the industrial revolution they turned to coal which was near at hand from the Lanarkshire coalfields. More recently, electricity has been used.

The other main sources of livelihood are from the rearing of sheep in the highlands, and from more intensive farming in the lower areas. The salmon fisheries are also of considerable monetary importance, as is tourism.

The following section describes the population, main industries and sewage disposal in individual counties in the area. By being described in this way, the main polluting influences can be pinpointed.

3.52 Lanarkshire

The only town of importance in this county which is included in the Tweed's drainage area is Biggar, which is situated on the Biggar Water. The majority of the population are involved in the farming of the richly cultivated plain in some form or another, the fertilization of the land producing more eutrophication of the Biggar Water than the town itself (Currie, personal communication). By 1901 the town had a sewerage system of settling tanks and a broad irrigation area of grass land. Wheaton and Curphey (1906) reported the effluent to be well purified with little effect on river eutrophication. A new plant was installed in 1961 which although adequate, still produced slight pollution in the tributary. This is not entirely due to the effluent, but also to the nature of the receiving stream which is slow moving, with a muddy substratum. Natural purification is thus slow. New improvements are under design.

3.53 Midlothian

The only town of any size in this county which is in the Tweed catchment area, is Stow. This town is situated on the Gala about 13 km above Galashiels. At the turn of the century, the town had a population of 1,560 mostly involved in a woollen industry that diverted most of the river water via a mill lade, and returned it to the river below the town in a polluted state. Neither the domestic, nor trade waste was treated in any way. A purification plant was installed in 1959 which in 1974 was still producing a satisfactory effluent.

3.54 Peebles

In this county are situated the towns of Peebles, Innerleithen and Walkerburn, all important centres of the wool trade. The surrounding areas are sparsely populated. Nearly the whole of the county consists of high lying pastures, with few large farms. Sheep are pastured in great numbers, and during the summer months the sheep washings and dips caused frequent and often serious pollution during the last, and in the beginning of this century (Colonel J. Ryan, personal communication). The Forestry Commission have acquired large estates along the Tweed and the hillsides have been extensively drained and planted up to a height of 500 m. When the plantations mature they will completely change the landscape of the upper Tweed.

In 1901, almost the entire 5,266 population of Peebles was engaged in the wool trade. Although the town was efficiently sewered, none of the trade or domestic waste was treated in any form or other. Wheaton and Curphey (1906) reported that the sewage, once discharged, would run separate from the clear river water and not mix until a long way below the town. Paper, wool, dye stained deposits and sewage-fungus were usually obvious. By 1931 the town still had not installed purification works capable of dealing with domestic sewage and trade wastes, which were still discharged untreated into the river, in direct violation of the Rivers Pollution Prevention Acts. The present purification works were installed over 25 years ago, and still produce an effluent that causes pollution. New works are proposed.

Ten kilometers below Peebles is the town of Innerleithen, which bisects the Leithen Water, and has a population exceeding 2,000. Both Innerleithen and Walkerburn, with four and two mills respectively, by 1931 still poured crude industral and domestic waste into the river. At this time, only settling tanks were present. The present works, like Peebles, were installed over a quarter of a century ago. Tenders have already gone out, and construction of new works began early in 1975.

3.55 Selkirkshire

There are only two towns of any importance, Selkirk and Galashiels, where over 80% of the county's population reside. The county coincides almost exactly with the entire Ettrick catchment area, with the Tweed flowing for almost 20 km throught it. During the last two centuries there has been little pollution of the rivers caused by artificial manuring or liming, although sheep washings and dipping used to cause occasional wholesale fish destruction (Colonel J. Ryan, personal communication). Large factories have always been confined to the two burghs.

Selkirk in 1901 had a population of 5,486 almost entirely engaged in all facits of the wool trade. The town was sewered, which conveyed domestic waste to a sewage farm situated about 1 km below the town. By 1931, the situation was unchanged; the old settling ponds and irrigation plants of 1878 were still used, even though they were completely inadequate when first installed.

The 10 mills, all over 50 years old, still discharged their waste untreated into a mill lade, or directly into the river. The sewage effluent was thick and a dirty grey colour, and for some distance below the outfall could be distinguished from the river water which was usually a bright blue colour. Wheaton and Curphey (1906) reported "Nearer the town, the river was deep black in colour, and a copious stream of black liquid was flowing into it from a dye works. The Ettrick at Selkirk is very foul, the bottom is black, the stones composing it being covered with a slime stained by spent dye liquid".

A modern sewage treatment plant was installed in 1974 which replaced the earlier one that produced an unsatisfactory effluent. During the building of the new plant, considerable quantities of raw domestic sewage fouled the bed of the Ettrick, and abundant sewage fungus developed (see 7.25).

Galashiels is situated on the lower 4 km of the Gala, and all branches of the wool trade have been carried out there. The Royal Commission on Tweed Fisheries (1896) reported that the effect of mill pollution was so great that at Mourton, 20 km below Galashiels the bottom of the Tweed was not visable from Monday night to Saturday. On Sunday the sediment was visable, but on Monday at approximately 1600 hours "the water would come down as black as can be".

Immediately below Gala Foot and for several km below, except after floods, the Tweed was often covered by knee-deep black sediments of unpurified sewage, discarded dye stuffs, and wool. These sediments were then overlaid by sewage fungus. Wheaton and Curphey (1906) reported that animal life was incapable of survival until below Melrose. Understandably, the pollution was attributable to the mills at Gala, and to a lesser extent those of Selkirk.

Chemical analyses do not seem to be accurate, but Dr Stevenson Macadam reported in the above Commission's report his experiments with salmon. When fish were immersed in the water at Gala Foot, they died very quickly, and always within a day. "Control fish", immersed in the Gala above Galashiels were unaffected. He made no attempt to ascertain the chemical composition of the water, except the relative amounts of different gases dissolved in the water. Above the mills, 28.3% of the dissolved gases was oxygen, but the mill effluents had oxygen levels below 2.0% of the total which rose to only 7.2% at Gala Foot.

At the turn of the century there was no municipal drainage scheme and private drains discharged directly to the Gala. In 1908 the Galashiels Drainage and Burgh Extension Order was passed, authorizing the Town Council to construct and regulate a system of drainage and sewerage purification to deal with industrial waste. Wheaton and Curphey (1906) reported that 30 years prior to this order, the riparian proprietors of the Tweed for some considerable distance below Gala Foot commenced proceedings against the manufacturers of Galashiels, and obtained compensation, as well as an undertaking from them to take steps to prevent the ill effects of their discharges.

The 1931 Commission reported that this had been implemented, and that little pollution of the river was caused at that time. New treatment plants were installed in 1965 which produce an adequate effluent, and a new biological section will be installed in 1975.

3.56 Roxburghshire

In this county are situated Hawick and Jedburgh, important towns in the wool trade and also the residential towns of Melrose and Kelso. The greater part of the county is high lying moorlands, but in the neighbourhood of the lower Teviot and Tweed valley there is much arable and highly cultivated land. Until recently, the drainage from the farmyards passed untreated, directly into the rivers, but pollution reports made little of the pollution thus caused, compared with that caused by the two mill towns.

Hawick is, and has for the past 200 years, been the largest town in the Borders, during which time almost the entire population has been involved in the woollen industry. Watson (1873) reports that the weavers of Hawick were a numerous and corporate body as early as 1640.

The burgh straddles the Teviot at a point where the Slitrig joins it. A hundred years ago, where the Teviot ran through the town, the bed of the river was for the most part dry stones. Nearly the whole of the water was extracted into mill lades, as was the water of the Slitrig.

In 1875 proceedings were taken against the Town Council and the principal manufacturers by the riparian owners of the Teviot below Hawick. As a result, the Town Council undertook to receive the waste liquids from the mills into their sewers and to purify it before discharging it into the river. The town was sewered in 1880, but the domestic refuse and industrial waste was conveyed directly to the river or mill lades, without treatment. Home (1874) wrote "The silver tide of our noble and classic stream is transformed into a puddle of dark-blue ink, the smell of which is enough to keep human beings at a respectable distance, and the cattle grazing on its banks will perish with thirst rather than quaff a mouthful of the noxious compound". And Ruskin (see Lang, 1923) at a lecture in Oxford in 1877 said "I saw the stream of the Teviot as black as ink, oozing not flowing - a mere sluggish injection among poisonous pools of scum covered ink".

Hawick, like Galashiels, was authorized in 1908 to implement sewage purification. A plant was built and operational by 1923, but the Commissioner's report (1931) found that it functioned inadequately, and that pollution of the river still occurred. The report recommended that the Town Council should be urged to complete their sewage purification works by the installation of adequate filters. New plants were installed in 1961 and 1971, and an extension is likely in the near future. The present plant is working to its full capacity, and during summer low flows, oxygen depletion occasionally occurs.

Jedburgh is situated on the Jed Water, 4 km before it flows into the

Teviot. The town has been greatly involved in the textile trade, not only with wool and its associated tanneries and skinneries, but also with rayon during this century. Domestic and industrial waste has heavily polluted the river, and in 1931 it was reported that untreated sewage was poured into the river from six pipes while over 90% of the water was diverted to mill lades. At night, and on Sundays, the sewage was said to be swept away because the water was not abstracted by the mill lades. Rubbish and dead carcasses of sheep were thrown into the river and left to fester until a flood washed them away. The condition of the water at the bottom of the mill lade was no better, often being brightly coloured by dyes and carrying a heavy load of suspended matter. A purification plant was installed in 1963 which treats domestic and industrial waste except that from the tanneries and skinneries. The plant is working to its full potential.

Kelso is situated below the junction of the Teviot and Tweed. In 1901 the population of Kelso was just over 4,000, but the town has had no major industries. The town was sewered last century, but the waste passed unpurified into the river until 1962, when treatment plants were installed. Today the effluent is of good quality.

In the Melrose area there are several small towns of varying populations. The 1901 census (see Scottish Development Department, 1968) made reference to the probable doubling of the population by tourists in the summer. The sewage was discharged untreated until purification plants were installed for Melrose and Gattonside in 1965, Newton St. Boswells in 1962, and St. Boswells over 25 years ago. The first plant produces an effluent of good quality, but the latter two work at, or above capacity. There are plans for expansion, if the population increases in the future.

3.57 Berwickshire

This large county stretches from the Leader in the west to the sea in the east. The extreme eastern portion of the county is not within the Tweed catchment area, but drained by the Eye. The county is chiefly pastoral in the upper reaches and highly cultivated in the lowlands. For the most part, the population is very sparsely distributed. The principal towns are Lauder, Earlston, Greenlaw, Duns, Churnside and Coldstream, none of which exceed 3,000 inhabitants. Factories are few, but there have been wool mills in three towns, and a large paper mill at Churnside. At the turn of this century, their was no purification of domestic sewage except by the town of Duns. Since most towns and villages are situated at the edges of steams, they merely discharged their raw waste directly into them. In the upper regions sheep farming has been practiced for many years, and the summer dippings and washing frequently fouled the smaller streams to a great extent. In the lowlands the farms are generally large, productive and highly fertilized. The effects of artificial manures is most obvious in the flat plain drained by the Leet. The T.R.P.B. has carried out extensive surveys in this area.

Lauder and Earlston are two towns situated on the Leader at the extreme west of the county. Their population sizes have not changed greatly, the former with under a 1000 inhabitants and the latter almost twice that size. The only manufactory is the wool mill at Earlston, which, at the end of the last century took a great deal of water from the Leader into a mill lade and returned it grossly polluted (Wheaton and Curphey, 1906). At the same time, both towns discharged their domestic waste unpurified into the river.

A new purification plant was installed at Lauder in 1974 because of the unsatisfactory nature of the previous effluent. The 1961 plant at Earlston continues to provide adequate treatment.

Duns has a population close to 2,000. At the turn of the century, the town had settling tanks and a broad irrigation farm, which for the period, produced an effluent of good quality which was discharged into the Whiteadder. The new works which were installed in 1969 are operating to their limit, and cause quite heavy suspended solids, and biological oxygen demand (B.O.D.) in the receiving Langton Burn. The effluent is improved on its journey before being discharged into the Blackadder.

Coldstream is situated on an incised meander of the Tweed, and is bisected by the Leet. The burgh has no manufactories, but has nevertheless been late to recognise the necessity for purification of its domestic waste. Previous to 1970 it discharged its raw waste into either the Tweed or the Leet. The newly installed plant produces an effluent of good quality.

Greenlaw and Churnside, although not so well populated as the previous mentioned towns, have produced pollution in their respective rivers Blackadder and Whiteadder (Wheaton and Curphey 1906). Greenlaw's mill was destroyed by fire at the beginning of this century at a time when all waste was discharged unpurified into the Blackadder, and obvious pollution was reported. Purification plants were installed in 1956, since which time a reasonably satisfactory effluent has been produced. Churnside, and particularly its paper mill, have caused serious pollution of the Whiteadder. Walpole and Young (1874) reported large sheets of slime froth floating on the surface of the Whiteadder below their discharge, with the resultant killing of thousands of fish. Analyses at Edinburgh showed the effluent to have a strong deoxygenating effect. The owners spent large amounts of money on partial purification of their waste, but up to near the present day, fish kills were often still attributed to their effluent. The purification plants installed over 25 years ago need improvements, tenders for which will be sent out in 1975.

Berwick-on-Tweed, which consists of three portions, is situated at the mouth of the Tweed. On the north side is Berwick, with a population approaching 10,000, and on the south, are the towns of Tweedmouth and Spittal, with combined populations of 5,000 inhabitants. The area depends for its prosperity to a considerable extent upon the salmon fisheries, both within the tidal Tweed and the surrounding sea. Since waste is disposed into tidal waters, the effects have not been monitored critically.

3.58 Northumberland

The majority of the northern part of Northumberland is drained by one of the Tweed's largest affluents, the Till. There are no major industries in that portion of the county which is in the drainage area of the Till, and the only town of any size is Wooler.

The inhabitants of this area are almost entirely dependent on agriculture. Large numbers of sheep are pastured on the Cheviots, and the greater part of the remaining area is highly cultivated. The streams at times were highly fouled by sheep washings and sheep dippings (Wheaton and Curphey, 1906). Many years ago there were coalmines in the district, the drainage from which contained large quantities of iron, so much so that it caused considerable deposits in the receiving burns, and discolouration in the Till and Tweed. The largest colliery was situated about 1 km from the river at Ford Forge (km -13.5). It has not been mined for well over a century, the old drainage outflow bursting in 1869.

3.59 Summary and discussion

The population explosion and concomitant build up of the wool trade in the nineteenth century have been described, as have many graphic descriptions of their effects upon river conditions. The present quality of effluents has also been given. Little mention has been made however of the improvement in conditions over the last 25 years since the inception of the T.R.P.B.

Following the Rivers (Prevention of Pollution - Scotland) Act, 1951, the T.R.P.B. was established together with eight other regional Boards in Scotland. The 1951 Act gave control to the Boards over all new discharges of sewage and trade effluent. In 1965 powers were extended to include existing discharges, and also new ones in tidal waters.

The Board's annual report of 1956 reported that many of the streams were unpolluted, whereas others showed 'Black spots'. The sewage plants at Galashiels and Hawick were described as obsolete, their effluents often being merely settled waste. Hawick's discharge was particularly bad and serious adverse effects on the Teviot were obvious. The same was true for Jedburgh; and the burghs of Melrose, Kelso and Coldstream had no treatment at all, save screens or settling tanks. The tenors of more recent reports would indicate great improvement; the comparative classification of sewage plant effluents in 1956 and 1973 bear witness. In the former year, only 30% were regarded as satisfactory compared with a figure in excess of 50% in 1973. (For details, see Tweed River Purification Board, 1955-1973).

Other data collected by the Board are published in their annual reports, but information published in 1957 is worthy of comment. The recent advent of severe growths of *Cladophora glomerata* was discussed and related to water chemistry. In the summer of 1955 during very low flows and a period of intense sunshine, *Cladophora* developed from Peebles to the tidal limit of the Tweed in 'immense quantities'. The report says that there was evidence that such extensive growths had developed only recently: it was also "doubtful if more extensive growths occurred in other rivers as in the Tweed in 1955-56". The condition of the Teviot below Hawick during this period was very similar to that of the Tweed.

It was noticed that the respiration of such large quantities of algal matter was having a profound effect on the river water. Fig. 3.59a (from Tweed River Purification Board, 1957) shows the results of a 24 hour survey of the Tweed above Gala Ford (km 75.5) carried out on 26/27.VI.56. The day chosen was mainly overcast so that the results were not so extreme as were experienced on other days. However it will be noted that diurnal fluctuations in pH of 7.8 to 10.5, and D.O. between 50% and 180% saturation were experienced. In other stretches of the river on bright sunny days, the D.O. exceeded 200% during the hours of daylight, and dropped to below 50% during the night. The absorption of carbon dioxide for photosynthesis during the day led to extremely high pH values.

The report suggested (as did Butcher et al., 1937) that the presence of Cladophora was associated with sewage effluents (see 7.21). From their analyses it seemed likely that phosphate was a limiting factor in the distribution and development of the alga. The presence of phosphate 'biulders' in synthetic detergents was thought to be an important factor since the Borders use well above the national average in the textile trade. Recently many of the mills have reverted to natural soaps. There was no information available relating phosphate content of sewages prior to the introduction of synthetic detergents, and so it is difficult to judge the extent of its influence. Currie (1973, personal communication)

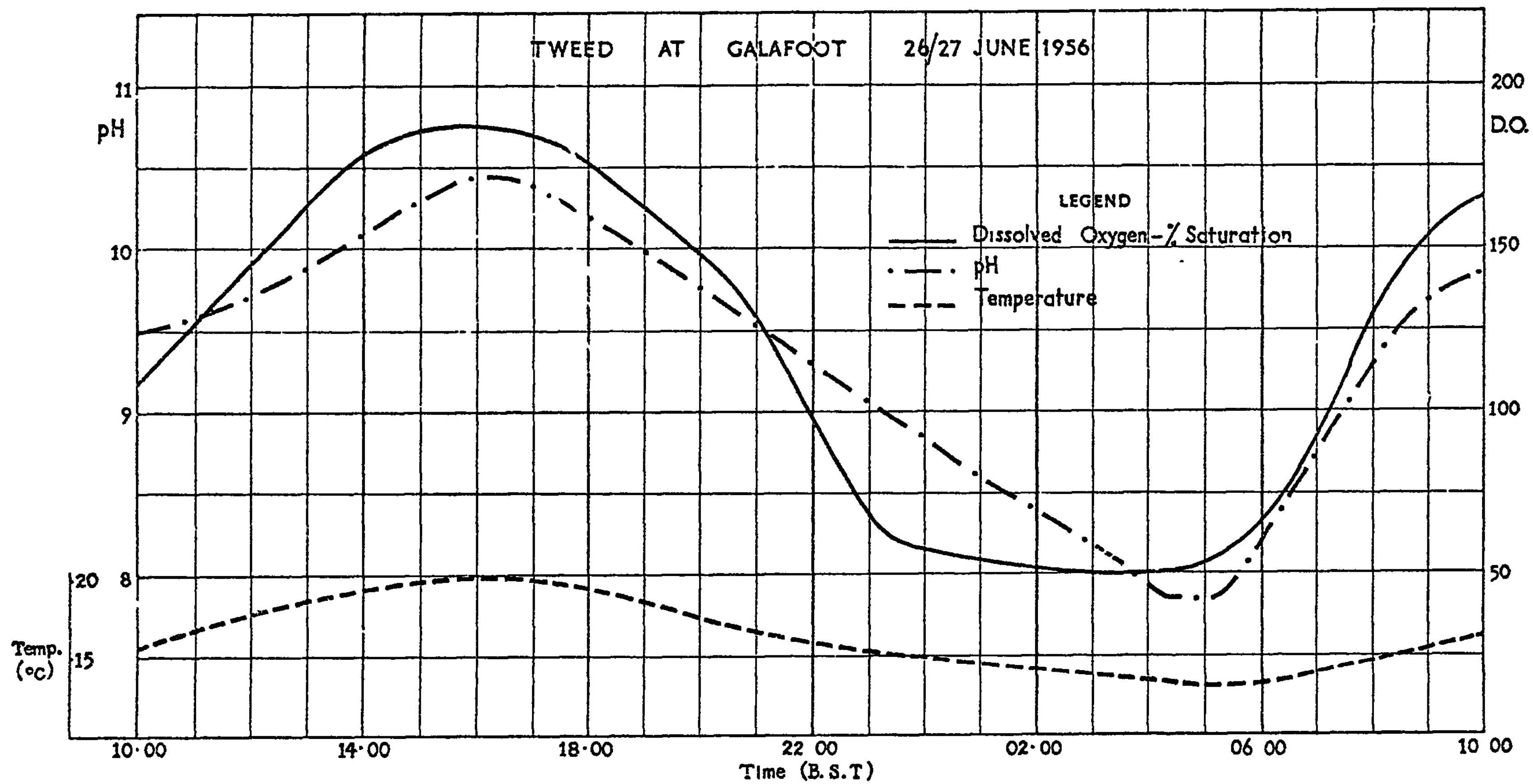


Fig. 3.59a Survey of the Tweed at Gala Foot carried out by the Tweed Purification Board to show the effects of Cladophora glomerata blooms over a period of 24 hours.

compared dissolved phosphate and total phosphate results from the Tweed at Gala Ford for the period 1961-72. The former showed no sign of any trends with the mean yearly values ranging from 0.020 to 0.080 mg l^{-1} PO_4-P (see 5.2). Total phosphate, however, showed a very marked trend towards much lower figures in recent times (see Table 3.59a). In the latter period, 1967-1972, the total phosphate levels were a sixth of the levels of the former period, 1961-1966.

Period	min.	max.	mean
1961-1966	0.63	1.40	1.00
1967-1972	0.10	0.24	0.15

Table 3.59a Mean annual total phosphate (PO_4-P) levels at Tweed Ford expressed in mg l^{-1}.

In 1972 the Scottish Development Department published a report 'Towards cleaner water', the object of which was to produce a broad picture of the extent to which rivers in Scotland are polluted. They classified rivers from I to IV based on B.O.D., Dissolved Oxygen and biological characteristics. In the Tweed area 95.6% of the rivers are class I (unpolluted or recovered from pollution), 3.2% class II, 0.9% class III and 0.3% class IV (grossly polluted). The whole length of the Tweed and all its tributaries save short lengths in four of them are class I. Both the Biggar and Teviot are class II for short lengths below the sewage outflows of the towns of Biggar and Hawick respectively. The Leet is unsatisfactory for considerable stretches in the upper and lower reaches as a result of farm drainage and the discharge into it of crude domestic sewage which causes classifications of II and III. The Whiteadder is class I for most of its length, but in short stretches above Blackadder

Foot the river shows deterioration from industrial waste, and short stretches are classified II and IV.

The 1972 report is valuable in a historical perspective in relation to earlier reports of the Pollution Commissions and Committees already mentioned. The report also came exactly a century after the first attempt was made to obtain a picture of the pollution of rivers in Scotland (and England and Wales) when a Royal Commission was appointed in 1868 which reported in 1872. Its findings showed that the Tweed area contained both some of the cleanest and also some of the foulest waters investigated. The Tweed itself was described as a grossly polluted river.

It was inevitable, with two reports available exactly a century apart that someone would pose the question 'are the rivers of the Tweed Basin cleaner now than they were a hundred years ago?' Nicoll (1972), in answering this question felt that the rivers conditions had definitely improved. His attempts to quantify the matter by using chemical data however did not lead to positive conclusions. The general tenor of the 1872 report with its many dramatic references and descriptions of pollution compared with that of the 1972 report would suggest that things had improved. In addition, the fact that the population was much larger a hundred years ago, and even rudimentary treatment of both domestic and industrial effluents was rare, can only imply that conditions today must be cleaner than they were. Reference to the Tweed River Purification Board (1953-1973) shows that the trend towards cleaner rivers continues.

3.6 Hydrology, and data from the continuous water monitor

3.61 Hydrology

A large amount of hydrological data is available at the T.R.P.B laboratories in Galashiels. Although at the time of their inception in 1952, there was only one gauging station within the Board's area, by 1973 at least one gauge had been installed on all the major tributaries. Data are published in the Annual Reports, and also for 19 stations in the Surface Water Year Book.

Hydrological data from seven stations on the Tweed, two on the Teviot, and from single stations on 10 different tributaries are summarized in Tables 3.61a and b. Where available, the mean flows for a 10 year period 1960-70 are given. Since several gauges were not installed until 1961, for these a 10 year mean for 1961-71 is given. In some cases however, 10 year means are not available because the gauges have been installed even more recently.

Peak monthly flows, and mean monthly flows for the same 10 year periods have been plotted in Fig. 3.61a from data from two stations on the Tweed, and one each from the three largest affluents Ettrick, Teviot and Till. Since the gauging station on the Till has been operational for a longer period than the others, maximum, minimum and mean monthly means are given for the period 1956-73.

Without exception, the mean flows in the Tweed and its tributaries during the winter months October to March are almost double that of the summer period April to September. Lowest mean flows occur during the months of June and July when floods are also minimal and highest monthly means occur during November, December and January. However, the Till's maximum, minimum and mean flows (Fig. 3.61a) show that there is great variation from one year to another. The greatest variation of mean flows occurs in the months within the winter period, with November showing the largest range. June, which has at all gauging stations the lowest monthly mean and the lowest flood peaks, also has the smallest yearly variation of flows.

river gauging stations

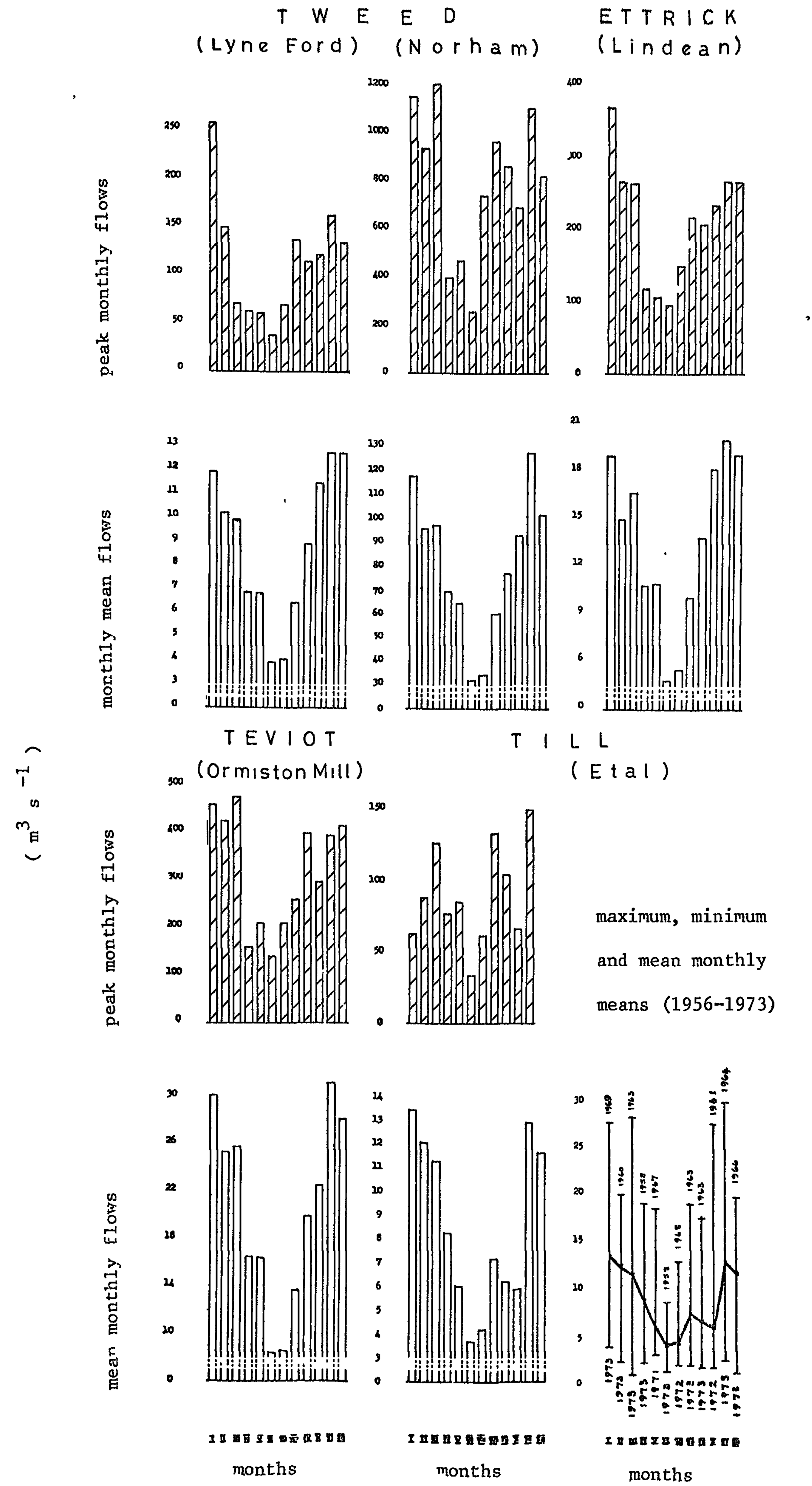
river	station	grid ref.	km ref.	drainage area (km^2)	records since
Tweed	Kingledores	109285	16.2	139	IX.61
Tweed	Lyne Ford	206397	34.6	373	II.61
Tweed	Peebles	257400	41.0	694	XII.50
Tweed	Boleside	493334	74.0	1500	VI.61
Tweed	Dryburgh	588320	88.5	2080	X.60
Tweed	Sprouston	752354	112.0	3330	XI.69
Tweed	Norham	898477	138.4	4390	IX.59
LYNE	LYNE STATION	20940[illegible]	- 0.4	175	II.61
MANOR	CADEMUIR	217369	- 4.4	61	X.68
YARROW	PHILIPHAUGH	439277	(- 8.1)	231	IX.62
ETTRICK	LINDEAN	486315	- 1.0	499	X.61
GALA	GALASHIELS	479374	- 4.4	207	X.63
LEADER	EARLSTON	565388	- 6.0	239	X.66
TEVIOT	HAWICK	522159	- 35.0	323	II.60
TEVIOT	ORMISTON MILL	702280	- 8.3	1110	XI.60
JED	JEDBURGH	655214	(- 3.4)	139	VIII.71 (replaces 1959)
LEET	COLDSTREAM	839396	- 0.6	113	X.70
TILL	ETAL		- 10.0	64[illegible]	X.56
WHITEADDER	HUTTON CASTLE	881559	- 15.0	503	IX.69

Table 3.61a River gauging stations of the Tweed Basin: background information.

	Tweed Kingledors	Tweed Lyne Ford	Tweed Peebles	Tweed Boleside	Tweed Dryburgh	Tweed Sprouston	Tweed Norham	LYNE LYNE STATION	MANOR CADEMUIR	YARROW PHILIPHAUGH	ETTRICK LINDEAN	GALA GALASHIELS	LEADER EARLSTON	TEVIOT HAWICK	TEVIOT ORMISTON MILL	JED JEDBURGH	TILL ETAL
drainage area (km^2)	139	373	694	1500	2080	3330	4390	175	62	231	499	207	239	323	1100	139	648
oct.- march 1961 -1971	5.15	11.40	20.39	46.72	61.06		104.7				19.41			11.44	26.47	1.90	
april - sept. 1961 - 1971	2.68	6.10	11.00	25.66	32.82		56.10				10.76			6.41	13.78	1.67	
oct. 1961 - sept. 1971	3.91	8.75	15.69	36.16	46.91		80.38				15.07			8.92	20.12	2.29	9.06
peak flow	195.3	266.0	481.1	605.6	999.4		1186				362.2			228.6	475.4		
date of peak flows	I.62	I.62	I.62	I.62	I.62		III.63				I.62			III.67	III.63		
oct. 1970 - sept. 1971	3.07	7.46	13.42	32.14	39.62	55.85	67.52	3.07	1.46	5.91	12.93	3.16	3.14	6.92	15.51	1.82	6.33
oct. 1971 - sept. 1972	3.30	7.35	12.69	31.11	36.77	52.22	62.27	2.41	1.45	5.99	12.74	1.35	2.81	7.10	15.39	1.79	5.94
oct. 1972 - sept. 1973	1.84	4.60	7.39	18.78	21.32	31.40	34.07	1.32	0.82	3.84	8.46	1.35	0.99	4.83	9.53	1.66	2.19

Table 3.61b Hydrological data : comparison of flows during three years of research with mean flows over 10 years ($m^3 s^{-1}$).

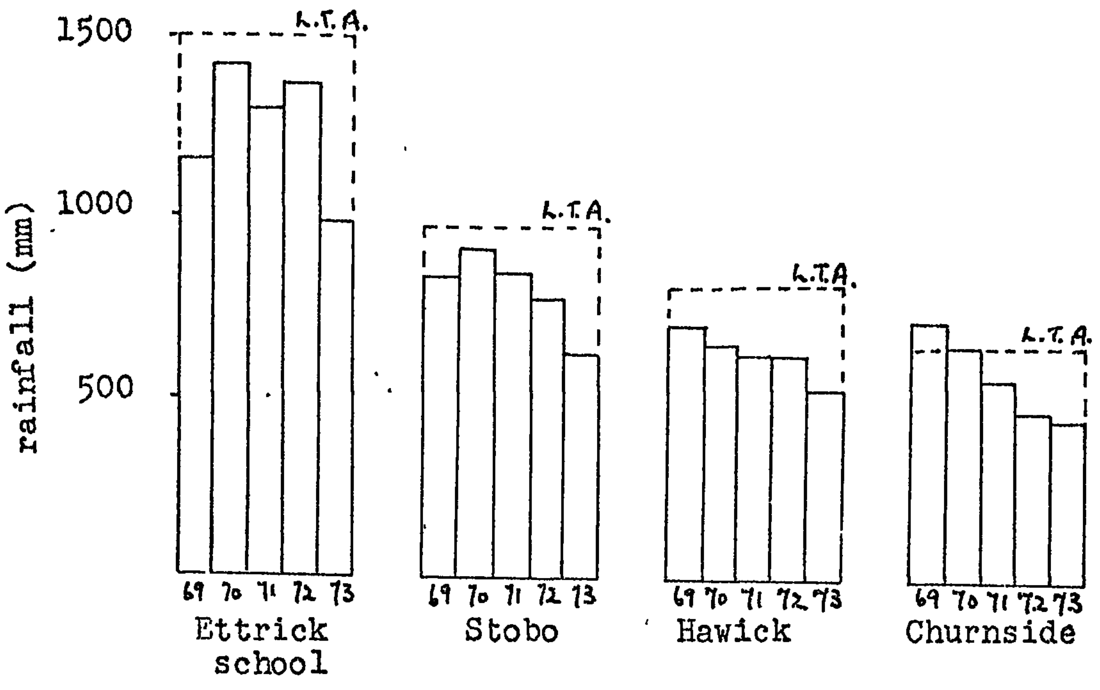
Fig. 3.61a (overleaf) Monthly mean and peak flows for two river gauging stations on the Tweed, and one each for the Ettrick, Teviot and Till.


TWEED
(Lyne Ford)
(Norham)
ETTRICK
(Lindean)
peak monthly flows
monthly mean flows
(m3 s-1)
TEVIOT
(Ormiston Mill)
TILL
(Etal)
peak monthly flows
mean monthly flows
maximum, minimum
and mean monthly
means (1956-1973)
months
months
months

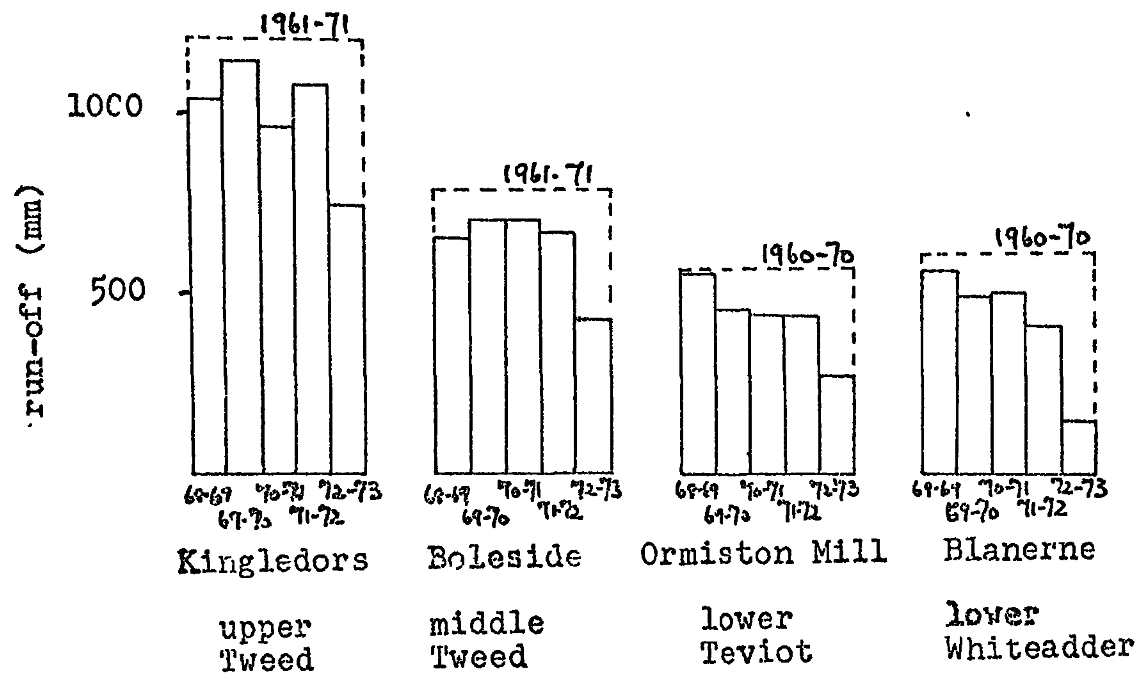
Since the Tweed drains such a large area, the principal tributaries often behave hydrologically in an autonomous manner. Heavy local rainfall in one valley may cause that tributary to flood while others are totally unaffected, but major floods on the Tweed usually result from all its affluents being affected.

In the last 15 years, by far the worst floods in the western part of the basin occurred on 16.I.62. This January maximum is clearly shown by the peak flow histograms for the Tweed at Lyne Ford and the Ettrick at Lindean (Fig. 3.61a). At Tweedsmuir, the Tweed reached its highest level for 52 years, but the severity of the flood decreased downstream. At Lyne Ford, the water level was 0.45 m above the deck of the footbridge, a level which had been reached on only two occasions in the past 30 years (1948 and 1956). Bank erosion was considerable, and the cableway and winch tower of the gauging station at Boleside was swept away. The Yarrow below Gordon Arms also developed a new course. However, the northern and eastern rivers were not exceptionally high. This explains why the Norham peak flow of that year was exceeded by a flood in March 1963, when the Teviot was also higher than in 1962.

South east Scotland is famous for abnormally high rainfall which periodically occurs in August and produces exceptionally high flows known as 'Border floods'. This local phenomenum has not occurred for nearly 20 years, the most recent ones being on 12.VIII.48 and 28.VIII.56. In 1948 most gauges recorded between 20 and 23% of their annual average in one day. At Kelso, the combined waters of the Tweed and Teviot rose 5.48 m above normal and exceeded the previous highest record of August 1832 by 0.15 m. The effect was similar over the whole area with the Whiteadder 1.5 km above its foot washing away New Mills Bridge. In 1956 the effect was less devastating, with between 50 and 100 mm of rain



Rainfall....last five years compared with the long term average (L.T.A.)



Run-off....last five years compared with the 1960-70 or 1961-71 averages

Fig. 3.61b Rainfall and run-off data.

falling. Probably the most famous 'Border flood' occurred on the 1st August 1294 when after heavy rainfall the Teviot and Tweed overflowed their banks, and the bridge at Berwick was washed away.

Climate is clearly the major factor affecting changing river flows. Droughts obviously result in low flows, but continuous hard frost can also have the same effect. Conversely, peak flows usually occur after a period of sustained heavy rainfall, or more commonly when rain falls on deep snow.

Rainfall, and consequently river flows during the past five years were below average. Fig. 3.61b represents diagrammatically the annual rainfall for the period 1969-73 for four stations. The rain gauge at Ettrick School is at a height of 232 m, and within the Ettrick catchment area. The other stations in decending order of height are from the Tweed, Teviot and Whiteadder catchments. All four examples are compared with the long term averages.

During the three years when research was undertaken, rainfall was below average. In 1972 river flows in September reached their lowest levels for 12 years, and 1973 was the fifth year in succession when annual rainfall was below normal. Universally over the whole area this was the lowest of the five. This resulted in the total flows for the water year 1972-73 being 65% of average in the south west of the basin, 50% in the middle Tweed and Teviot, 20% in the Whiteadder and as low as 10% in the Leet.

Fig. 3.61b also represents the annual run-off from four stations during the past five years compared with the 1960-70 or 1961-71 averages. All are below average, especially 1972-73. Run-off represents the total quantity of water running off the drainage area in a year, expressed as a depth of water over the whole area. It therefore gives a direct comparison between different catchment areas. During 1973, as a gathering ground for water during the winter, 1 km^2 at the head of the Ettrick was equivalent to 100 km^2 in the Merse area of the Tweed.

Many reports by Pollution Commissions (e.g. 1872) during the nineteenth century made reference to land drainage that tended to make the rivers rise and fall more rapidly than in former days. Government grants were made available in 1846 to land owners who wished to improve their estates. The result was a massive drainage programme which enevitably meant that after periods of high rainfall, instead of the earth acting as a sponge and the water gradually percolating through the earth, it was rapidly drained away directly to the rivers via a network of pipes and man made channels. Floods were reported to begin and end more quickly, and the effect of summer droughts were more pronounced. However, the T.R.P.B. and Colonel J. Ryan, Chairman of the Tweed Commissioners made a comparative study of floods which have occurred during the past 80 years. Their conclusions were published in the Tweed River Purification Board Annual Report (1966).

Data from Boleside would indicate that fewer large floods have occurred in recent times, but the time taken for the river to rise and fall has changed little. The effects thus reported must have occurred rapidly after 1846, if at all.

Suggestions were made by Stoddart (1866) and the Scotch Salmon Fisheries Enquiry (1871) to build reservoirs in the head waters so as to hold water during periods of high rainfall in the winter, and then let it down the river when required in the summer. Although the valleys of the Talla (1895) and the Fruid (1968) were impounded, it was to supply Edinburgh with its potable water supply, and not with river regulation in mind. The former reservoir has no compensation flow for seven months of the year, the latter being the most important contribution.

3.62 Continuous water monitor data

In July 1971 a continuous water quality recording unit stationed on the Tweed at Boleside (km 74.0) became operational. This unit measures pH, dissolved oxygen (D.O.) temperature, suspended solids and conductivity. A two year cycle of three parameters is discussed.

pH, D.O. and temperature data are summarized in Fig. 3.62a. The mean of monthly maxima and the daily maxima differences within each month are plotted. Although the machine was installed in July 1971, accurate data are only available from April 1972. In order to obtain a clear picture of seasonal variation, the two year period has been plotted. In some cases results are not a true representation of the whole month since damage to the whole machine or individual components resulted in lack of data until the fault was recitified. In such instances, the mean of figures available have been used, which in the case of October 1972 was as few as nine days due to machine failure, and similar periods in November 1973 and January 1974 when the machine had to be switched off during the power crisis.

From a glance at Fig. 3.62a it can be seen that all three parameters are interrelated and show seasonal variation. The summer high maximum temperatures are corrolated with corresponding higher maxima of pH and D.O. With all parameters, the variation of their maxima is always greater in the summer months when levels are higher.

Diurnal fluctuations are frequent. In general, slight daily cycles begin in late March, and by April, providing the temperature did not drop below 8°C the cycles became very pronounced. Under normal conditions these variations in daily values continued until October, but the amplitude of difference is markedly reduced in the autumn. Cloudy days and cold weather also have the same effect; floods are unpredictable, but generally pH and D.O. drop, and suspended solids increase very obviously. During winter periods November to March there is rarely any difference between day and night readings.

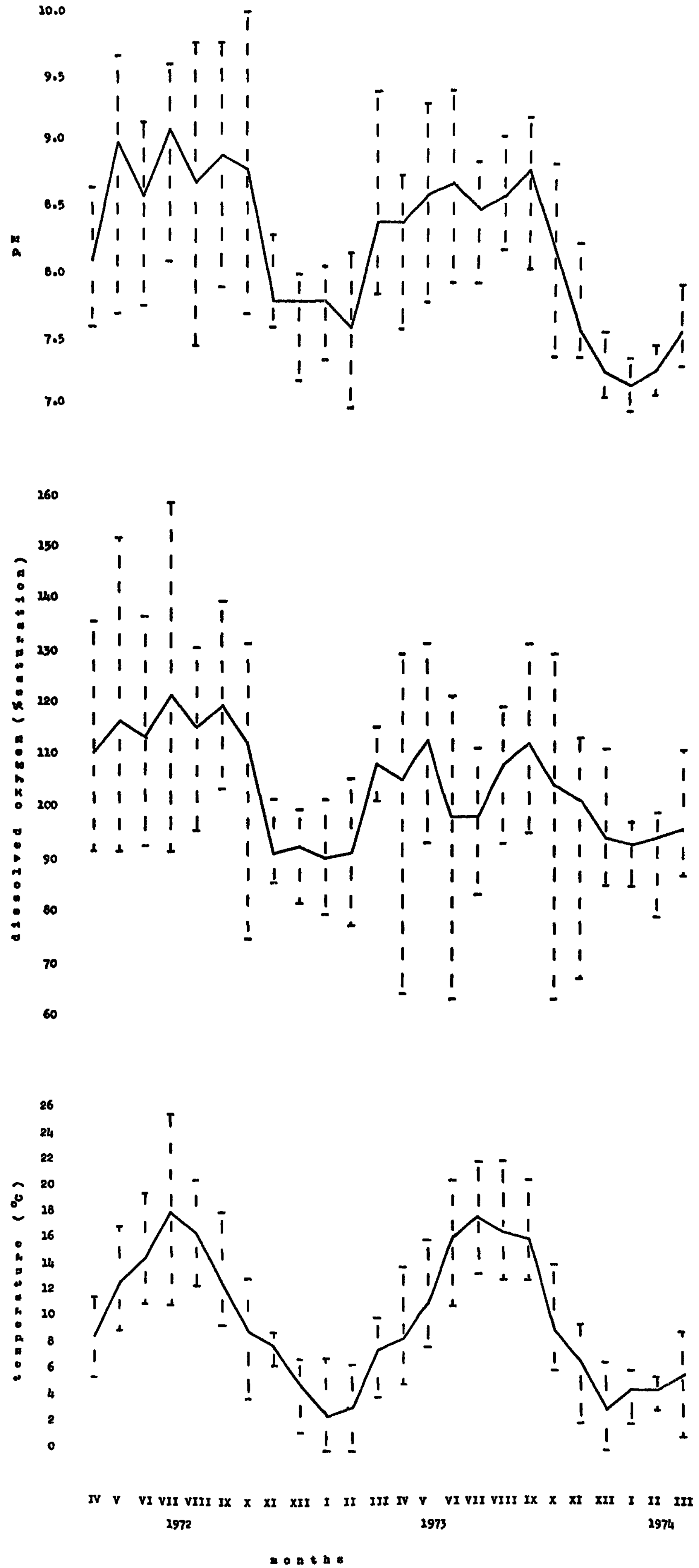


Fig. 3.62a Monthly mean, maxima and minima data from the continuous water monitor.

4. CHECK LIST OF MACROPHYTES RECORDED IN THE TWEED BASIN

4.1 Check list

4.11 Introduction

All macrophytes recorded from the Tweed and its tributaries are listed in 4.12 to 4.17. This enables efficient comparison with species compositions of other rivers.

Each species is preceded by a six digit figure which refers to its computer number at the Botany Department, University of Durham. It is included here as a reference which may be of value in the future when computer analysis of the data are published.

The full name of a macrophyte species is followed by its relevant authority. In cases where macrophyte growths have been recorded at genus level only, species within the genus known to be present are listed in parenthesis below the genus name.

The naming of algae and lichens follow that used by the most recent publications quoted in 4.21 and 4.22. Hepatics and mosses follow the check-lists of Paton (1965) and Warburg (1963) respectively, and angiosperm names are those used by Clapham, Tutin and Warburg (1962).

4.12 Algae

011250 Chamaesiphon spp.

011203 (C. fuscus (Rostaf.) Hansg.)

011210 (C. polonicus (Rostaf.) Hansg.)

015209 Nostoc parmelioides Kütz.

015212 Nostoc sp. 'A' = N. rivulare Kütz

015202 Nostoc other sp. = N. commune Vauch.

0157 Phormidium spp.

015703 (P. autumnale (C.A. Ag.) Gomont)

015710 (P. subfuscum Kütz.)

016505 Rivulare biasolettiana Menegh.

017611 Tolypothrix penicillata (C.A. Ag.) Thur.

021601 Hildenbrandia rivularis (Liebm.) J. Ag.

021902 Lemanea fluviatilis (L.) Ag.

030250 Euglena Ehrenberg spp.

060201 Botrydium granulatum (L.) Grev.

060250 Vaucheria sp(p).

060203 (V. sessilis de Candolle)

090404 Melosira varians C.A. Ag.

101050 Diatoma spp.

(D. elongatum A.)

(D. hiemale (Lyngb. Heiburg)

(D. vulgare Bory)

101101 Didymosphenia geminata (Lyngb.) Schmidt

110401 Heribaudiella fluviatilis (Aresch.) Sved.

151003 Chaetophora sp. = C. pisiformis (Roth.) Ag.

160302 Cladophora glomerata (L.) Kütz.

160304 Cladophora sp. 'A' = C. aegagropila (L.) Rabenh.

1524 Enteromorpha sp(p).

152402 E. flexuosa (Walfen.ex Roth.) J. Ag.)

(E. crinita J. Ag.)

152403 (E. intestinalis (L.) Link.)

152404 (E. prolifera (O. F. Mull.) J. Ag.)

152405 (E. torta (Mert. in Jurg) Reinb.)

152903 Gongrosira incrustans Schmidle

131201 Haematococcus lacustris (Girod.) Rostaf.

153401 Monostroma bullosum (Roth.) Wittrock.

1607 Oedogonium Link spp.

153701 Prasiola crispa (Lightf.) Menegh.

Rhodoplax schinzii Schmidle and Wellheim.

154532 Stigeoclonium tenue Kütz

132401 Tetraspora sp(p). = T. lubrica Ag.

154703 Ulothrix zonata Kütz.

1221 Spirogyra Link spp.

Charophyta sp(p).

160105 (Chara vulgaris L.)

170301 (Nitella flexilis (L.) C.A. Ag.)

4.13 Lichens

210201 Collema flaccidum (Ach.) Ach.

210202 C. fluviatile (Huds.) Stend.

210301 Dermatocarpon fluviatile (Web.) Th. Fr.

211008 Verrucaria praetermissa (Trevis.) Anzi

Verrucaria other spp.

211001 (V. aethiobola Wahlenb. ex Ach.)

211002 (V. aquatilis Mudd.)

211003 (V. elaeomelaena (Massal.) Arnold)

211004 (V. hydrela Ach.)

211007 (V. margacea (Wahlenb. ex Ach.) Wahlenb.)

4.14 Hepatics

Blasia pusilla L.

220201 Calypogeia fissa (L.) Raddi

220401 Chiloscyphus polyanthos (L.) Corda

220501 Conocephalum conicum (L.) Underw.

221101 Marchantia polymorpha L.

221601 Pellia endiviifolia Dicks. (P. fabbroniana Raddi)

221602 P. epiphylla (L.) Corda

221701 Plagiochila asplenioides (L.) Dum.

Priessia quadrata (Scop.) Nees

222102 Scapania undulata (L.) Dum

222204 Solenostoma triste (Nees) K. Müll.

4.15 Mosses

230101 Acrocladium cuspidatum (Hedw.) Lindb.

230102 A. giganteum (Schimp.) Rich. and Wall.

230201 Amblystegium serpens (Hedw.) B.S. and G.

230301 Amphidium mougeotii (B. and S.) Schimp.

230601 Atrichum crispum (James) Sull.

230602 A. tenellum (Rohl.) B. and S.

230701 Barbula cylindrica (Tayl.) Schimp.

230702 B. fallax Hedw.

230704 B. recurvirostra (Hedw.) Dix.

230706 B. spadicea (Mitt.) Braithw.

230801 Blindia acuta (Hedw.) B. S. and G.

230901 Brachythecium mildeanum (Schimp.) Milde

230902 B. plumosum (Hedw.) B. S. and G.

230903 B. rivulare B. S. and G.

230904 B. rutabulum (Hedw.) B. S. and G.

230905 B. salibrosum (Web. and Mohr) B. S. and G. (var. β palustre Schp. Dixon 1924)

231001 Bryum alpinum With.

231002 B. calophyllum R. Br.

231005 B. pallens Sw.

231006 B. pseudotriquetrum (Hedw.) Schwaegr.

231201 Campylopus atrovirens de Not.

231401 Ceratodon purpureus (Hedw.) Brid.

231601 *Cinclidotus fontinaloides* (Hedw.) P. Beauv.

231701 *Climacium dendroides* (Hedw.) Web and Mohr.

Cratoneuron commutatum (Hedw.) Roth.

(α *commutatum* and β *falcatum* (Brid.) Mönk.)

231803 *C. filicinum* (Hedw.) Spruce

231901 *Ctenidium molluscum* (Hedw.)

232001 *Dichodontium pellucidum* (Hedw.) Schimp.

232001 *D. pellucidum* (Hedw.) Schimp. var. *flavescens* (With.) Husu.

232102 *Dicranella palustris* (Dick.) Crundw. ex E. F. Warb.

232103 *D. rufescens* (With.) Schimp.

D. varia (Hedw.) Schimp.

232202 *Dicranum scoparium* Hedw.

232304 *Drepanocladus uncinatus* (Hedw.) Warnst.

Eurhynchium praelongum (Hedw.) Hobk.

232501 *E. riparioides* (Hedw.) Rich.

E. swartzii (Turn.) Curn.

232601 *Fissidens adianthoides* Hedw.

232602 *F. crassipes* Wils. ex B. S. and G.

232605 *F. rufulus* B. S. and G.

232701 *Fontinalis antipyretica* Hedw.

232702 *F. antipyretica* Hedw. var. *gracilis* Schp.

Funaria hygrometrica Hedw.

Grimmia alpicola Hedw. β *rivularis* (Brid.) Broth.

232901 *Gymnostomum aeruginosum* Sm.

232902 *G. recurvirostrum* Hedw.

233001 *Hedwigia ciliata* (Hedw.) P. Beauv.

233101 *Hygroamblystegium fluviatile* (Hedw.) B. S. and G.

233201 Hygrohypnum luridum (Hedw.) Jena.

233202 H. ochraceum (Turn. ex Wils.) Loeske

233401 Leptodictyum riparium (Hedw.) Warnst.

233501 Leskea polycarpa Hedw.

233604 Mnium longirostrum Brid.

233607 M. punctatum Hedw.

233901 Orthotrichum anomalum Hedw.

233902 O. cupulatum Brid. var. nudum (Dicks) Braithw.

233903 O. rivulare Turn.

234001 Philonotis calcareus (B. S.) Schp.

234002 P. fontana (Hedw.) Brid.

234101 Physcomitrium pyriforme (Hedw.) Brid.

234303 Pohlia delicatula (Hedw.) Groat.

231401 Polytrichum aloides Hedw.

234402 P. nanum Hedw.

234403 P. piliferum Hedw.

234404 P. urnigerum Hedw.

234501 Rhacomitrium aciculare (Hedw.) Brid.

234502 R. aquaticum (Brid.) Brid.

234601 Rhytidiadelphus squarrosus (Hedw.) Warnst.

234701 Scorpidium scorpiodes (Hedw.) Limpr.

235001 Thamnium alopecurum (Hedw.) B. S. and G.

235101 Thuidium delicatulum (Hedw.) Mitt.

235301 Tortula latifolia Hartm. (T. mutica (Schultz) Lindb.)

4.16 Angiosperms

250401 Butomus umbellatus L.

260201 Callitriche hermaphroditica L.

260250 Callitriche other sp(p).

(*C. platycarpa* Kütz.)

260204 (*C. stagnalis* Scop.)

260301 *Caltha palustris* L.

250501 *Carex acuta* L.

250502 *C. acutiformis* Ehrh.

250505 *C. hirta* L.

250506 *C. nigra* (L.) Reichard

250507 *C. ovalis* Good

C. paniculata L.

250509 *C. riparia* Curt.

250910 *C. rostrata* Stokes

250550 *Carex* other spp.

Cochlearia alpina = *C. officinalis* L. ssp. *alpina* (Bab.) Hook.

250600 *Eleocharis palustris* (L.) Roem. and Schult.

250801 *Elodea canadensis* Michx.

240201 *Equisetum fluviatile* L.

260501 *Filipendula ulmaria* (L.) Maxim

250902 *Glyceria fluitans* (L.) R. Br.

251201 *Iris pseudacorus* L.

251301 *Juncus acutiflorus* Hoffm.

251302 *J. effusus* L.

251303 *J. inflexus*

251402 *Lemna minor* L.

260601 *Mentha aquatica* L.

260701 *Mimulus guttatus* D.C.

260802 *Myosotis scorpioides* L.

260901 *Myriophyllum alterniflorum* D.C.

260902 *M. spicatum* L.

250701 *Phalaris arundinacea* L.

251801 *Phragmites communis* Trin.

261001 *Polygonum amphibium* L.

251901 *Potamogeton berchtoldii* Fieb.

251902 *P.* x *cooperi* (Fryer) Fryer

251903 *P. cripus* L.

251905 *P. lucens* L.

251906 *P. natans* L.

251909 *P.* x *olivaceus* G. Fisch.

251910 *P. pectinatus* L.

251911 *P. perfoliatus* L.

P. polygonifolius Pourr.

251914 *P. pusillus* L.

251915 *P.* x *salicifolius* Wolfg.

251916 *P.* x *suecicus* Richt.

261101 *Ranunculus aquatilis* agg.

(*R. aquatilis* L.)

(*R. peltatus* schrank)

(*R. trichophyllus* Chaix)

261103 *R. circinatus* Sibth.

261104 *R. circinatus* x *R. pencillatus* var. *calcareus*

R. flammula L.

261106 *R. fluitans* Lam. x ?

261107 *R. hederaceus* L.

261110 *R. penicillatus* (Dumort.) Bab. var. *calcareus* (R. W. Butcher) C. D. K. Cook (from Cook 1966)

261201 *Rorippa amphibia* (L.) Besser

261204 *R. nasturtium-aquaticum* (L.) Hayek

Rumex hydrolapathum Huds.

252201 *Scirpus lacustris* (L.) Palla

252202 *S. sylvaticus* L.

252403 *Sparganium erectum* L.

252502 *Typha latifolia* L.

261402 *Veronica beccabunga* L.

252801 *Zannichellia palustris* L.

4.17 Other microscopic microbial communities

purple photosynthetic bacteria

329941/42 "sewage-fungus community"

4.2 Taxonomic literature

The following is a guide to the main taxonomic works consulted for identification of the macrophytes listed.

4.21 Algae

General works covering all phyla; West and Fritsch (1927), Jaag (1945), Prescott (1961, 1969), Bourrelly (1966, 1968, 1970), Fott (1971), Fritsch collection of algae, Micro-edition by International Documentation Centre.

Myxophyta; Frémy (1930), Geitler (1932), Desikachary (1959), Starmach (1966). For Chamaesiphon; Backhaus (1967b), Kann (1972): Phormidium; Kann and Komarek (1973); Tolypothrix; Golubič and Kann (1966).

Rhodophyta; Skuja (1926), Israelsson (1942), Kylin (1956), Flint (1970)

Euglenophyta; Gojdics (1953), Leedale (1967).

Xanthophyta; for Vaucheria; Venkataraman (1961), Blum (1972).

Bacillariophyta; Pascher (1930).

Phaeophyta; Pascher (1925), Hamel (1931-1939).

Chlorophyta; for Cladophora; Hoek van den (1963): Chaetophorales; Printz (1964), Cox and Bold (1966), Bliding (1963, 1968), Tupa (1974).

Charophyta; Pal et al. (1962), Wood and Imahori (1964, 1965), Procter et al. (1971).

4.22 Lichens: Degelius (1954), Duncan (1959), Swincow (1968).

4.23 Bryophytes: Dixon (1924), MacVicar (1926), Nyholm and Arnell (1954), Watson (1968).

4.24 Angiosperms

General floras: Butcher (1961), Clapham et al. (1962). Callitriche; Jones (1955). Carex; Jermy and Tutin (1968). Potamogeton; Fryer and Bennet (1915), Hagström (1916), Misra (1944). Ranunculus; Langlet (1927), Butcher (1940), Bostrock and Millington (1962), Cook (1963, 1966, 1967, 1969), Turala (1970). Rorippa; Javurková-Kratochrilová and Tomšovic (1972).

4.3 Verification of taxonomy

Where the taxonomy of groups was difficult or uncertain, confirmation of published names has been obtained from the following:

Phormidium and *Tolypothrix* (E. Kann)

Rhodoplax (D. Backhaus and E. Kann)

Cladophora (C. van den Hoek)

Enteromorpha (E. M. Burrows and M. Wilkinson)

lichens (J. F. Skinner)

bryophytes (G. G. Graham)

Potamogeton (J. E. Dandy)

Ranunculus (C. D. K. Cook)

addresses:

D. Backhaus, Landestelle für Gewasserkunde und Wasserwirtschaftliche Planung, Baden-Wurtemburg, 75 Karlsruhe, Germany.

E. M. Burrows, Department of Botany, University of Liverpool, P.O. Box 147, L69 3BX.

C. D. K. Cook, Der Universität Zürich, 8039 Zürich, Pelikanstraße 40, Switzerland.

J. E. Dandy, British Museum (Natural History), Tring, Hertfordshire.

G. G. Graham, The Vicarage, Hunswick, Bishop Auckland, Co. Durham.

E. Kann, 3293 Lunz a See, Biologische Station, Austria.

J. F. Skinner, Southend Central Museum, Southend-on-Sea, Essex.

C. van den Hoek, Riejks Herbarium, Leiden, The Netherlands.

M. Wilkinson, Department of Brewing and Biological Sciences, Heriot-Watt University, Chambers Street, Edinburgh EH1 1HX.

Voucher specimens of all *Potamogeton* and *Ranunculus* species, as well as many others found in the Tweed Basin have been deposited in herbariums at the Botany Departments of Durham and St. Andrews Universities, and also the British Museum (Natural History).

5. CHEMISTRY OF THE TWEED BASIN

5.1 Introduction

The primary survey to determine the water chemistry of the Tweed and its tributaries involved the collection of samples on five separate occasions (see 2.1). It was not possible to carry out separate surveys to determine the variable characteristics of the water during high, medium and low flows. Since the chemistry of low flows were regarded as biologically more meaningful than high flows, sampling was attempted only during below average flows. It was realised however, that during periods of high flow for instance, the chemistry of the water would most probably be very different (see 1.4, p. 11).

Table 5.1a tabulates the mean flow of 12 gauging stations on the days samples were collected. Six are from the Tweed, and six from tributaries. The stations selected all have hydrological data for a minimum period of 10 years, (see 3.61 for particulars of each station). By use of flow frequency diagrams, (supplied by the Tweed River Purification Board) the flows on the day of sampling were related to long term values. The lower figure in Table 5.1a expresses as a percentage the number of days in the 10 year period 1960 - 1970, or 1961 - 1971, when flows were higher than they were on the days of sampling, e.g. Kingledors, where levels on 8.XI.72 were low, and at levels only experienced less than one in every 100 days during the period 1961 - 1971.

With reference to Table 5.1a it can be observed that at all gauging stations, the only date when levels were below 50% was on 30.I.72. For the purpose of calculating mean element values, the data collected on that day have not been considered.

The primary chemical data for the five main surveys are tabulated element by element in 5.21, and the mean data from the four lowest flows

gauging station	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Kingledors	.89	.66	2.46	89	1.96
	95 %	100 %	42 %	95 %	53 %
Tweed Lyne Ford	2.30	1.47	7.57	3.10	5.35
	96 %	100 %	38 %	87 %	52 %
Tweed Peebles	3.65	2.65	13.43	5.05	9.53
	98 %	100 %	38 %	88 %	56 %
Tweed Boleside	8.82	5.64	33.18	9.38	25.58
	94 %	99 %	36 %	92 %	53 %
Tweed Dryburgh	11.17	7.88	36.18	11.58	29.96
	93 %	98 %	45 %	92 %	54 %
Tweed Norham	18.32	11.18	54.96	18.97	47.04
	92 %	100 %	54 %	92 %	60 %
LYNE STATION	0.75	0.65	2.56	1.09	2.03
	98 %	99 %	37 %	86 %	52 %
ETTRICK LINDEAN	3.49	2.42	13.15	2.79	7.30
	87 %	95 %	35 %	92 %	61 %
TEVIOT HAWICK	1.32	0.96	7.22	1.74	4.94
	96 %	99 %	36 %	94 %	54 %
TEVIOT ORMISTON MILL	3.24	2.49	13.27	4.13	11.77
	97 %	99 %	48 %	92 %	55 %
JED JEDBURGH	0.45	0.38	1.12	0.45	0.74
	97 %	100 %	58 %	96 %	79 %
TILL ETAL					
	94 %	93 %	74 %	99 %	46 %
WHITEADDER BLANERNE	0.81	1.20	1.53	0.60	2.52
	96 %	85 %	78 %	100 %	60 %

Table 5.1a Actual flow values ($m^3 s^{-1}$) on days chemical samples collected, in relation to long term flow values (see text, p.93)

summarized in 5.22. The mean values of each element from all sites in the Tweed are plotted in 5.23 to illustrate the changes that occur on passing downstream, and to show the relationship between one element and another. A short description of the water chemistry of the Tweed and its tributaries is given in 5.3 and 5.4. Mention is made only of features that are frequently referred to in the discussions on macrophyte distribution in Chapters 7, 8 and 9.

The data collected from an additional 20 sites on 22.V.73 are listed in 5.24. Gauging stations were not present on all tributaries surveyed; it can however be presumed that the flows were below average (see 5.1a which shows that all but one of the sites listed had below average flows on 22.V.73). Reference in the text is made only to approximately half the data, but the rest is included to indicate the range of water chemistry within the Tweed Basin.

Data collected from an additional 10 sites in the Tweed Basin over the three years of research are available at the Department of Botany, University of Durham. The analyses did not include PO_4-P, NH_4-N, NO_2-N and NO_3-N, and so are not included here for comparison. The cation analyses however, showed that the data furnished from the five main surveys were representative of water chemistry characteristics over the whole period of research. The sampling programme mentioned above was a part of a much larger survey carried out by the Botany Department to ascertain the comparative water chemistries of rivers and streams in the north east. Some of the data have been referred to in Chapter 1.

5.2 Chemical data

5.21 Primary data from five surveys

OPTICAL DENSITY$_{420\ nm}$

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	0.013	0.014	0.018	0.002	0.031
Tweed Tweedsmuir	0.013	0.008	0.009	0.002	0.009
Tweed Kingledors	0.013	0.006	0.010	0.001	0.005
Tweed Dawych Bridge	0.011	0.007	0.004	0.001	0.003
Tweed Lyne Ford	0.015	0.003	0.008	0.000	0.004
LYNE WATER FOOT	0.013	0.001	0 006	0.001	0.015
Tweed Manor Foot	0.029	0.006	0.007	0.001	0.005
MANOR WATER FOOT	0.024	0.004	0.006	0.000	0.000
EDDLESTON WATER FOOT	0.010	0.002	0.010	0.007	0.021
Tweed Peebles gauge	0.024	0.004	0.005	0.000	0.010
Tweed Peebles dump	0.025	0.008	0.007	0.015	0.012
Tweed Horsburgh Ford	0.042	0.002	0.005	0.003	0.015
Tweed Traquair Bridge	0.016	0.006	0.006	0.001	0.015
Tweed Walkerburn Bridge	0.010	0.008	0.007	0.005	0.003
Tweed Juniper Bank	0.014	0.005	0.006	0.006	0.005
Tweed Peel Hospital	0.033	0.005	0.008	0.002	0.006
Tweed Yair Bridge	0.012	0.005	0.003	0.001	0.003
Tweed Tweed Bridge	0.022	0.005	0.004	0.007	0.001
MEGGET WATER FOOT	0.011	0.002	0.005	0.006	0.021
YARROW WATER	0.020	0.005	0.006	0.003	0.004
ETTRICK WATER FOOT	0.013	0.007	0.005	0.018	0.011
Tweed Gala Ford	0.011	0.007	0.003	0.006	0.010
GALA WATER FOOT	0.018	0.003	0.005	0.000	0.012
Tweed Lowood Bridge	0.023	0.005	0.004	0.003	0.011
Tweed Gattonside Bridge	0.014	0.007	0.004	0.009	0.009
Tweed Leader Bridge	0.040	0.010	0.004	0.009	0.008
LEADER WATER FOOT	0.014	0.002	0.006	0.008	0.011
Tweed Dryburgh Abbey	0.033	0.008	0.004	0.009	0.012
Tweed Mourton Bridge	0.014	0.002	0.004	0.010	0.007
Tweed Rutherford Lodge	0.018	0.004	0.004	0.018	0.008
TEVIOT HAWICK	0.016	0.005	0.003	0.005	0.009
ALE WATER FOOT	0.018	0.008	0.006	0.007	0.013
TEVIOT ANCRUM	0.021	0.005	0.006	0.007	0.009
JED WATER FOOT	0.028	0.010	0.008	0.015	0.009
TEVIOT FOOT	0.017	0.010	0.005	0.005	0.007
Tweed Kelso Bridge	0.012	0.005	0.006	0.007	0.011
Tweed Sprouston Bridge	0.021	0.008	0.005	0.010	0.008
EDEN WATER FOOT	0.019	0.016	0.014	0.012	0.016
Tweed below Birgham	0.015	0.005	0.005	0.009	0.010
LAMBDEN BURN SPRINGWELLS	0.032	0.016	0.006	0.009	0.024
LEET WATER FOOT	0.031	0.009	0.010	0.010	0.030
Tweed Coldstream	0.016	0.005	0.005	0.010	0.015
TILL WATER FOOT	0.018	0.006	0.006	0.015	0.081
Tweed Norham Bridge	0.022	0.006	0.004	0.010	0.034
Tweed Fishwick Mains	0.020	0.006	0.005	0.010	0.038
Tweed Union Bridge	0.020	0.006	0.005	0.010	0.050
WHITEADDER CHURNSIDE	0.023	0.005	0.005	0.014	0.023
BLACKADDER FOOT	0.019	0.006	0.013	0.010	0.019
WHITEADDER FOOT	0.028	0.004	0.004	0.013	0.017

pH

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	7.6	7.3	6.9	7.7	7.1
Tweed Tweedsmuir	7.5	7.0	6.9	7.7	6.9
Tweed Kingledors	7.5	7.0	7.0	7.7	7.0
Tweed Dawych Bridge	7.3	7.0	6.8	7.6	6.9
Tweed Lyne Ford	7.6	7.1	6.7	7.6	7.1
LYNE WATER FOOT	7.8	7.8	6.8	8.2	7.1
Tweed Manor Foot	7.6	7.5	6.7	8.2	7.1
MANOR WATER FOOT	7.6	7.4	6.8	7.9	7.1
EDDLESTON WATER FOOT	8.3	7.4	6.7	7.7	6.4
Tweed Peebles gauge	7.9	7.6	6.8	7.4	7.2
Tweed Peebles dump	7.6	7.3	6.9	7.2	7.2
Tweed Horsburgh Ford	7.8	7.7	6.9	7.4	7.2
Tweed Traquair Bridge	8.0	7.8	6.7	7.5	7.4
Tweed Walkerburn Bridge	7.9	7.6	6.8	7.5	7.1
Tweed Juniper Bank	7.6	7.6	6.8	7.5	7.2
Tweed Peel Hospital	7.8	7.6	6.8	7.4	6.8
Tweed Yair Bridge	7.5	7.4	6.7	7.5	7.0
Tweed Tweed Bridge	7.4	7.4	6.8	7.4	7.0
MEGGET WATER FOOT	7.3	7.0	6.7	7.4	6.8
YARROW WATER	7.2	7.3	6.7	7.2	7.0
ETTRICK WATER FOOT	7.5	7.3	6.9	7.4	7.3
Tweed Gala Ford	7.4	7.4	6.7	7.1	7.0
GALA WATER FOOT	7.3	7.5	6.8	7.4	7.3
Tweed Lowood Bridge	7.7	7.4	6.9	7.5	7.5
Tweed Gattonside Bridge	7.5	7.4	6.9	7.7	7.4
Tweed Leader Bridge	7.9	7.6	7.0	7.7	7.2
LEADER WATER FOOT	8.5	7.7	7.1	7.7	7.6
Tweed Dryburgh Abbey	7.0	7.3	7.2	7.7	7.6
Tweed Mourton Bridge	7.6	7.5	7.2	7.7	7.3
Tweed Rutherford Lodge	8.0	7.6	7.1	7.7	7.5
TEVIOT HAWICK	8.2	7.8	7.2	8.1	7.9
ALE WATER FOOT	8.1	7.9	7.5	8.4	7.9
TEVIOT ANCRUM	8.2	7.9	7.7	8.3	7.9
JED WATER FOOT	8.2	7.8	7.5	8.4	8.2
TEVIOT FOOT	8.3	7.9	7.4	8.4	8.0
Tweed Kelso Bridge	8.0	7.8	7.4	8.1	7.9
Tweed Sprouston Bridge	8.2	7.9	7.2	8.2	8.0
EDEN WATER FOOT	8.3	7.9	7.6	8.2	8.2
Tweed below Birgham	8.3	7.9	7.2	8.2	8.0
LAMBDEN BURN SPRINGWELLS	8.2	7.9	7.8	8.5	7.6
LEET WATER FOOT	8.1	7.6	7.3	8.2	8.0
Tweed Coldstream	8.5	8.0	7.3	8.3	7.9
TILL WATER FOOT	8.2	7.9	7.4	8.5	7.9
Tweed Norham Bridge	8.5	7.9	7.3	8.7	7.8
Tweed Fishwick Mains	9.2	7.8	7.0	8.4	7.5
Tweed Union Bridge	8.2	7.5	6.9	8.7	7.5
WHITEADDER CHURNSIDE	8.5	8.1	7.3	8.5	7.5
BLACKADDER FOOT	9.0	8.1	7.3	8.4	8.0
WHITEADDER FOOT	9.0	8.2	7.4	7.7	7.5

CONDUCTIVITY
micro-mhos

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	125	125	85	110	90
Tweed Tweedsmuir	125	100	95	100	95
Tweed Kingledors	100	105	95	95	85
Tweed Dawych Bridge	125	120	105	115	105
Tweed Lyne Ford	130	130	105	115	105
LYNE WATER FOOT	225	200	175	175	80
Tweed Manor Foot	140	150	120	135	120
MANOR WATER FOOT	105	100	80	80	75
EDDLESTON WATER FOOT	175	175	130	140	125
Tweed Peebles gauge	120	145	115	150	115
Tweed Peebles dump	150	120	120	150	120
Tweed Horsburgh Ford	150	140	120	150	125
Tweed Traquair Bridge	130	145	115	135	125
Tweed Walkerburn Bridge	145	150	90	140	120
Tweed Juniper Bank	115	145	115	135	125
Tweed Peel Hospital	120	145	115	140	120
Tweed Yair Bridge	145	145	115	140	120
Tweed Tweed Bridge	150	150	135	85	120
MEGGET WATER FOOT	55	60	45	55	45
YARROW WATER	100	80	70	90	80
ETTRICK WATER FOOT	100	135	100	120	110
Tweed Gala Ford	130	135	120	150	125
GALA WATER FOOT	175	175	135	150	140
Tweed Lowood Bridge	150	145	120	145	135
Tweed Gattonside Bridge	125	140	110	145	125
Tweed Leader Bridge	125	175	110	135	125
LEADER WATER FOOT	300	225	175	200	175
Tweed Dryburgh Abbey	175	150	120	150	140
Tweed Mourton Bridge	135	170	110	145	130
Tweed Rutherford Lodge	140	170	120	150	130
TEVIOT HAWICK	200	250	200	225	200
ALE WATER FOOT	300	275	225	250	225
TEVIOT ANCRUM	275	275	200	250	225
JED WATER FOOT	350	425	140	350	325
TEVIOT FOOT	300	325	130	250	250
Tweed Kelso Bridge	145	200	105	150	130
Tweed Sprouston Bridge	175	210	150	175	175
EDEN WATER FOOT	350	350	300	325	325
Tweed below Birgham	175	200	140	175	175
LAMBDEN BURN SPRINGWELLS	450	450	425	400	400
LEET WATER FOOT	200	300	350	350	550
Tweed Coldstream	200	225	150	200	175
TILL WATER FOOT	250	275	190	250	135
Tweed Norham Bridge	200	225	150	200	175
Tweed Fishwick Mains	175	250	150	200	175
Tweed Union Bridge	185	250	150	200	175
WHITEADDER CHURNSIDE	250	225	175	225	175
BLACKADDER FOOT	450	425	300	375	275
WHITEADDER FOOT	300	325	175	350	250

SODIUM mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	5.3	5.5	5.2	5.7	5.9
Tweed Tweedsmuir	5.0	4.9	5.1	5.0	5.0
Tweed Kingledors	4.6	4.9	5.0	4.9	4.6
Tweed Dawych Bridge	6.3	6.1	5.7	6.3	5.8
Tweed Lyne Ford	6.7	6.4	6.0	6.4	5.8
LYNE WATER FOOT	9.1	8.6	7.7	8.2	7.7
Tweed Manor Foot	7.3	7.3	6.2	6.7	6.3
MANOR WATER FOOT	5.5	5.6	4.5	4.9	4.3
EDDLESTON WATER FOOT	9.0	8.6	7.3	7.6	7.3
Tweed Peebles gauge	7.2	7.4	6.5	7.0	6.7
Tweed Peebles dump	8.1	10.1	6.9	8.5	7.6
Tweed Horsburgh Ford	7.4	8.0	6.5	7.3	6.4
Tweed Traquair Bridge	7.3	7.2	6.5	7.2	6.9
Tweed Walkerburn Bridge	7.3	7.6	6.4	6.8	6.4
Tweed Juniper Bank	7.6	8.9	6.7	7.5	6.4
Tweed Peel Hospital	7.5	8.5	6.6	7.3	6.4
Tweed Yair Bridge	7.2	8.5	6.3	7.1	6.9
Tweed Tweed Bridge	7.3	8.6	6.2	7.4	6.1
MEGGET WATER FOOT	4.0	4.1	3.4	3.9	3.1
YARROW WATER	4.5	4.9	4.2	4.5	3.7
ETTRICK WATER FOOT	5.1	9.4	5.7	9.1	5.8
Tweed Gala Ford	6.6	8.6	5.7	7.5	6.6
GALA WATER FOOT	9.4	9.6	7.7	8.3	8.9
Tweed Lowood Bridge	8.4	10.1	7.2	10.0	7.0
Tweed Gattonside Bridge	7.5	9.7	6.7	8.5	7.0
Tweed Leader Bridge	6.8	9.0	6.8	8.5	8.0
LEADER WATER FOOT	10.8	11.7	9.0	10.5	10.7
Tweed Dryburgh Abbey	7.1	11.4	7.2	10.1	11.3
Tweed Mourton Bridge	7.4	12.0	6.7	9.7	7.0
Tweed Rutherford Lodge	7.2	11.2	6.9	10.2	9.0
TEVIOT HAWICK	6.5	8.0	9.9	5.9	4.8
ALE WATER FOOT	7.7	8.0	5.8	7.1	6.6
TEVIOT ANCRUM	9.7	11.0	6.3	9.7	6.3
JED WATER FOOT	18.2	25.4	12.3	23.9	21.0
TEVIOT FOOT	10.0	15.5	7.5	10.0	8.2
Tweed Kelso Bridge	7.4	11.7	6.8	9.1	6.9
Tweed Sprouston Bridge	8.6	11.0	7.2	9.3	8.1
EDEN WATER FOOT	12.5	12.0	10.8	11.8	11.3
Tweed below Birgham	8.2	10.5	7.0	9.8	7.4
LAMBDEN BURN SPRINGWELLS	20.0	18.4	17.1	19.0	15.5
LEET WATER FOOT	10.9	13.4	14.4	14.6	21.0
Tweed Coldstream	8.3	11.0	7.1	10.3	7.7
TILL WATER FOOT	12.0	13.6	10.4	12.1	10.1
Tweed Norham Bridge	8.8	11.6	7.3	9.4	9.0
Tweed Fishwick Mains	8.2	11.4	7.2	9.7	7.5
Tweed Union Bridge	8.5	11.6	6.9	9.9	9.0
WHITEADDER CHURNSIDE	10.4	10.2	9.8	12.3	9.8
BLACKADDER FOOT	15.0	12.8	10.9	12.5	9.3
WHITEADDER FOOT	11.5	13.6	10.8	13.4	12.0

POTASSIUM mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	0.58	0.56	0.37	0.59	0.34
Tweed Tweedsmuir	0.55	0.54	0.36	0.53	0.31
Tweed Kingledors	0.45	0.54	0.33	0.46	0.30
Tweed Dawych Bridge	0.81	0.73	0.46	0.79	0.58
Tweed Lyne Ford	0.88	0.81	0.52	0.82	0.64
LYNE WATER FOOT	1.24	1.08	0.75	0.95	0.80
Tweed Manor Foot	1.01	1.00	0.65	0.84	0.62
MANOR WATER FOOT	0.75	0.82	0.45	0.62	0.37
EDDLESTON WATER FOOT	1.35	1.24	0.91	1.11	0.93
Tweed Peebles gauge	1.02	1.16	0.71	0.94	0.69
Tweed Peebles dump	1.71	1.93	0.78	1.34	0.94
Tweed Horsburgh Ford	1.10	1.31	0.73	0.99	0.91
Tweed Traquair Bridge	1.04	0.98	0.75	0.92	0.66
Tweed Walkerburn Bridge	0.95	1.12	0.73	0.88	0.64
Tweed Juniper Bank	1.17	1.30	0.76	0.93	0.65
Tweed Peel Hospital	1.08	1.35	0.75	0.96	0.65
Tweed Yair Bridge	0.94	1.18	0.62	0.95	0.64
Tweed Tweed Bridge	0.98	1.13	0.56	1.06	0.66
MEGGET WATER FOOT	0.35	0.44	0.31	0.38	0.23
YARROW WATER	0.67	0.62	0.48	0.52	0.38
ETTRICK WATER FOOT	0.90	1.08	0.57	0.95	0.67
Tweed Gala Ford	0.95	1.07	0.58	1.01	0.66
GALA WATER FOOT	1.35	1.15	0.83	0.97	0.73
Tweed Lowood Bridge	1.66	1.25	0.75	1.56	0.81
Tweed Gattonside Bridge	1.28	1.12	0.72	1.27	0.67
Tweed Leader Bridge	0.53	1.00	0.69	1.19	0.66
LEADER WATER FOOT	0.99	1.34	0.77	1.48	0.99
Tweed Dryburgh Abbey	0.65	1.52	0.91	1.25	1.02
Tweed Mourton Bridge	0.83	1.72	0.86	1.24	0.66
Tweed Rutherford Lodge	0.65	1.58	0.89	1.27	0.73
TEVIOT HAWICK	0.94	0.98	0.78	0.86	0.50
ALE WATER FOOT	1.43	1.68	0.61	1.14	0.77
TEVIOT ANCRUM	2.69	1.82	0.67	1.35	0.76
JED WATER FOOT	2.68	5.00	1.63	3.10	1.73
TEVIOT FOOT	1.10	2.22	1.10	1.41	0.99
Tweed Kelso Bridge	0.77	1.80	0.97	1.21	0.76
Tweed Sprouston Bridge	1.00	1.78	1.09	1.25	0.84
EDEN WATER FOOT	1.70	2.52	2.40	2.20	2.00
Tweed below Birgham	1.03	1.98	1.11	1.66	1.02
LAMBDEN BURN SPRINGWELLS	4.74	5.24	5.80	5.00	7.20
LEET WATER FOOT	1.75	2.68	3.40	3.00	7.80
Tweed Coldstream	1.10	1.94	1.16	1.75	1.40
TILL WATER FOOT	1.68	2.40	1.78	2.10	1.40
Tweed Norham Bridge	1.29	2.08	1.15	1.41	0.98
Tweed Fishwick Mains	0.86	2.04	1.15	1.41	1.09
Tweed Union Bridge	1.22	2.12	1.10	1.42	1.30
WHITEADDER CHURNSIDE	1.37	1.78	1.63	1.84	1.11
BLACKADDER FOOT	2.13	3.08	2.45	2.30	1.40
WHITEADDER FOOT	1.47	2.48	1.74	2.10	1.37

MAGNESIUM mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	5.0	5.2	3.4	5.1	3.8
Tweed Tweedsmuir	4.2	4.4	3.4	4.2	4.2
Tweed Kingledors	3.5	4.1	3.1	4.0	3.5
Tweed Dawych Bridge	4.1	4.2	3.7	4.6	4.2
Tweed Lyne Ford	4.3	4.5	3.8	4.6	4.2
LYNE WATER FOOT	8.6	8.2	5.8	7.8	6.7
Tweed Manor Foot	5.4	5.8	4.1	5.3	5.0
MANOR WATER FOOT	3.4	3.7	2.9	3.4	3.0
EDDLESTON WATER FOOT	6.4	6.2	5.0	5.9	5.1
Tweed Peebles gauge	5.3	5.5	4.2	5.4	5.0
Tweed Peebles dump	5.2	5.4	4.2	5.1	4.7
Tweed Horsburgh Ford	5.1	5.3	4.2	4.7	4.7
Tweed Traquair Bridge	5.0	5.2	4.1	4.8	4.6
Tweed Walkerburn Bridge	5.1	5.3	4.2	4.9	4.6
Tweed Juniper Bank	5.1	5.4	4.3	4.7	4.7
Tweed Peel Hospital	5.1	5.4	4.2	4.7	4.7
Tweed Yair Bridge	5.0	5.5	4.1	4.5	4.7
Tweed Tweed Bridge	5.4	5.8	4.0	5.4	4.9
MEGGET WATER FOOT	1.8	2.3	1.7	2.0	1.8
YARROW WATER	3.6	3.8	2.9	3.2	3.3
ETTRICK WATER FOOT	3.9	4.7	3.4	4.4	4.2
Tweed Gala Ford	4.7	5.1	4.0	5.1	4.5
GALA WATER FOOT	7.5	7.3	5.0	6.4	5.7
Tweed Lowood Bridge	5.0	5.5	4.2	5.3	4.9
Tweed Gattonside Bridge	4.8	5.7	4.0	5.5	4.7
Tweed Leader Bridge	5.0	5.8	3.9	5.4	4.9
LEADER WATER FOOT	11.2	11.1	7.2	10.0	8.5
Tweed Dryburgh Abbey	5.3	6.2	4.4	5.9	5.9
Tweed Mourton Bridge	5.4	5 5	4.2	5.8	5.2
Tweed Rutherford Lodge	5.4	6.2	4.2	6.0	5.2
TEVIOT HAWICK	9.3	8.9	6.5	9.1	7.9
ALE WATER FOOT	10.6	11.4	7.1	10.0	8.0
TEVIOT ANCRUM	11.9	12.5	7.5	10.7	8.3
JED WATER FOOT	20.6	22.2	12.0	20.2	19.0
TEVIOT FOOT	12.9	16.0	8.0	12.4	11.2
Tweed Kelso Bridge	6.4	8.2	4.3	5.9	5.6
Tweed Sprouston Bridge	7.5	9.7	6.2	8.1	7.4
EDEN WATER FOOT	20.4	21.5	18.1	22.0	20.0
Tweed below Birgham	7.5	9.7	5.5	8.3	7.3
LAMBDEN BURN SPRINGWELLS	26.1	27.4	25.1	26.9	22.6
LEET WATER FOOT	8.5	11.8	13.6	14.8	22.0
Tweed Coldstream	7.4	9.2	5.5	8.2	8.0
TILL WATER FOOT	10.3	12.2	7.8	10.4	5.2
Tweed Norham Bridge	7.5	9.9	5.6	8.3	6.8
Tweed Fishwick Mains	6.7	10.0	5.7	8.6	7.0
Tweed Union Bridge	7.3	10.0	5.7	8.4	7.0
WHITEADDER CHURNSIDE	11.6	12.6	9.0	12.7	9.0
BLACKADDER FOOT	23.9	26.6	18.3	23.9	18.9
WHITEADDER FOOT	16.0	18.7	11.9	17.1	12.8

CALCIUM mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	15.8	15.4	10.1	15.9	11.1
Tweed Tweedsmuir	14.5	14.0	11.6	15.0	14.5
Tweed Kingledors	13.1	14.4	11.3	14.8	13.3
Tweed Dawych Bridge	15.0	14.8	13.2	16.3	14.0
Tweed Lyne Ford	15.4	15.7	13.5	16.3	14.6
LYNE WATER FOOT	33.0	32.3	22.8	31.1	26.1
Tweed Manor Foot	19.6	21.4	14.8	19.6	17.8
MANOR WATER FOOT	12.5	13.3	10.8	12.8	10.8
EDDLESTON WATER FOOT	18.7	18.6	15.6	18.6	15.5
Tweed Peebles gauge	19.0	18.6	15.2	18.7	16.3
Tweed Peebles dump	19.3	19.7	14.8	19.1	16.4
Tweed Horsburgh Ford	18.5	19.0	15.2	19.1	16.2
Tweed Traquair Bridge	18.2	18.7	14.5	18.9	15.9
Tweed Walkerburn Bridge	18.8	19.1	14.3	18.2	15.8
Tweed Juniper Bank	18.9	18.9	14.2	18.1	16.0
Tweed Peel Hospital	17.6	19.0	14.3	18.5	16.2
Tweed Yair Bridge	17.6	19.0	14.0	18.5	16.1
Tweed Tweed Bridge	18.5	19.5	14.2	18.4	16.0
MEGGET WATER FOOT	5.7	6.2	4.1	5.6	4.2
YARROW WATER	11.9	10.8	8.5	10.1	8.8
ETTRICK WATER FOOT	12.4	15.0	10.0	14.7	13.9
Tweed Gala Ford	16.4	17.0	15.1	17.5	15.7
GALA WATER FOOT	21.5	21.0	14.7	18.7	16.2
Tweed Lowood Bridge	16.6	17.8	13.8	18.0	16.2
Tweed Gattonside Bridge	16.1	19.0	14.2	19.6	16.3
Tweed Leader Bridge	16.4	15.4	12.9	18.0	16.3
LEADER WATER FOOT	31.0	31.4	21.3	28.6	23.9
Tweed Dryburgh Abbey	16.5	19.3	15.1	20.3	20.3
Tweed Mourton Bridge	17.5	18.1	14.0	19.2	16.9
Tweed Rutherford Lodge	17.4	19.5	14.0	19.7	17.1
TEVIOT HAWICK	32.0	40.8	34.0	41.8	36.7
ALE WATER FOOT	45.1	49.5	39.4	45.5	42.3
TEVIOT ANCRUM	45.4	48.5	40.1	45.6	38.8
JED WATER FOOT	42.8	48.9	30.5	41.8	38.8
TEVIOT FOOT	40.8	46.8	34.2	42.4	41.0
Tweed Kelso Bridge	20.1	25.3	14.6	18.6	17.2
Tweed Sprouston Bridge	24.1	29.4	22.4	26.2	25.8
EDEN WATER FOOT	46.5	47.4	44.0	48.4	49.0
Tweed below Birgham	23.4	29.2	20.5	25.9	26.2
LAMBDEN BURN SPRINGWELLS	55.3	54.9	55.1	54.5	50.9
LEET WATER FOOT	27.8	40.3	56.7	55.0	93.0
Tweed Coldstream	24.1	28.6	20.0	27.0	27.6
TILL WATER FOOT	32.0	36.8	24.6	33.3	14.9
Tweed Norham Bridge	24.4	31.0	20.0	26.5	21.7
Tweed Fishwick Mains	21.6	31.2	20.1	27.6	22.0
Tweed Union Bridge	23.8	30.5	19.8	27.7	22.5
WHITEADDER CHURNSIDE	25.0	27.3	21.0	27.7	19.1
BLACKADDER FOOT	49.5	57.0	42.8	52.1	39.3
WHITEADDER FOOT	36.1	44.0	31.0	40.3	28.9

ZINC det. limit 0.002 mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	0.003	all except one below det. limit	<0.002	Zn contamination of samples	0.008
Tweed Tweedsmuir	<0.002		<0.002		0.007
Tweed Kingledors	0.003		<0.002		0.006
Tweed Dawych Bridge	<0.002		<0.002		0.009
Tweed Lyne Ford	0.002		<0.002		0.005
LYNE WATER FOOT	0.004		0.005		0.006
Tweed Manor Foot	0.010		<0.002		0.003
MANOR WATER FOOT	0.003		0.005		0.002
EDDLESTON WATER FOOT	0.002		<0.002		0.008
Tweed Peebles gauge	0.004		<0.002		0.008
Tweed Peebles dump	0.002		<0.002		0.003
Tweed Horsburgh Ford	<0.002		<0.002		0.002
Tweed Traquair Bridge	0.002		<0.002		0.005
Tweed Walkerburn Bridge	0.008		<0.002		0.004
Tweed Juniper Bank	<0.002		<0.002		0.004
Tweed Peel Hospital	0.008		<0.002		0.007
Tweed Yair Bridge	0.006		<0.002		0.006
Tweed Tweed Bridge	0.002		0.005		0.006
MEGGET WATER FOOT	<0.002		0.004		0.006
YARROW WATER	0.007		<0.002		0.004
ETTRICK WATER FOOT	<0.002		0.003		0.014
Tweed Gala Ford	0.007		0.013		0.014
GALA WATER FOOT	0.007		0.011		0.011
Tweed Lowood Bridge	0.008		0.018		0.008
Tweed Gattonside Bridge	0.005		0.006		0.013
Tweed Leader Bridge	0.008		0.003		0.016
LEADER WATER FOOT	0.010		0.014		0.033
Tweed Dryburgh Abbey	0.002		<0.002		0.012
Tweed Mourton Bridge	0.006		0.003		0.008
Tweed Rutherford Lodge	<0.002		0.002		0.009
TEVIOT HAWICK	0.004	0.002	0.042		0.005
ALE WATER FOOT	0.007		0.006		0.007
TEVIOT ANCRUM	<0.002		0.006		0.002
JED WATER FOOT	<0.002		<0.002		0.006
TEVIOT FOOT	0.007		0.005		0.012
Tweed Kelso Bridge	<0.002		0.002		0.010
Tweed Sprouston Bridge	<0.002		<0.002		0.005
EDEN WATER FOOT	<0.002		<0.002		0.009
Tweed below Birgham	0.007		<0.002		0.006
LAMBDEN BURN SPRINGWELLS	0.005		<0.002		0.016
LEET WATER FOOT	0.009		<0.002		0.007
Tweed Coldstream	0.006		<0.002		0.003
TILL WATER FOOT	0.005		<0.002		0.046
Tweed Norham Bridge	0.003		0.003		0.015
Tweed Fishwick Mains	0.004		<0.002		0.011
Tweed Union Bridge	0.006		<0.002		0.016
WHITEADDER CHURNSIDE	0.011		0.003		0.011
BLACKADDER FOOT	0.005		0.003		0.002
WHITEADDER FOOT	0.006		0.003		0.007

COPPER det. limit 0.002 mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	<0.002	0.014	<0.002		<0.002
Tweed Tweedsmuir	<0.002	0.011	0.010		<0.002
Tweed Kingledors	<0.002	0.018	0.002		0.011
Tweed Dawych Bridge	<0.002	0.005	0.012		0.012
Tweed Lyne Ford	<0.002	0.013	<0.002		0.007
LYNE WATER FOOT	0.009	0.011	<0.002		0.010
Tweed Manor Foot	0.004	0.007	<0.002		<0.002
MANOR WATER FOOT	0.009	0.004	<0.002		<0.00
EDDLESTON WATER FOOT	0.004	0.006	0.004		0.005
Tweed Peebles gauge	<0.002	0.007	<0.002		0.007
Tweed Peebles dump	<0.002	0.008	<0.002		0.005
Tweed Horsburgh Ford	0.004	0.008	<0.002		0.007
Tweed Traquair Bridge	0.002	0.005	<0.002		<0.002
Tweed Walkerburn Bridge	<0.002	0.004	<0.002		<0.002
Tweed Juniper Bank	<0.002	0.009	<0.002		0.007
Tweed Peel Hospital	<0.002	0.008	<0.002		0.010
Tweed Yair Bridge	0.004	0.009	<0.002		0.002
Tweed Tweed Bridge	0.004	0.007	<0.002		<0.002
MEGGET WATER FOOT	<0.002	0.010	<0.002		<0.002
YARROW WATER	0.004	0.008	<0.002		<0.002
ETTRICK WATER FOOT	0.004	0.009	0.018		0.026
Tweed Gala Ford	0.012	0.014	0.004		0.005
GALA WATER FOOT	0.010	0.011	0.010		<0.002
Tweed Lowood Bridge	0.009	0.022	0.006		0.005
Tweed Gattonside Bridge	0.002	0.021	0.018		0.010
Tweed Leader Bridge	0.010	0.019	0.005		0.012
LEADER WATER FOOT	0.010	0.018	0.005		0.013
Tweed Dryburgh Abbey	0.015	0.021	0.007		0.012
Tweed Mourton Bridge	0.010	0.020	0.010		0.011
Tweed Rutherford Lodge	0.004	0.018	0.008		0.010
TEVIOT HAWICK	0.008	0.010	0.012		0.010
ALE WATER FOOT	0.012	0.007	0.007		<0.002
TEVIOT ANCRUM	0.012	0.007	<0.002		0.002
JED WATER FOOT	0.007	0.009	0.006		0.007
TEVIOT FOOT	0.015	0.006	0.003		0.006
Tweed Kelso Bridge	0.002	0.012	0.008		0.012
Tweed Sprouston Bridge	0.015	0.011	<0.002		0.011
EDEN WATER FOOT	0.004	0.009	<0.002		0.008
Tweed below Birgham	0.015	0.009	0.004		0.002
LAMBDEN BURN SPRINGWELLS	0.014	0.009	0.002		<0.002
LEET WATER FOOT	0.022	0.016	<0.002		0.011
Tweed Coldstream	0.010	0.010	0.002		0.007
TILL WATER FOOT	0.009	0.017	<0.002		0.012
Tweed Norham Bridge	0.007	0.023	<0.002		0.005
Tweed Fishwick Mains	0.004	0.019	0.006		0.002
Tweed Union Bridge	0.007	0.019	<0.002		0.011
WHITEADDER CHURNSIDE	0.002	0.009	0.006		0.005
BLACKADDER FOOT	0.007	0.009	<0.002		0.006
WHITEADDER FOOT	0.010	0.012	<0.002		0.003

Cu contamination of samples

MANGANESE det.limit 0.002 mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	0.010	0.004	0.010	0.008	0.015
Tweed Tweedsmuir	0.010	0.006	0.007	0.009	0.005
Tweed Kingledors	0.011	<0.002	<0.002	<0.002	0.002
Tweed Dawych Bridge	0.006	0.002	0.002	0.008	0.007
Tweed Lyne Ford	0.004	<0.002	0.006	0.008	<0.002
LYNE WATER FOOT	0.010	<0.002	0.014	0.013	0.007
Tweed Manor Foot	0.011	<0.002	<0.002	0.005	<0.002
MANOR WATER FOOT	0.008	<0.002	0.004	0.009	0.003
EDDLESTON WATER FOOT	0.013	<0.002	0.025	0.013	0.014
Tweed Peebles gauge	0.013	0.003	0.002	0.012	0.004
Tweed Peebles dump	0.013	0.002	<0.002	0.008	0.009
Tweed Horsburgh Ford	0.010	0.004	0.010	0.006	0.004
Tweed Traquair Bridge	0.018	0.002	<0.002	0.005	0.007
Tweed Walkerburn Bridge	0.008	0.002	<0.002	<0.002	<0.002
Tweed Juniper Bank	0.018	<0.002	<0.002	0.009	0.008
Tweed Peel Hospital	0.010	<0.002	0.009	0.005	0.002
Tweed Yair Bridge	0.013	0.004	0.005	0.003	0.009
Tweed Tweed Bridge	0.011	0.018	0.007	<0.002	0.009
MEGGET WATER FOOT	0.011	<0.002	<0.002	0.002	0.004
YARROW WATER	0.013	<0.002	<0.002	0.002	0.003
ETTRICK WATER FOOT	0.010	<0.002	0.030	0.026	0.052
Tweed Gala Ford	0.010	0.002	<0.002	0.017	0.009
GALA WATER FOOT	0.013	0.006	<0.002	0.017	0.004
Tweed Lowood Bridge	0.012	0.009	<0.002	0.022	0.017
Tweed Gattonside Bridge	0.010	0.011	0.020	0.022	0.004
Tweed Leader Bridge	0.010	0.004	0.020	0.022	0.010
LEADER WATER FOOT	0.020	<0.002	0.011	0.097	0.013
Tweed Dryburgh Abbey	0.010	0.005	<0.002	0.024	0.058
Tweed Mourton Bridge	0.017	<0.002	<0.002	0.022	0.011
Tweed Rutherford Lodge	0.023	0.008	<0.002	0.014	0.010
TEVIOT HAWICK	0.012	0.022	0.005	0.009	0.012
ALE WATER FOOT	0.018	0.007	0.004	0.009	0.005
TEVIOT ANCRUM	0.018	0.002	0.005	<0.002	0.005
JED WATER FOOT	0.027	0.009	<0.002	0.004	0.007
TEVIOT FOOT	0.023	0.008	<0.002	0.013	0.005
Tweed Kelso Bridge	0.017	0.005	0.008	0.014	0.011
Tweed Sprouston Bridge	0.023	0.004	0.004	0.012	0.009
EDEN WATER FOOT	0.014	<0.002	0.006	0.028	0.016
Tweed below Birgham	0.016	<0.002	0.009	0.012	0.028
LAMBDEN BURN SPRINGWELLS	0.090	0.029	0.011	0.024	0.047
LEET WATER FOOT	0.021	0.012	0.021	0.035	0.031
Tweed Coldstream	0.017	0.007	0.011	0.021	0.023
TILL WATER FOOT	0.029	0.007	0.011	0.024	0.044
Tweed Norham Bridge	0.021	0.011	<0.002	0.014	0.017
Tweed Fishwick Mains	0.029	0.009	<0.002	0.027	0.011
Tweed Union Bridge	0.037	0.013	<0.002	0.018	0.035
WHITEADDER CHURNSIDE	0.027	0.007	<0.002	0.020	0.022
BLACKADDER FOOT	0.029	0.009	<0.002	0.024	0.010
WHITEADDER FOOT	0.040	0.011	0.023	0.041	0.024

IRON

det. limit 0.01 mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	0.04	0.07	0.09	<0.01	0.10
Tweed Tweedsmuir	0.11	0.14	0.06	0.02	0.04
Tweed Kingledors	0.13	0.10	0.07	<0.01	0.05
Tweed Dawych Bridge	0.09	0.05	0.06	0.06	0.07
Tweed Lyne Ford	0.07	0.03	0.03	0.04	0.07
LYNE WATER FOOT	0.12	0.04	0.01	0.06	0.15
Tweed Manor Foot	0.10	0.03	0.04	0.05	0.10
MANOR WATER FOOT	0.04	0.01	<0.01	<0.01	0.03
EDDLESTON WATER FOOT	0.11	0.05	0.11	0.07	0.19
Tweed Peebles gauge	0.08	0.04	0.07	0.05	0.14
Tweed Peebles dump	0.09	0.04	0.04	0.05	0.11
Tweed Horsburgh Ford	0.14	0.04	0.07	0.06	0.09
Tweed Traquair Bridge	0.08	0.02	0.06	0.05	0.06
Tweed Walkerburn Bridge	0.09	0.03	0.02	0.05	0.07
Tweed Juniper Bank	0.08	0.02	0.07	0.04	0.08
Tweed Peel Hospital	0.08	0.04	0.06	0.01	0.12
Tweed Yair Bridge	0.08	0.02	0.03	0.01	0.07
Tweed Tweed Bridge	0.05	0.03	0.01	0.02	0.07
MEGGET WATER FOOT	0.06	0.02	<0.01	<0.01	0.11
YARROW WATER	0.07	0.01	0.08	<0.01	0.04
ETTRICK WATER FOOT	0.05	0.05	0.05	0.01	0.06
Tweed Gala Ford	0.05	0.03	0.05	<0.01	0.04
GALA WATER FOOT	0.08	0.03	0.03	<0.01	0.06
Tweed Lowood Bridge	0.10	0.02	0.09	0.05	0.06
Tweed Gattonside Bridge	0.10	0.03	0.09	0.02	0.09
Tweed Leader Bridge	0.09	0.04	0.06	0.04	0.05
LEADER WATER FOOT	0.03	0.02	0.06	0.17	0.05
Tweed Dryburgh Abbey	0.08	0.02	0.04	0.02	0.14
Tweed Mourton Bridge	0.07	0.04	0.03	0.04	0.04
Tweed Rutherford Lodge	0.08	0.03	0.05	0.03	0.03
TEVIOT HAWICK	0.05	0.02	0.06	<0.01	0.06
ALE WATER FOOT	0.03	0.02	0.07	0.02	0.04
TEVIOT ANCRUM	0.06	0.03	0.09	<0.01	0.06
JED WATER FOOT	0.08	0.03	0.05	0.01	0.05
TEVIOT FOOT	0.08	0.02	0.04	<0.01	0.03
Tweed Kelso Bridge	0.08	0.03	0.04	0.02	0.05
Tweed Sprouston Bridge	0.11	0.03	0.06	0.02	0.05
EDEN WATER FOOT	0.07	0.03	0.06	0.02	0.05
Tweed below Birgham	0.07	0.02	0.08	0.02	0.05
LAMBDEN BURN SPRINGWELLS	0.25	0.17	0.11	0.10	0.23
LEET WATER FOOT	0.09	0.03	0.06	0.03	0.13
Tweed Coldstream	0.07	0.02	0.08	<0.01	0.05
TILL WATER FOOT	0.11	0.04	0.12	0.10	0.89
Tweed Norham Bridge	0.09	0.02	0.05	0.10	0.31
Tweed Fishwick Mains	0.14	0.02	0.04	0.04	0.35
Tweed Union Bridge	0.09	0.03	0.09	0.05	0.54
WHITEADDER CHURNSIDE	0.06	0.02	0.04	<0.01	0.10
BLACKADDER FOOT	0.04	0.02	0.09	0.03	0.07
WHITEADDER FOOT	0.05	0.02	0.08	0.03	0.06

ALUMINIUM det. limit 0.03 $mg\ l^{-1}$

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
		all except one below det. limit	all below det. limit	all except one below det. limit	
Tweed Finglands	0.06				<0.03
Tweed Tweedsmuir	<0.03				<0.03
Tweed Kingledors	<0.03				<0.03
Tweed Dawych Bridge	0.03				<0.03
Tweed Lyne Ford	0.04				<0.03
LYNE WATER FOOT	<0.03				<0.03
Tweed Manor Foot	<0.03				<0.03
MANOR WATER FOOT	<0.03				<0.03
EDDLESTON WATER FOOT	0.04				<0.03
Tweed Peebles gauge	0.03				0.10
Tweed Peebles dump	<0.03				<0.03
Tweed Horsburgh Ford	0.03				<0.03
Tweed Traquair Bridge	0.03				0.05
Tweed Walkerburn Bridge	0.03				0.07
Tweed Juniper Bank	0.03				<0.03
Tweed Peel Hospital	<0.03				0.07
Tweed Yair Bridge	0.04				<0.03
Tweed Tweed Bridge	0.03				<0.03
MEGGET WATER FOOT	0.06				0.05
YARROW WATER	<0.03				0.03
ETTRICK WATER FOOT	<0.03				0.03
Tweed Gala Ford	0.06				0.03
GALA WATER FOOT	<0.03				0.03
Tweed Lowood Bridge	0.04				<0.03
Tweed Gattonside Bridge	0.03				<0.03
Tweed Leader Bridge	<0.03				<0.03
LEADER WATER FOOT	0.03				<0.03
Tweed Dryburgh Abbey	<0.03				0.03
Tweed Mourton Bridge	<0.03				<0.03
Tweed Rutherford Lodge	<0.03				<0.03
TEVIOT HAWICK	<0.03				<0.03
ALE WATER FOOT	0.06				<0.03
TEVIOT ANCRUM	0.03				0.10
JED WATER FOOT	0.03				<0.03
TEVIOT FOOT	0.03			0.03	<0.03
Tweed Kelso Bridge	0.06				<0.03
Tweed Sprouston Bridge	<0.03				<0.03
EDEN WATER FOOT	0.03				<0.03
Tweed below Birgham	<0.03				<0.03
LAMBDEN BURN SPRINGWELLS	0.06	0.08			<0.03
LEET WATER FOOT	0.03				<0.03
Tweed Coldstream	<0.03				<0.03
TILL WATER FOOT	<0.03				0.86
Tweed Norham Bridge	0.04				0.26
Tweed Fishwick Mains	<0.03				0.28
Tweed Union Bridge	0.03				0.45
WHITEADDER CHURNSIDE	0.06				0.03
BLACKADDER FOOT	<0.03				0.03
WHITEADDER FOOT	<0.03				0.03

LEAD det. limit 0.001 mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	<0.001	0.002	0.003	0.002	0.018
Tweed Tweedsmuir	<0.001	0.003	0.001	0.001	<0.001
Tweed Kingledors	<0.001	0.002		0.002	<0.001
Tweed Dawych Bridge	0.002			0.001	0.004
Tweed Lyne Ford	<0.001			0.001	0.006
LYNE WATER FOOT	<0.001			0.001	0.003
Tweed Manor Foot	0.002			<0.001	0.003
MANOR WATER FOOT	0.002			<0.001	<0.001
EDDLESTON WATER FOOT	<0.001			0.002	0.007
Tweed Peebles gauge	0.002		0.002	0.002	0.004
Tweed Peebles dump	0.002	0.002		0.003	0.006
Tweed Horsburgh Ford	0.001			0.001	0.002
Tweed Traquair Bridge	<0.001			<0.001	0.003
Tweed Walkerburn Bridge	0.002			0.001	0.003
Tweed Juniper Bank	0.001			<0.001	0.002
Tweed Peel Hospital	0.001			<0.001	0.002
Tweed Yair Bridge	<0.001	0.001		<0.001	0.001
Tweed Tweed Bridge	<0.001			0.002	0.002
MEGGET WATER FOOT	<0.001	rest less than det. limit		<0.001	0.003
YARROW WATER	0.006			<0.001	0.001
ETTRICK WATER FOOT	0.001			0.003	0.002
Tweed Gala Ford	0.002			0.002	0.004
GALA WATER FOOT	0.001		0.001	0.002	0.012
Tweed Lowood Bridge	0.002			0.002	0.005
Tweed Gattonside Bridge	0.004		0.001	0.001	0.003
Tweed Leader Bridge	0.004			0.004	0.002
LEADER WATER FOOT	0.001			0.008	0.002
Tweed Dryburgh Abbey	0.005			0.003	0.032
Tweed Mourton Bridge	0.003			0.006	0.002
Tweed Rutherford Lodge	0.002			0.002	<0.001
TEVIOT HAWICK	<0.001		0.003	0.001	0.008
ALE WATER FOOT	0.005			0.003	0.003
TEVIOT ANCRUM	0.006		rest less than det. limit	0.002	<0.001
JED WATER FOOT	0.002	0.001		0.002	0.001
TEVIOT FOOT	0.003	0.002		<0.001	0.001
Tweed Kelso Bridge	0.003	0.001		<0.001	0.001
Tweed Sprouston Bridge	0.005			<0.001	<0.001
EDEN WATER FOOT	0.003	0.002		0.003	<0.001
Tweed below Birgham	0.006	0.001		<0.003	<0.001
LAMBDEN BURN SPRINGWELLS	0.009	0.003		0.001	0.001
LEET WATER FOOT	0.006	0.002		0.016	0.001
Tweed Coldstream	0.007	0.002		0.002	0.001
TILL WATER FOOT	0.004			0.002	0.003
Tweed Norham Bridge	0.007	0.002		<0.001	<0.001
Tweed Fishwick Mains	0.006	0.008		0.017	0.006
Tweed Union Bridge	0.008	0.004		<0.001	0.006
WHITEADDER CHURNSIDE	0.002	0.002		<0.001	0.002
BLACKADDER FOOT	0.005	0.002		0.002	<0.001
WHITEADDER FOOT	0.002	0.001		0.003	0.001

CHLORIDE mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	9.2	10.4	11.1	12.0	10.5
Tweed Tweedsmuir	8.0	8.0	11.1	11.2	10.7
Tweed Kingledors	6.5	10.0	11.1	10.0	10.7
Tweed Dawych Bridge	8.1	14.0	14.9	12.0	13.8
Tweed Lyne Ford	10.0	16.0	20.0	11.2	13.5
LYNE WATER FOOT	18.0	17.4	17.8	18.0	17.7
Tweed Manor Foot	13.0	14.4	14.9	14.4	15.0
MANOR WATER FOOT	8.2	11.4	10.2	10.0	10.2
EDDLESTON WATER FOOT	14.0	17.6	18.8	16.4	19.4
Tweed Peebles gauge	11.2	13.6	15.3	15.6	14.7
Tweed Peebles dump	11.3	14.8	14.9	17.6	15.7
Tweed Horsburgh Ford	11.2	14.4	13.9	15.2	15.2
Tweed Traquair Bridge	11.0	13.4	15.3	16.4	15.0
Tweed Walkerburn Bridge	11.1	17.6	15.8	16.0	14.0
Tweed Juniper Bank	11.2	16.0	14.0	14.8	14.8
Tweed Peel Hospital	13.0	14.4	15.3	17.0	18.0
Tweed Yair Bridge	11.2	16.0	14.8	16.8	14.6
Tweed Tweed Bridge	12.2	15.4	14.8	16.8	16.2
MEGGET WATER FOOT	7.5	10.8	11.7	10.0	9.5
YARROW WATER	10.0	9.0	10.6	15.6	10.0
ETTRICK WATER FOOT	13.0	16.0	15.3	15.2	12.5
Tweed Gala Ford	10.6	14.2	17.5	24.0	14.4
GALA WATER FOOT	16.0	18.8	19.2	24.0	16.7
Tweed Lowood Bridge	11.1	16.8	18.2	19.0	15.2
Tweed Gattonside Bridge	11.8	17.6	16.2	16.0	14.0
Tweed Leader Bridge	11.1	19.0	14.9	16.0	14.0
LEADER WATER FOOT	20.6	21.4	24.7	22.4	19.2
Tweed Dryburgh Abbey	13.0	18.8	16.7	17.2	17.5
Tweed Mourton Bridge	13.1	20.0	17.0	18.0	16.0
Tweed Rutherford Lodge	13.2	18.8	17.5	19.0	18.0
TEVIOT HAWICK	21.9	13.6	20.5	13.6	13.0
ALE WATER FOOT	23.6	15.4	13.6	16.0	9.6
TEVIOT ANCRUM	25.5	17.4	14.9	16.4	13.0
JED WATER FOOT	47.7	40.0	22.6	38.0	37.2
TEVIOT FOOT	27.6	30.4	16.4	30.0	16.2
Tweed Kelso Bridge	13.9	18.0	14.9	17.6	18.0
Tweed Sprouston Bridge	16.0	21.0	16.0	17.4	15.0
EDEN WATER FOOT	26.0	24.6	29.0	25.0	25.0
Tweed below Birgham	15.6	17.6	15.8	18.4	15.2
LAMBDEN BURN SPRINGWELLS	25.8	26.4	33.0	32.0	33.8
LEET WATER FOOT	18.8	22.6	32.3	29.6	42.9
Tweed Coldstream	15.7	20.0	18.8	18.0	16.0
TILL WATER FOOT	22.2	25.6	21.3	24.4	19.4
Tweed Norham Bridge	16.0	19.2	15.3	18.0	17.0
Tweed Fishwick Mains	14.6	20.6	19.2	20.0	16.0
Tweed Union Bridge	15.7	22.2	17.0	20.0	17.0
WHITEADDER CHURNSIDE	23.5	20.0	21.8	21.2	19.0
BLACKADDER FOOT	24.0	27.4	25.6	33.4	22.5
WHITEADDER FOOT	26.0	24.0	20.5	25.0	35.0

SILICATE - Si mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	2.75	1.00	3.15	2.35	1.95
Tweed Tweedsmuir	1.95	0.65	3.35	2.05	1.75
Tweed Kingledors	1.75	0.70	3.40	2.05	1.85
Tweed Dawych Bridge	1.85	0.95	3.90	2.75	2.80
Tweed Lyne Ford	1.75	0.95	4.15	2 55	3.10
LYNE WATER FOOT	4.35	1.70	5.30	3.25	3.60
Tweed Manor Foot	3.25	1.40	4.35	2.65	3.25
MANOR WATER FOOT	2.80	0.95	3.70	2.45	2.65
EDDLESTON WATER FOOT	3.25	1.35	4.60	3.30	3.30
Tweed Peebles gauge	3.25	1.20	4.30	2.75	3.25
Tweed Peebles dump	3.25	1.00	4.45	2.55	2.90
Tweed Horsburgh Ford	3.45	0.80	4.40	2.60	3.05
Tweed Traquair Bridge	3.30	0.80	4.40	3.30	3.10
Tweed Walkerburn Bridge	3.15	0.95	4.30	2.60	3.30
Tweed Juniper Bank	3.55	0.85	4.20	2.65	2.95
Tweed Peel Hospital	3.20	0.75	4.25	2.45	2.70
Tweed Yair Bridge	3.15	0.60	4.05	2.60	2.80
Tweed Tweed Bridge	3.30	0.55	4.10	2.60	2.90
MEGGET WATER FOOT	2.75	0.80	2.95	2.30	2.05
YARROW WATER	1.55	0.40	2.25	1.15	0.80
ETTRICK WATER FOOT	1.45	0.30	2.30	0.80	0.50
Tweed Gala Ford	2.60	0.45	5.05	2.30	2.10
GALA WATER FOOT	2.80	0.30	3.90	1.65	1.85
Tweed Lowood Bridge	3.20	0.40	3.55	2.30	2.00
Tweed Gattonside Bridge	1.95	0.95	3.50	2.65	2.15
Tweed Leader Bridge	1.75	0.45	3.45	1.65	1.45
LEADER WATER FOOT	1.90	0.20	4.00	0.70	0.85
Tweed Dryburgh Abbey	1.80	0.40	3.15	1.60	2.40
Tweed Mourton Bridge	1.95	0.25	3.30	1.75	1.70
Tweed Rutherford Lodge	0.65	0.80	3.55	1.85	1.40
TEVIOT HAWICK	3.85	1.10	2.40	0.65	1.05
ALE WATER FOOT	1.80	0.80	2.95	1.30	1.10
TEVIOT ANCRUM	1.75	0.60	2.85	1.30	1.25
JED WATER FOOT	2.35	0.60	3.15	0.55	0.45
TEVIOT FOOT	3.85	0.25	3.15	0.60	0.35
Tweed Kelso Bridge	1.95	0.25	3.55	2.05	1.30
Tweed Sprouston Bridge	2.50	0.30	3.40	1.15	1.20
EDEN WATER FOOT	1.85	1.30	4.15	0.45	1.15
Tweed below Birgham	1.95	0.25	3.25	1.20	1.00
LAMBDEN BURN SPRINGWELLS	6.50	2.45	6.45	2.35	4.50
LEET WATER FOOT	1.70	0.50	4.45	1.00	4.00
Tweed Coldstream	1.60	0.45	3.25	1.05	1.05
TILL WATER FOOT	4.65	0.80	4.80	1.25	3.15
Tweed Norham Bridge	2.30	0.70	3.40	0.80	1.50
Tweed Fishwick Mains	2.20	0.55	3.35	0.80	1.00
Tweed Union Bridge	2.00	0.35	3.40	1.05	1.00
WHITEADDER CHURNSIDE	2.80	0.35	3.10	0.80	2.05
BLACKADDER FOOT	1.75	0.50	3.45	1.20	0.95
WHITEADDER FOOT	1.50	0.50	3.30	0.60	1.80

PHOSPHATE (as PO_4-P)　　　det. limit 0.010 mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	<0.010	<0.010	0.011	<0.010	0.010
Tweed Tweedsmuir	<0.010	<0.010	0.010	<0.010	<0.010
Tweed Kingledors	0.018	<0.010	0.019	<0.010	<0.010
Tweed Dawych Bridge	0.019	0.037	0.015	<0.010	<0.010
Tweed Lyne Ford	0.016	0.010	0.020	<0.010	<0.010
LYNE WATER FOOT	0.030	0.021	0.024	<0.010	0.010
Tweed Manor Foot	0.033	0.014	0.017	0.012	<0.010
MANOR WATER FOOT	0.052	<0.010	0.010	<0.010	<0.010
EDDLESTON WATER FOOT	0.027	0.027	0.024	0.010	0.018
Tweed Peebles gauge	0.029	0.010	0.034	0.016	0.014
Tweed Peebles dump	0.157	0.168	0.044	0.089	0.064
Tweed Horsburgh Ford	0.096	0.053	0.033	0.023	0.017
Tweed Traquair Bridge	0.055	0.033	0.030	0.014	0.019
Tweed Walkerburn Bridge	0.043	0.020	0.034	0.012	0.014
Tweed Juniper Bank	0.067	0.080	0.034	0.024	0.018
Tweed Peel Hospital	0.064	0.067	0.034	0.015	0.019
Tweed Yair Bridge	0.041	0.059	0.033	0.015	0.010
Tweed Tweed Bridge	0.059	0.060	0.028	0.016	0.010
MEGGET WATER FOOT	0.015	0.015	0.010	<0.010	<0.010
YARROW WATER	0.010	<0.010	0.010	<0.010	<0.010
ETTRICK WATER FOOT	0.026	0.119	0.059	0.137	0.083
Tweed Gala Ford	0.036	0.091	0.033	<0.041	0.012
GALA WATER FOOT	0.036	0.020	0.024	0.010	0.023
Tweed Lowood Bridge	0.141	0.116	0.041	0.065	0.025
Tweed Gattonside Bridge	0.157	0.096	0.038	0.047	0.014
Tweed Leader Bridge	0.061	0.150	0.036	0.040	<0.010
LEADER WATER FOOT	0.061	0.093	0.039	<0.010	0.020
Tweed Dryburgh Abbey	0.094	0.155	0.055	0.080	0.041
Tweed Mourton Bridge	0.094	0.255	0.041	0.047	0.016
Tweed Rutherford Lodge	0.073	0.208	0.042	0.055	0.019
TEVIOT HAWICK	0.010	0.013	0.012	<0.010	0.010
ALE WATER FOOT	0.028	0.017	0.026	<0.010	0.010
TEVIOT ANCRUM	0.292	0.219	0.044	0.093	0.030
JED WATER FOOT	0.065	0.199	0.065	0.098	0.260
TEVIOT FOOT	0.125	0.199	0.067	0.060	0.033
Tweed Kelso Bridge	0.079	0.197	0.050	0.062	0.025
Tweed Sprouston Bridge	0.059	0.142	0.061	0.052	0.028
EDEN WATER FOOT	0.065	0.118	0.082	0.024	0.033
Tweed below Birgham	0.065	0.140	0.054	0.043	0.022
LAMBDEN BURN SPRINGWELLS	0.250	0.195	0.147	0.071	0.140
LEET WATER FOOT	0.220	0.146	0.188	0.062	0.424
Tweed Coldstream	0.084	0.186	0.059	0.051	0.033
TILL WATER FOOT	0.057	0.044	0.052	0.017	0.070
Tweed Norham Bridge	0.069	0.147	0.065	0.036	0.034
Tweed Fishwick Mains	0.078	0.121	0.061	0.043	0.032
Tweed Union Bridge	0.082	0.154	0.054	0.042	0.043
WHITEADDER CHURNSIDE	0.021	0.069	0.022	0.019	0.012
BLACKADDER FOOT	0.180	0.295	0.145	0.177	0.045
WHITEADDER FOOT	0.065	0.133	0.059	0.042	0.015

AMMONIA (as $[NH_3 + NH_4]$ − N) mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	0.190	0.050	0.160	0.105	0.290
Tweed Tweedsmuir	0.185	0.050	0.110	0.135	0.160
Tweed Kingledors	0.170	0.080	0.065	0.130	0.075
Tweed Dawych Bridge	0.740	0.080	0.100	0.085	0.135
Tweed Lyne Ford	0.195	0.070	0.085	0.160	0.170
LYNE WATER FOOT	0.195	0.060	0.120	0.160	0.500
Tweed Manor Foot	0.310	0.090	0.060	0.105	0.220
MANOR WATER FOOT	0.320	0.085	0.060	0.110	0.655
EDDLESTON WATER FOOT	0.260	0.065	0.130	0.135	0.050
Tweed Peebles gauge	0.310	0.090	0.065	0.160	0.115
Tweed Peebles dump	0.450	0.510	0.115	0.290	0.160
Tweed Horsburgh Ford	0.340	0.160	0.105	0.290	0.125
Tweed Traquair Bridge	0.300	0.075	0.100	0.130	0.330
Tweed Walkerburn Bridge	0.155	0.070	0.065	0.135	0.125
Tweed Juniper Bank	0.110	0.105	0.095	0.115	0.175
Tweed Peel Hospital	0.095	0.095	0.100	0.115	0.270
Tweed Yair Bridge	0.145	0.100	0.155	0.115	0.320
Tweed Tweed Bridge	0.165	0.075	0.115	0.090	0.080
MEGGET WATER FOOT	0.245	0.170	0.050	0.100	0.530
YARROW WATER	0.750	0.080	0.135	0.135	0.270
ETTRICK WATER FOOT	0.190	0 350	1.425	0.310	0.405
Tweed Gala Ford	0.220	0.110	0.110	0.235	0.170
GALA WATER FOOT	0.155	0.050	0.100	0.080	0.120
Tweed Lowood Bridge	0.530	0.200	0.120	0.470	0.170
Tweed Gattonside Bridge	0.405	0.225	0.120	0.120	0.135
Tweed Leader Bridge	0.130	0.120	0.115	0.100	0.095
LEADER WATER FOOT	0.120	0.210	0.095	0.090	0.220
Tweed Dryburgh Abbey	0.455	0.150	0.140	0.105	0.105
Tweed Mourton Bridge	0.660	0.110	0.105	0.100	0.100
Tweed Rutherford Lodge	0.735	0.140	0.095	0.090	0.095
TEVIOT HAWICK	0.110	0.660	0.155	0.165	0.145
ALE WATER FOOT	0.110	0.150	0.140	0.075	0.140
TEVIOT ANCRUM	0.250	0.080	0.110	0.095	0.140
JED WATER FOOT	0.715	1.000	0.625	1.650	0.595
TEVIOT FOOT	0.465	0.300	0.550	0.070	0.095
Tweed Kelso Bridge	0.610	0.160	0.115	0.090	0.125
Tweed Sprouston Bridge	0.405	0.200	0.205	0.100	0.120
EDEN WATER FOOT	0.710	0.220	0.200	0.120	0.210
Tweed below Birgham	0.740	0.180	0.115	0.100	0.110
LAMBDEN BURN SPRINGWELLS	0.750	0.200	0.150	0.115	0.200
LEET WATER FOOT	0.740	0.320	0.360	0.130	0.270
Tweed Coldstream	0.660	0.165	0.150	0.150	0.530
TILL WATER FOOT	0.740	0.195	0.255	0.100	0.210
Tweed Norham Bridge	0.740	0.155	0.215	0.115	0.410
Tweed Fishwick Mains	0.660	0.165	0.195	0.090	0.405
Tweed Union Bridge	0.660	0.150	0.150	0.100	0.345
WHITEADDER CHURNSIDE	0.660	0.090	0.130	0.075	0.220
BLACKADDER FOOT	0.745	0.100	0.165	0.120	0.470
WHITEADDER FOOT	0.745	0.105	0.165	0.105	0.345

NITRITE (NO_2-N)   det. limit 0.002 mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	<0.002	0.002	0.004	<0.002	0.002
Tweed Tweedsmuir	0.004	0.003	0.003	<0.002	0.006
Tweed Kingledors	<0.002	0.006	0.004	<0.002	0.003
Tweed Dawych Bridge	0.004	0.004	0.007	0.006	0.009
Tweed Lyne Ford	0.002	0.004	0.008	<0.002	0.009
LYNE WATER FOOT	0.007	0.005	0.012	0.005	0.010
Tweed Manor Foot	0.003	0.005	0.009	0.005	0.009
MANOR WATER FOOT	<0.002	0.003	0.004	<0.002	0.004
EDDLESTON WATER FOOT	0.017	0.009	0.012	0.006	0.010
Tweed Peebles gauge	0.004	0.005	0.007	0.005	0.009
Tweed Peebles dump	0.009	0.022	0.012	0.017	0.014
Tweed Horsburgh Ford	0.009	0.015	0.010	0.009	0.009
Tweed Traquair Bridge	0.008	0.009	0.009	0.006	0.007
Tweed Walkerburn Bridge	0.004	0.010	0.009	0.005	0.008
Tweed Juniper Bank	0.002	0.020	0.010	0.007	0.009
Tweed Peel Hospital	0.004	0.017	0.010	0.006	0.009
Tweed Yair Bridge	0.004	0.016	0.006	0.007	0.009
Tweed Tweed Bridge	0.005	0.015	0.008	0.009	0.010
MEGGET WATER FOOT	0.002	0.008	0.004	<0.002	<0.002
YARROW WATER	0.002	0.007	0.005	<0.002	0.002
ETTRICK WATER FOOT	0.003	0.005	0.006	0.015	0.007
Tweed Gala Ford	0.005	0.018	0.012	0.016	0.011
GALA WATER FOOT	0.004	0.005	0.007	0.005	0.009
Tweed Lowood Bridge	0.011	0.017	0.008	0.020	0.013
Tweed Gattonside Bridge	0.009	0.018	0.009	0.018	0.013
Tweed Leader Bridge	0.012	0.027	0.009	0.014	0.013
LEADER WATER FOOT	<0.002	0.010	0.008	0.007	0.007
Tweed Dryburgh Abbey	0.009	0.022	0.010	0.022	0.016
Tweed Mourton Bridge	0.007	0.023	0.010	0.025	0.016
Tweed Rutherford Lodge	0.007	0.018	0.009	0.031	0.018
TEVIOT HAWICK	<0.002	0.003	0.005	0.004	<0.002
ALE WATER FOOT	<0.002	0.004	0.007	0.003	0.002
TEVIOT ANCRUM	0.010	0.012	0.009	0.015	0.009
JED WATER FOOT	0.011	0.058	0.009	0.018	0.040
TEVIOT FOOT	0.009	0.015	0.017	0.017	0.032
Tweed Kelso Bridge	0.004	0.012	0.012	0.020	0.016
Tweed Sprouston Bridge	0.007	0.016	0.017	0.014	0.023
EDEN WATER FOOT	0.003	0.007	0.015	0.007	0.016
Tweed below Birgham	0.006	0.014	0.018	0.016	0.023
LAMBDEN BURN SPRINGWELLS	0.032	0.019	0.028	0.009	0.066
LEET WATER FOOT	0.015	0.017	0.024	0.018	0.090
Tweed Coldstream	0.008	0.013	0.017	0.020	0.020
TILL WATER FOOT	0.010	0.011	0.012	0.009	0.027
Tweed Norham Bridge	0.006	0.015	0.018	0.018	0.022
Tweed Fishwick Mains	0.011	0.018	0.018	0.014	0.022
Tweed Union Bridge	0.005	0.018	0.016	0.014	0.027
WHITEADDER CHURNSIDE	0.005	0.006	0.008	0.007	0.006
BLACKADDER FOOT	0.011	0.015	0.017	0.010	0.010
WHITEADDER FOOT	0.016	0.025	0.014	0.013	0.013

NITRATE (NO_3-N) det. limit 0.20 mg l^{-1}

sampling site	14.8.72	8.11.72	30.1.73	22.3.73	22.5.73
Tweed Finglands	0.25	<0.20	0.25	0.21	<0.20
Tweed Tweedsmuir	0.20	<0.20	0.50	0.25	<0.20
Tweed Kingledors	0.20	0.23	0.47	0.20	<0.20
Tweed Dawych Bridge	0.21	0.81	0.97	0.20	0.62
Tweed Lyne Ford	1.00	0.78	0.97	0.55	0.54
LYNE WATER FOOT	1.95	1.44	0.36	1.10	1.12
Tweed Manor Foot	1.15	0.81	1.08	0.49	1.08
MANOR WATER FOOT	0.42	0.41	0.78	0.33	<0.20
EDDLESTON WATER FOOT	2.14	1.57	1.82	1.33	1.52
Tweed Peebles gauge	1.35	0.97	1.15	0.73	1.16
Tweed Peebles dump	1.43	1.03	1.17	0.62	0 97
Tweed Horsburgh Ford	1.09	1.17	1.10	0.67	0.93
Tweed Traquair Bridge	1.53	0.92	1.20	0.62	1.00
Tweed Walkerburn Bridge	0.97	0.95	1.08	0.70	0.79
Tweed Juniper Bank	1.13	0.97	1.17	0.74	0.78
Tweed Peel Hospital	0.45	1.02	1.10	0.71	0.41
Tweed Yair Bridge	0.82	1.00	1.19	0.68	0.30
Tweed Tweed Bridge	1.00	1.26	0.98	0.81	0.67
MEGGET WATER FOOT	0.20	<0.20	0.25	0.45	<0.20
YARROW WATER	0.37	0.32	0.55	0.46	0.24
ETTRICK WATER FOOT	0.20	0.55	0.05	0.51	0.24
Tweed Gala Ford	0.72	1.16	1.00	0.87	0.54
GALA WATER FOOT	0.83	1.04	1.74	0.73	0.79
Tweed Lowood Bridge	0.51	0.97	1.10	0.83	0.78
Tweed Gattonside Bridge	1.03	1.11	0.90	0.79	0.74
Tweed Leader Bridge	0.94	1.16	1.06	0.83	0.94
LEADER WATER FOOT	1.10	1.68	2.12	0.94	1.00
Tweed Dryburgh Abbey	0.90	1.15	1.02	0.87	0.76
Tweed Mourton Bridge	1.19	1.26	1.00	0.86	0.76
Tweed Rutherford Lodge	1.25	1.30	0.98	0.79	0.76
TEVIOT HAWICK	0.29	0.62	1.28	0.29	0.27
ALE WATER FOOT	0.87	0.71	2.08	0.86	0.81
TEVIOT ANCRUM	1.13	0.92	2.08	0.81	0.65
JED WATER FOOT	1.11	0.87	1.54	0.34	0.51
TEVIOT FOOT	1.32	1.53	2.00	0.76	0.98
Tweed Kelso Bridge	1.09	0.63	1.58	0.69	0.87
Tweed Sprouston Bridge	0.95	1.09	1.89	0.84	0.70
EDEN WATER FOOT	1.53	2.45	6.74	0.81	1.38
Tweed below Birgham	1.11	1.09	2.00	0.68	1.00
LAMBDEN BURN SPRINGWELLS	1.11	1.47	4.85	1.32	2.72
LEET WATER FOOT	1.15	1.69	2.92	1.46	1.19
Tweed Coldstream	0.99	1.75	2.12	0.80	0.98
TILL WATER FOOT	1.24	1.44	1.90	0.31	0.56
Tweed Norham Bridge	0.93	1.57	2.16	0.73	0.81
Tweed Fishwick Mains	0.78	1.57	2.08	0.71	0.78
Tweed Union Bridge	0.82	1.63	1.54	0.68	0.92
WHITEADDER CHURNSIDE	1.05	1.50	2.10	0.91	0.57
BLACKADDER FOOT	0.75	2.30	3.14	1.42	0.60
WHITEADDER FOOT	0.66	1.78	2.80	0.89	0.40

5.22 Element means for the four lowest flows

sampling site	O.D. 420 nm	Conductivity micro-mhos	pH	Na	K	Mg	Ca
Tweed Finglands	0.015	115	7.4	5.6	0.52	4.8	14.6
Tweed Tweedsmuir	0.008	105	7.3	5.0	0.48	4.3	14.5
Tweed Kingledors	0.006	95	7.3	4.8	0.44	3.8	13.9
Tweed Dawych Bridge	0.005	115	7.2	6.1	0.73	4.3	15.0
Tweed Lyne Ford	0.005	120	7.3	6.3	0.79	4.4	15.5
LYNE WATER FOOT	0.008	170	7.7	8.4	1.02	7.8	30.4
Tweed Manor Foot	0.010	135	7.6	6.9	0.87	5.4	19.6
MANOR WATER FOOT	0.007	90	7.5	5.1	0.64	3.4	12.3
EDDLESTON WATER FOOT	0.010	155	7.5	8.1	1.16	5.9	17.9
Tweed Peebles gauge	0.009	135	7.5	7.1	0.95	5.3	18.2
Tweed Peebles dump	0.015	145	7.3	8.1	1.48	5.1	18.6
Tweed Horsburgh Ford	0.016	140	7.5	7.3	1.08	5.0	18.2
Tweed Traquair Bridge	0.009	135	7.7	7.2	0.90	4.9	17.9
Tweed Walkerburn Bridge	0.006	140	7.5	7.0	0.90	5.0	18.0
Tweed Juniper Bank	0.008	130	7.5	7.7	1.01	5.1	18.0
Tweed Peel Hospital	0.011	130	7.4	7.4	1.01	5.0	17.8
Tweed Yair Bridge	0.005	135	7.4	7.4	0.93	4.9	17.8
Tweed Tweed Bridge	0.009	125	7.3	7.4	0.96	5.4	18.1
MEGGET WATER FOOT	0.010	55	7.1	3.8	0.35	2.0	5.4
YARROW WATER	0.009	90	7.2	4.4	0.55	3.5	10.4
ETTRICK WATER FOOT	0.012	115	7.4	7.4	0.90	4.3	14.0
Tweed Gala Ford	0.009	135	7.2	7.3	0.93	4.9	16.7
GALA WATER FOOT	0.009	160	7.4	9.1	1.05	6.7	19.4
Tweed Lowood Bridge	0.010	145	7.5	8.9	1.32	5.2	17.2
Tweed Gattonside Bridge	0.010	135	7.5	8.2	1.09	5.2	17.8
Tweed Leader Bridge	0.017	140	7.6	8.1	1.20	5.3	16.5
LEADER WATER FOOT	0.009	225	7.9	10.9	1.20	10.2	28.7
Tweed Dryburgh Abbey	0.010	155	7.4	10.0	1.11	5.8	19.1
Tweed Mourton Bridge	0.008	145	7.5	9.0	1.11	5.6	17.9
Tweed Rutherford Lodge	0.012	150	7.9	9.4	1.06	5.7	18.4
TEVIOT HAWICK	0.009	220	8.0	6.3	0.82	8.8	37.8
ALE WATER FOOT	0.012	265	8.1	7.4	1.26	10.0	45 6
TEVIOT ANCRUM	0.011	255	8.1	9.2	1.66	10.9	44.6
JED WATER FOOT	0.016	365	8.2	22.1	3.13	20.5	43.1
TEVIOT FOOT	0.010	280	8.2	10.9	1.43	13.1	42.3
Tweed Kelso Bridge	0.012	155	7.9	8.8	1.14	6.5	20.3
Tweed Sprouston Bridge	0.012	185	8.1	9.3	1.22	8.2	26.4
EDEN WATER FOOT	0.016	340	8.2	11.9	2.11	20.1	47.8
Tweed below Birgham	0.012	180	8.1	9.0	1.42	8.2	26.2
LAMBDEN BURN SPRINGWELLS	0.020	425	8.1	18.2	5.55	25.8	53.9
LEET WATER FOOT	0.020	350	8.0	15.0	3.81	14.3	54.0
Tweed Coldstream	0.011	200	8.2	9.3	1.55	8.2	26.8
TILL WATER FOOT	0.030	230	8.1	12.0	1.90	9.5	29.3
Tweed Norham Bridge	0.018	200	8.2	9.7	1.44	8.2	25.9
Tweed Fishwick Mains	0.015	200	8.2	9.2	1.35	8.1	25.6
Tweed Union Bridge	0.021	200	8.0	9.8	1.52	8.2	26.1
WHITEADDER CHURNSIDE	0.016	220	8.2	10.7	1.53	11.5	24.8
BLACKADDER FOOT	0.014	380	8.4	12.4	2.23	23.5	50.0
WHITEADDER FOOT	0.016	305	8.1	12.6	1.86	16.2	37.3

* mean of 3 as Zn & Cu contamination of samples on 22.III.13

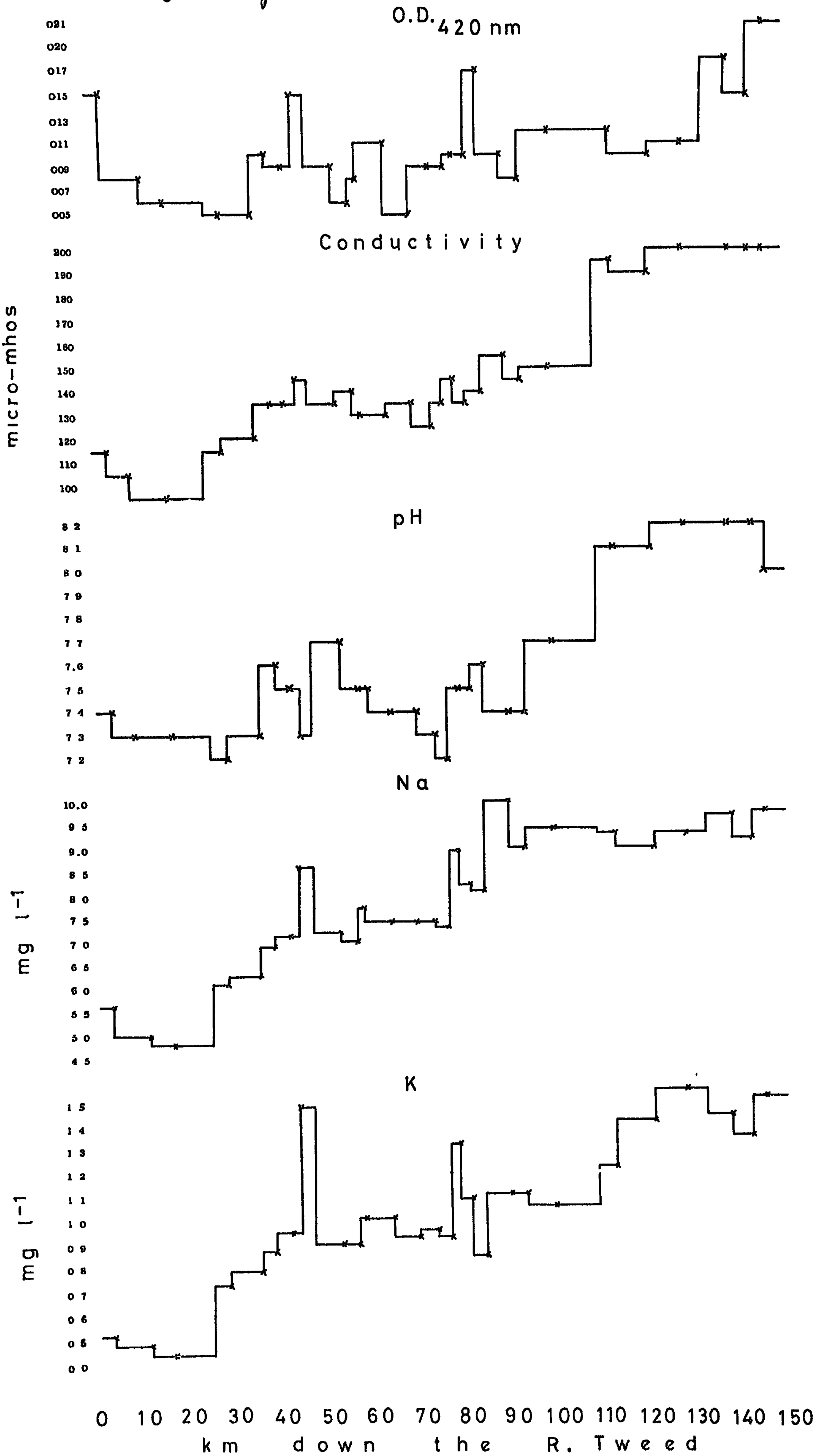
mean of 4 lowest flows

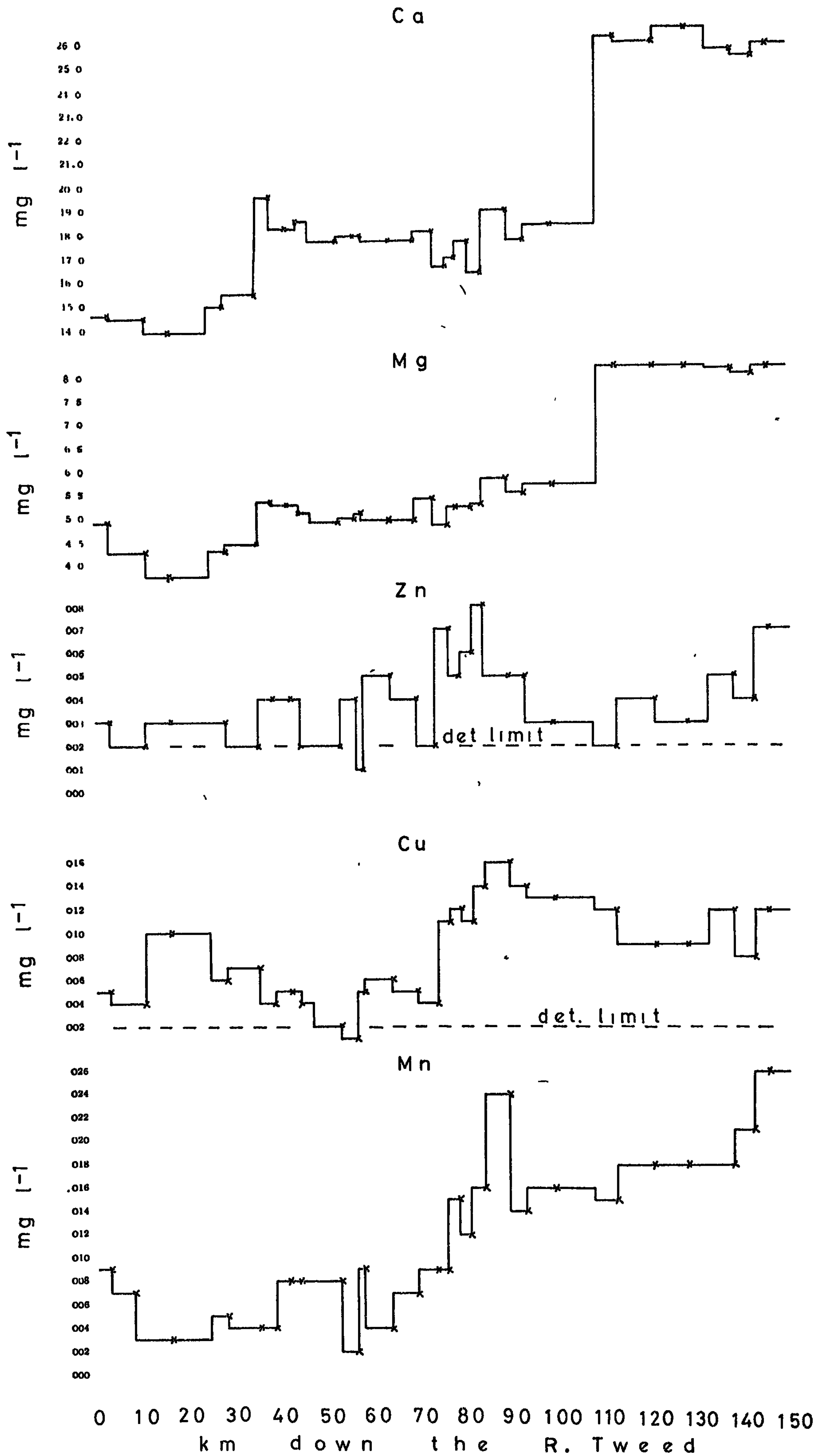
sampling site	Zn*	Cu*	Mn	Fe	Al	Pb
Tweed Finglands	0.003	0.005	0.009	0.05		0.005
Tweed Tweedsmuir	0.002	0.004	0.007	0.08		0.001
Tweed Kingledors	0.003	0.010	0.003	0.07		0.001
Tweed Dawych Bridge	0.003	0.006	0.005	0.07		0.002
Tweed Lyne Ford	0.002	0.007	0.004	0.04		0.002
LYNE WATER FOOT	0.003	0.010	0.008	0.12		0.001
Tweed Manor Foot	0.004	0.004	0.004	0.07		0.001
MANOR WATER FOOT	0.002	0.004	0.005	0.02		0.001
EDDLESTON WATER FOOT	0.004	0.005	0.010	0.11		0.002
Tweed Peebles gauge	0.004	0.005	0.008	0.03	0.03	0.002
Tweed Peebles dump	0.002	0.004	0.008	0.07		0.003
Tweed Horsburgh Ford	<0.002	0.006	0.006	0.08		0.001
Tweed Traquair Bridge	0.002	0.002	0.008	0.05		0.001
Tweed Walkerburn Bridge	0.004	0.001	0.002	0 06		0.001
Tweed Juniper Bank	<0.002	0.005	0.009	0.06		0.001
Tweed Peel Hospital	0.005	0.006	0.004	0.06		0.001
Tweed Yair Bridge	0.004	0.005	0.007	0.05		0.001
Tweed Tweed Bridge	0.003	0.004	0.009	0.04		0.001
MEGGET WATER FOOT	0.002	0.003	0.004	0.05	0.03	0.001
YARROW WATER	0.004	0.004	0.005	0.03	rest below det. limit	0.002
ETTRICK WATER FOOT	0.005	0.010	0.022	0.04		0.002
Tweed Gala Ford	0.007	0.011	0.009	0.04		0.002
GALA WATER FOOT	0.006	0.007	0.010	0.04		0.004
Tweed Lowood Bridge	0.005	0.012	0.015	0.06		0.002
Tweed Gattonside Bridge	0.006	0.011	0.012	0.06		0.002
Tweed Leader Bridge	0.008	0.014	0.014	0.06		0.002
LEADER WATER FOOT	0.019	0.010	0.033	0.08		0.003
Tweed Dryburgh Abbey	0.005	0.016	0.024	0.07		0.010
Tweed Mourton Bridge	0.005	0.014	0.012	0.05		0.002
Tweed Rutherford Lodge	0.003	0.013	0.014	0.04		0.001
TEVIOT HAWICK	0.004	0.009	0.014	0.03		0.002
ALE WATER FOOT	0.005	0.006	0.010	0.03		0.003
TEVIOT ANCRUM	<0.002	0.007	0.006	0.04	0.03	0.002
JED WATER FOOT	0.002	0.008	0.012	0.04		0.002
TEVIOT FOOT	0.006	0.009	0.013	0.03		0.002
Tweed Kelso Bridge	0.003	0.007	0.013	0.04		0.001
Tweed Sprouston Bridge	0.002	0.012	0.013	0.05		0.001
EDEN WATER FOOT	0.003	0.007	0.013	0.14		0.002
Tweed below Birgham	0.004	0.009	0.016	0.04		0.002
LAMBDEN BURN SPRINGWELLS	0.007	0.008	0.048	0.19	0.04	0.003
LEET WATER FOOT	0.005	0.016	0.025	0.07		0.006
Tweed Coldstream	0.003	0.009	0.016	0.04		0.003
TILL WATER FOOT	0.017	0.013	0.025	0.31	0.22	0.002
Tweed Norham Bridge	0.006	0.012	0.016	0.13	0.07	0.002
Tweed Fishwick Mains	0.006	0.008	0.019	0.13	0.07	0.009
Tweed Union Bridge	0.007	0.012	0.026	0.20	0.12	0.004
WHITEADDER CHURNSIDE	0.007	0.005	0.017	0.05		0.002
BLACKADDER FOOT	0.002	0.007	0.018	0.04		0.002
WHITEADDER FOOT	0.004	0.008	0.029	0.04		0.002

mean of 4 lowest flows

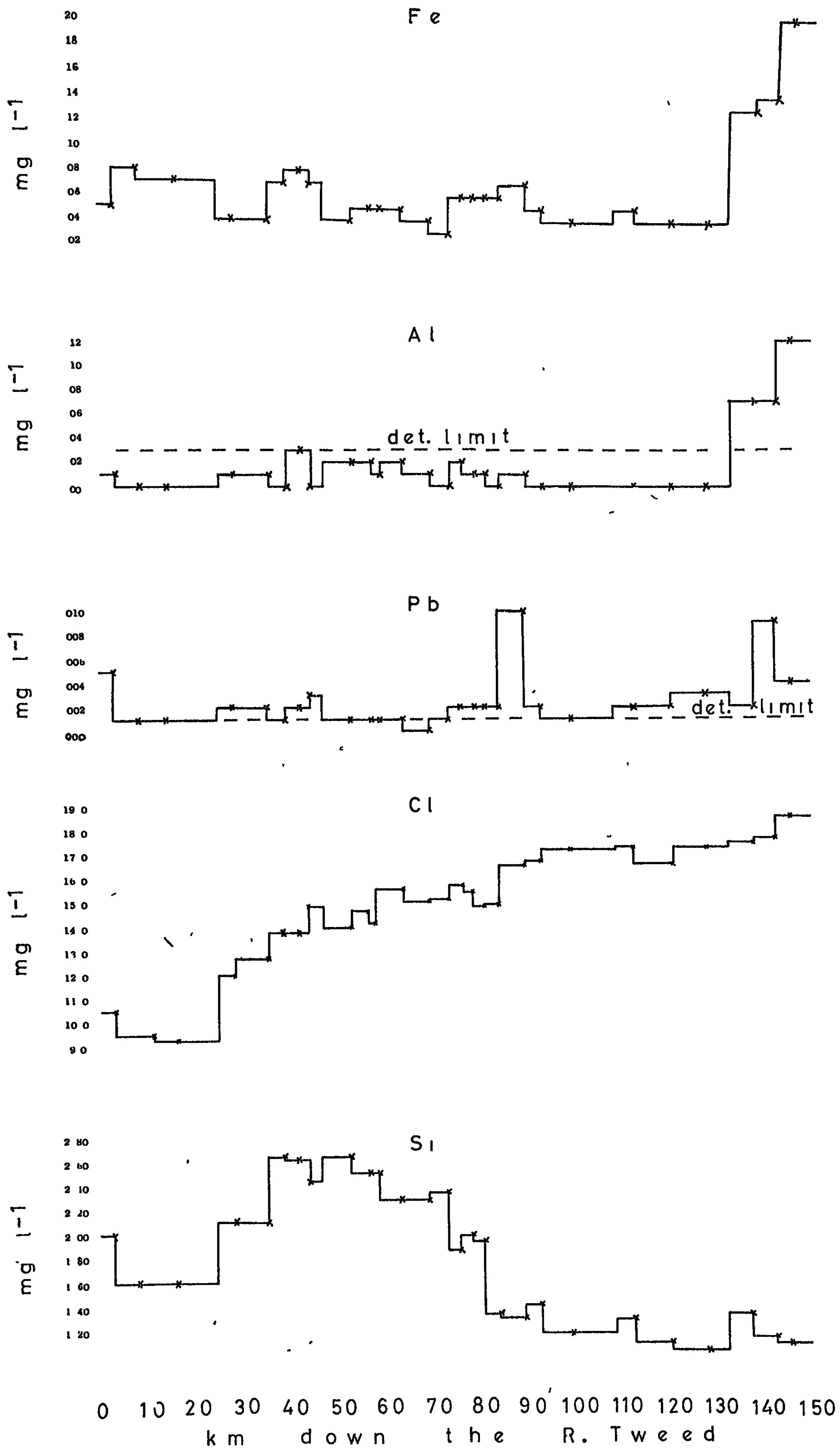
sampling site	Cl	Si	PO_4-P	NH_4-N	NO_2-N	NO_3-N
Tweed Finglands	10.5	2.00	<0.010	0.159	<0.002	<0.20
Tweed Tweedsmuir	9.5	1.60	<0.010	0.133	0.003	<0.20
Tweed Kingledors	9.3	1.60	<0.010	0.144	0.002	<0.20
Tweed Dawych Bridge	12.0	2.10	0.016	0.260	0.006	0.46
Tweed Lyne Ford	12.7	2.10	0.020	0.195	0.004	0.72
LYNE WATER FOOT	17.8	3.20	0.015	0.229	0.007	1.40
Tweed Manor Foot	14.2	2.60	0.016	0.181	0.006	0.88
MANOR WATER FOOT	10.0	2.20	0.013	0.293	0.002	0.29
EDDLESTON WATER FOOT	16.9	2.80	0.021	0.128	0.011	1.64
Tweed Peebles gauge	13.8	2.60	0.015	0.169	0.006	1.05
Tweed Peebles dump	14.9	2.40	0.120	0.350	0.015	1.04
Tweed Horsburgh Ford	14.0	2.50	0.047	0.229	0.011	0.97
Tweed Traquair Bridge	14.0	2.60	0.030	0.209	0.008	1.02
Tweed Walkerburn Bridge	14.7	2.50	0.022	0.121	0.007	0.85
Tweed Juniper Bank	14.2	2.50	0.047	0.126	0.009	0.91
Tweed Peel Hospital	15.6	2.30	0.041	0.144	0.009	0.65
Tweed Yair Bridge	15.1	2.30	0.031	0.170	0.009	0.70
Tweed Tweed Bridge	15.3	2.35	0.035	0.103	0.010	0.94
MEGGET WATER FOOT	9.5	2.00	<0.010	0.261	0.003	<0.20
YARROW WATER	11.6	1.00	<0.010	0.309	0.003	0.35
ETTRICK WATER FOOT	14.2	0.80	0.091	0.583	0.008	0.38
Tweed Gala Ford	15.8	1.90	0.045	0.184	0.014	0.82
GALA WATER FOOT	18.9	1.65	0.022	0.107	0.006	0.85
Tweed Lowood Bridge	15.5	2.00	0.087	0.343	0.015	0.77
Tweed Gattonside Bridge	14.9	1.95	0.079	0.248	0.014	0.92
Tweed Leader Bridge	15.0	1.35	0.063	0.111	0.015	0.96
LEADER WATER FOOT	20.9	0.90	0.044	0.160	0.006	1.18
Tweed Dryburgh Abbey	16.6	1.30	0.086	0.204	0.016	0.92
Tweed Mourton Bridge	16.8	1.40	0.103	0.243	0.017	1.02
Tweed Rutherford Lodge	17.3	1.20	0.089	0.265	0.018	1.03
TEVIOT HAWICK	15.5	1.70	<0.010	0.270	0.002	0.37
ALE WATER FOOT	16.2	1.25	0.014	0.119	0.002	0.81
TEVIOT ANCRUM	18.1	1 25	0.159	0.141	0.012	0.88
JED WATER FOOT	40.7	1.00	0.156	0.990	0.032	0.71
TEVIOT FOOT	26.1	1.25	0.104	0.233	0.018	1.15
Tweed Kelso Bridge	16.9	1.40	0.091	0.246	0.013	0.82
Tweed Sprouston Bridge	17.4	1.30	0.070	0.206	0.015	0.90
EDEN WATER FOOT	25.2	1.20	0.060	0.315	0.006	1.54
Tweed below Birgham	16.7	1.10	0.067	0.283	0.015	0.97
LAMBDEN BURN SPRINGWELLS	29.5	3.95	0.164	0.316	0.032	1.66
LEET WATER FOOT	28.5	1.80	0.213	0.365	0.035	1.37
Tweed Coldstream	17.4	1.05	0.089	0.376	0.016	1.13
TILL WATER FOOT	22.9	2.40	0.047	0.311	0.014	0.89
Tweed Norham Bridge	17.6	1.35	0.070	0.355	0.016	1.01
Tweed Fishwick Mains	17.8	1.15	0.069	0.330	0.017	0.96
Tweed Union Bridge	18.7	1.10	0.080	0.314	0.017	1.01
WHITEADDER CHURNSIDE	20.9	1.50	0.030	0.261	0.016	1.01
BLACKADDER FOOT	26.8	1.10	0.174	0.359	0.012	1.27
WHITEADDER FOOT	27.5	1 10	0.063	0.325	0.017	0.93

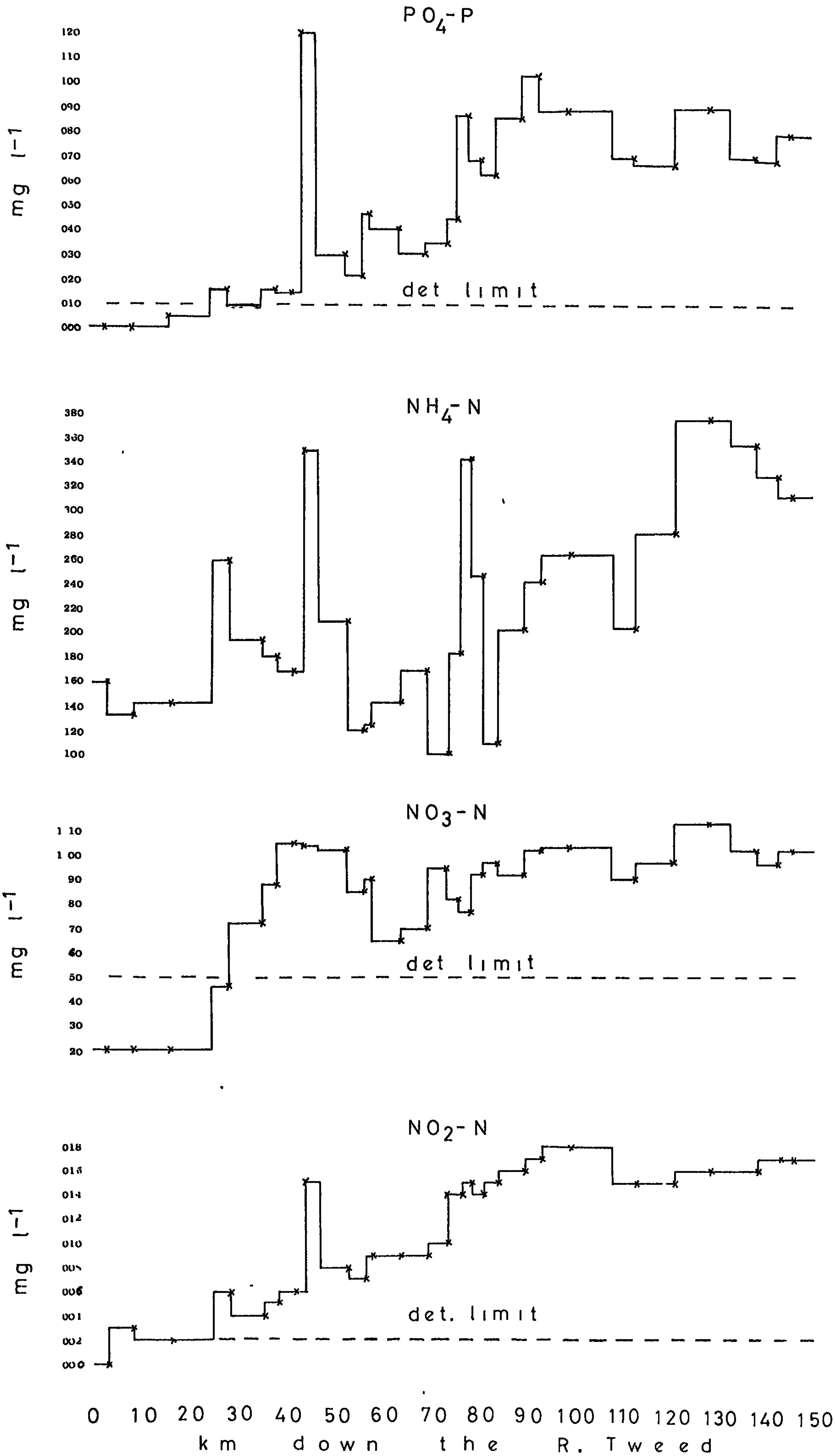
S.23 Diagrams of element changes throughout the Tweed





Ca
Mg
Zn
Cu
Mn
mg l-1
det limit
det. limit
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
km down the R. Tweed


Fe
mg l⁻¹
20
18
16
14
12
10
08
06
04
02
Al
mg l⁻¹
12
10
08
06
04
02
00
det. limit
Pb
mg l⁻¹
010
008
006
004
002
000
det. limit
Cl
mg l⁻¹
19 0
18 0
17 0
16 0
15 0
14 0
13 0
12 0
11 0
10 0
9 0
Si
mg l⁻¹
1 20
1 40
1 60
1 80
2 00
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
km down the R. Tweed


PO4-P
NH4-N
NO3-N
NO2-N
mg l-1
det limit
det. limit
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150
km down the R. Tweed

sampling site	O.D	conductivity	pH	Na	K	Mg	Ca	Zn	Cu	Mn	Fe	Al	Pb	Cl	Si	PO_4-P	NH_4-N	NO_2-N	NO_3-N
Tweed at source	0.050	75	6.7	6.8	0.40	3.3	9.4	0.010	0.005	0.050	0.20	0.04	0.002	16.2	1.85	0.012	0.910	<0.001	0.16
Burn at Tweed source	0.036	110	6.6	4.1	0.31	4.3	17.5	0.029	0.006	0.115	0.12	0.10	<0.001	11.0	1.15	0.021	0.600	<0.001	0.10
Kingledors Burn	0.002	95	7.0	5.0	0.29	4.6	14.7	0.006	<0.002	0.009	0.02	0.05	<0.001	11.5	3.30	<0.010	0.075	<0.001	0.20
Holms Burn	0.008	75	7.0	5.0	0.27	3.2	8.8	0.004	<0.002	<0.002	0.03	<0.03	<0.001	14.6	3.70	0.044	0.135	<0.001	0.16
Biggar Water	0.015	145	6.7	8.2	1.08	5.6	15.8	0.011	<0.002	0.015	0.17	<0.03	0.001	25.7	4.45	0.050	0.170	0.025	1.44
Cairn Burn	0.069	150	6.3	6.2	0.97	9.6	20.9	0.030	<0.002	0.810	4.79	<0.03	0.002	15.0	6.05	0.020	0.500	0.011	0.24
Meldon Burn	0.018	95	7.0	6.8	0.39	4.0	10.3	<0.002	<0.002	0.004	0.17	0.05	0.002	15.5	3.40	0.023	0.220	0.005	0.43
Eddleston Water	0.084	90	6.8	7.2	1.03	4.5	11.0	0.017	0.006	0.068	1.56	1.09	0.004	19.5	3.40	0.052	0.655	0.028	1.03
Leither Water	0.05	100	7.2	6.9	0.36	5.1	14.1	0.002	<0.002	0.004	0.02	0.03	<0.001	13.0	2.90	<0.010	0.051	<0.001	0.13
Walkerburn mill-lade	0.009	145	7.2	7.1	0.65	4.9	15.6	0.005	<0.002	<0.002	0.08	0.09	0.003	15.0	3.85	0.023	0.115	0.011	0.81
Ettrick above Yarrow	0.013	145	7.1	4.3	0.41	4.7	14.7	0.009	<0.002	<0.002	0.06	<0.03	<0.001	20.5	1.20	0.022	0.160	0.002	0.10
Gala Water	0.013	150	7.3	7.4	0.71	6.0	15.6	0.005	<0.002	0.009	0.10	<0.03	0.001	17.5	2.30	0.036	0.125	0.007	0.60
Slitrig Water	0.016	250	7.1	6.1	0.67	8.6	31.2	0.003	0.002	0.013	0.07	<0.03	<0.001	22.5	8.05	0.068	0.330	0.004	0.41
Jed above Jedburgh	0.005	300	8.3	8.3	1.10	17.4	34.2	<0.002	0.003	0.010	0.04	<0.03	<0.001	18.0	1.40	0.006	0.125	<0.001	0.27
Jed above sewage works	0.005	300	8.0	8.7	1.20	17.7	36.2	0.004	0.002	0.008	0.07	<0.03	<0.001	16.5	1.05	0.018	0.175	0.001	0.60
Loet at Leitholm	0.021	750	7.7	22.0	5.60	23.8	129.0	0.020	0.008	0.033	0.12	<0.03	0.006	48.0	5.30	0.313	0.270	0.030	1.00
Lambden	0.029	600	7.9	25.0	6.90	24.2	69.2	0.015	0.010	0.068	0.18	<0.03	0.001	62.2	4.95	0.192	0.320	0.034	1.32
Blackadder above Greenlaw	0.036	225	8.0	9.9	0.84	12.5	24.3	0.008	0.004	0.009	0.20	<0.03	0.004	23.5	1.55	0.006	0.530	0.005	0.31
Blackadder at Nisbet	0.038	250	8.5	9.0	1.25	13.8	27.5	0.004	0.003	0.022	0.12	<0.03	0.003	20.5	1.55	0.040	0.405	0.007	0.46
Langton Burn	0.023	325	8.3	12.4	2.40	17.8	37.0	0.005	<0.002	0.010	0.07	<0.03	0.001	26.0	2.00	0.576	0.270	0.057	1.49

5.24 Chemical data from 20 additional sites collected on 22. V. 73.

5.3 Summary of the water chemistry of the Tweed

In the following descriptions of the chemistry of the Tweed (and its tributaries in 5.4), the terms 'hardness' and nutrients' are frequently used.

Water hardness is related to the amount of Ca and Mg in the water. With reference to Table 5.3a it can be observed that in most cases Ca levels were approximately three times higher than Mg. On passing down the Tweed for example, both elements increased proportionally. In lowland tributaries however, the relative Mg content was slightly higher in proportion to Ca. In general discussions, the terms very soft, soft, average, moderately hard and hard waters refer to Ca hardness, which are related to values tabulated in Table 5.3b. Where a more accurate description is required, the actual levels of Mg and Ca are given.

sampling site	Mg mean	Ca mean	Mg as percentage of Ca levels
Tweed finglands	4.8	14.6	33
LYNE FOOT	7.8	30.4	26
Tweed Walkerburn	5.0	18.0	28
ETTRICK FOOT	4.3	14.0	31
Tweed Gattonside	5.2	17.8	30
JED FOOT	20.5	43.1	47
TEVIOT FOOT	13.1	42.3	31
EDEN FOOT	20.1	47.8	42
TILL FOOT	9.5	29.3	32
Tweed Union Bridge	8.2	26.1	31
BLACKADDER FOOT	23.5	50.0	47

Table 5.3a Examples of chemistry results to show relationship between Mg and Ca levels in the Tweed and its tributaries.

classification	Ca mg l^{-1}
very soft	< 9.9
soft	10.0 - 19.9
average	20.0 - 29.9
moderately hard	30.0 - 44.9
hard	> 45.0

Table 5.3b Hardness terms used in the text related to Ca levels.

The parameters that are referred to by the term 'nutrients' are PO_4-P, NH_4-N, NO_2-N and NO_3-N. Since these rarely showed proportional changes related to one another down the Tweed (see 5.23), each is usually described separately. In many cases however, the nutrient status of various sites were so diverse that the terms nutrient poor and nutrient rich could be used in a comparative manner. (For example, see below, taken from 5.22).

sampling point	PO_4-P	NH_4-N	NO_2-N	NO_3-N
Tweed Finglands	< 0.010	0.159	< 0.002	< 0.20
LEET FOOT	0.213	0.365	0.035	1.37

It is important to stress that the terms described above are relative, in as much as they refer to data from the Tweed Basin only, and are not related to levels in other river systems.

Changes in the concentration of each element throughout the Tweed has been plotted in Fig. 5.23. For the most part the diagrams are self explanatory, however, it is noteworthy that the following elements could usually be correlated with one another.

(i) The patterns of Na and K curves were very similar, and in the upper two-thirds of the river, almost identical.

(ii) The patterns of conductivity, Mg and Ca curves were also very similar, with Ca almost exactly three times higher than Mg.

(iii) Most heavy metal levels were low in comparison with those reported from other rivers in the N-E. (Data from Holmes et al., 1972 and Department of Botany, University of Durham, see 1.2). In comparison with the nearby Tyne and Wear, Cu, Mn and Pb levels were comparable, but Zn, Fe and Al were much lower.

(iv) PO_4-P and NH_4-N curves showed coinciding peaks and troughs, both fluctuating greatly throughout the river; NO_2-N and NO_3-N showed less fluctuation.

The water chemistry of the Tweed can most easily be summarized by dividing the river into four regions delimited by the three largest tributaries.

(i) The upper region above the Lyne, the largest tributary of the upper 70 km of the Tweed (km 0.0 - 34.5).

(ii) Between Lyne Foot and Ettrick Foot (km 35.0 - 71.5).

(iii) Between Ettrick Foot and Teviot Foot (km 72.0 - 108.0)

(iv) Teviot Foot to the brackish water above Whiteadder Foot (108.5 - 149.5).

(i) The upper region above the Lyne

In this uppermost 35 km of the Tweed, conductivity, Na, K, Mg and Ca levels were lower than any other stretch of the river. A slight increase in all occurred at km 24.5 below the influx of the Biggar. Levels of Cl, PO_4-P, NO_2-N and NO_3-N were also the lowest in the Tweed, the last three being almost always below the detection limit. NH_4-N levels throughout the river are difficult to compare since great fluctuations were evident; levels were most generally low in this stretch, with a small peak below Biggar Foot. Si was slightly below the mean for the whole of the Tweed, and again a slight increase was evident below Biggar Water. Perhaps the Biggar's canal like features were not suitable for diatoms, and silica depletion from this source was minimal.

This stretch was thus softer and less nutrient rich than any other stretch of the Tweed. This was particularly evident above Biggar Foot.

(ii) Between Lyne Foot and Ettrick Foot

Conductivity showed an immediate increase from the former stretch, due to the Lyne. Apart from a small peak below Peebles Sewage Works, the level was maintained throughout the stretch. Na and K both increased below Lyne Foot, but peaked conspicuously below Peebles, and to a lesser extent below the effluent discharged by the towns of Innerleithen and Walkerburn. The curves stabilized below these peaks to levels much greater than in the stretch of river above the Biggar. Mg and Ca levels were boosted by the Lyne, particularly the latter. Both dropped slightly on passing downstream. Cl showed only a slight and gradual increase on passing downstream, and only a small peak was visable at Peebles. The Lyne was also responsible for increasing Si levels, and in this section of the Tweed the element reached its maximum. PO_4-P, NH_4-N, and NO_2-N showed obvious peaks at Peebles Sewage Works. The PO_4-P peak was the most conspicuous, but although the level dropped suddenly to approximately 0.030 mg l^{-1}, it was still far greater than in the upper 35 km, where it was rarely detectable. NH_4-N dropped to below levels in the upper stretches.

NO_2-N which had the smallest peak, initially dropped, and then rose slightly on passing downstream. NO_3-N did not peak at the sewage works, but reached a plateau and then dropped. It however reached far higher levels than in the former, more upstream stretch.

The main characteristics of this stretch were an increase in conductivity, Mg and Ca. Although levels were greater than in the upper stretches, water hardness remained soft. Cl and Si were also higher, the latter greater than elsewhere in the Tweed. Na, K, PO_4-P, NH_4-N and NO_2-N all showed obvious peaks resulting from the discharge of sewage from the Burgh of Peebles. All except NH_4-N remained at significantly higher levels than in the former, more upstream stretch. The stretch was thus slightly harder than km 0.0 - 35.0, but still soft, and far more nutrient rich.

(iii) Ettrick Foot to Teviot Foot

Conductivity increased slightly from the former described stretch, primarily due to the influx of the Gala and the Leader. Mg and Ca showed a slight initial decrease because of the addition of the large volume of water from the relatively softer Ettrick. Levels increased again further downstream due to the influence of the smaller, yet harder Leader. Na and K peaked below Gala Sewage Works, and boosted levels to higher than in the former stretch, especially Na. Cl continued its very slight downstream increase, and Si dropped significantly below all three affluents Ettrick, Gala and Leader. Both PO_4-P and NH_4-N peaked below Gala, the former remained at its highest consistent level in the river, and the latter dropped very low and then increased again. NO_2-N and NO_3-N increased gradually, the latter only slightly, and the former to double its level in the former stretch.

This stretch was thus only marginally harder than the former, and still classed as soft, and Na, PO_4-P, NH_4-N and NO_2-N were significantly higher than before. It is noteworthy that the PO_4-P mean at Gala Ford was 0.045 mg l^{-1}, 0.005 mg l^{-1} lower than the mean value for all the Tweed River Purification Board analyses during the period 1962-1973 (see 3.59).

(iv) Teviot Foot to Whiteadder Foot

Conductivity showed a 25% increase below Teviot Foot. It rose to 200 micro-mhos, and remained at the same level throughout the rest of the river. pH showed a consistent increase of half a unit which was also maintained throughout the stretch, except for a slight drop in the tidal region. Mg and Ca increased by greater amounts, and also stayed at constant levels throughout. Na remained the same, but K increased steadily to reach a maximum in the middle of the stretch. Cl only increased marginally, and Si showed a marginal decrease. The levels of the four nutrients in the Tweed and Teviot prior to their mixing were very similar, and only NH_4-N showed a significant increase below their confluence. NO_3-N rose only slightly, and PO_4-P and NO_2-N dropped slightly.

This lower stretch was characterised by harder water of average hardness, increased pH, K, NH_4-N, with little change in other elements.

A discussion of the levels of heavy metals down the river has not been included because levels were so low, and varied little from one stretch to another. Only in the three lowest sites in the Tweed were levels of Fe and Al significantly higher than elsewhere in the river; this could be attributed to high levels in the Till on 22.V.73. The Till's flow on that date was above average.

5.4 Water chemistry of tributaries

The main features of the chemistry of each tributary are summarized and compared with stretches of the Tweed, and to a lesser extent other tributaries. Only the elements most frequently referred to in discussions of plant distribution are described.

BIGGAR WATER: Data are available from only one survey (22.V.72), however, it shows that the Biggar was of higher conductivity, Na, K, Mg, Ca, Cl, Si, PO_4-P, NO_2-N and NO_3-N than the upper reaches of the Tweed. It was comparable in hardness and Na and K levels to the mid-reaches of the Tweed; it was however, more nutrient rich. Cl and Si were higher than any stretch of the Tweed.

LYNE WATER: Conductivity, Mg and Ca in this tributary were akin to levels in the lowest stretches of the Tweed, and almost double that of the upper reaches above its confluence. Na and K were also high, and similar to levels in the Biggar. Cl and Si were higher than the upper stretches of the Tweed, but lower than in the Biggar. The Lyne, apart from NO_3-N, was nutrient poor and similar to the upper Tweed. The Lyne most resembled the upper Whiteadder in hardness characteristics.

MANOR and EDDLESTON: These tributaries were not surveyed for macrophytes, their water chemistry being important only when considering their influence on the main river. The former river was soft and nutrient poor (except for NH_4-N), and thus had a clean water, dilution effect on the Tweed. The latter on the other hand, was slightly harder than the Tweed, and very much richer in nutrients (except NH_4-N). The Eddleston thus had the opposite effect to the Manor.

YARROW WATER: At the head of this tributary is St. Mary's Loch, into which the very soft and nutrient poor water of the Megget flows. The influence of the loch in affecting the river's chemistry is unknown. The lower stretches of the Yarrow were softer, and as nutrient poor as the Tweed above the Biggar. Hardness levels were intermediate between very soft and soft; Si was as low as at any site in the whole catchment, and only NH_4-N was higher than in upper Tweed.

ETTRICK WATER: For a comprehensive description of the water chemistry of this tributary, it would have been necessary to sample above and below Yarrow Foot, and above and below Selkirk Sewage Works. The foot of the river was sampled on five occasions, but the stretch above Yarrow Foot was sampled only once. That single sample indicated that above the Yarrow, the Ettrick had a chemistry almost identical to that of the upper Tweed, and that the Yarrow effected a slight softening of its waters. The effect of the sewage discharge of Selkirk was to slightly increase NO_3-N, almost double Na, K, NH_4-N and NO_2-N and more than quadruple the PO_4-P level. In comparison with the Tweed, only PO_4-P and NH_4-N were high; the former was equivalent to the reaches above Teviot Foot, where it was consistantly at its highest level in the Tweed; and the latter was higher than in any other sites, except in the Jed below Jedburgh Sewage Works.

GALA and LEADER WATERS: These tributaries discharge their waters into the Tweed between the Ettrick and Teviot. They were not surveyed for macrophytes, and are thus discussed only briefly. Gala was marginally harder, and of similar nutrient status as the Tweed, and thus had little effect on the chemistry of the larger river. The latter was, however, of average hardness, and hence being harder than the Tweed it caused a rise in conductivity, Mg and Ca.

RIVER TEVIOT: Three sites were regularly sampled to show any changes down its entire length. Even in the upper stretches above Hawick, hardness levels were far greater than in the lowest stretches of the Tweed. The water was hard from the beginning, and only increased slightly downstream, with Mg showing a disproportionate increase to Ca. Na and K increased downstream, but in the lower reaches was no greater than in the equivalent stretch of the Tweed. Cl also increased on passing downstream, but was only higher than in the Tweed in stretches below the Jed. Si, as in the Tweed, decreased downstream. PO_4-P was undetectable above Hawick, but increased to a maximum in mid-river (almost certainly due to Hawick), and then became slightly reduced in the lowest stretches. Between Hawick and Teviot Foot, PO_4-P levels were consistently higher than in the Tweed. NH_4-N was highest above Hawick, and in the lower stretches less than in the lower half of the Tweed. NO_2-N and NO_3-N levels were similar to those in the Tweed. The major tributary influencing the chemistry of the Teviot was the Jed, and since it was surveyed for macrophytes, it will be discussed separately.

JED WATER: Jed Foot was included in the main survey, and on 22.V.73, two additional samples were taken from above the burgh's sewage works. The Jed had moderately hard water and Mg, Na and K were double that of the Teviot. The additional samples above the sewage works indicate that the burgh's effluent was responsible. Cl was higher than elsewhere in the Basin, and like Na, double the value above the sewage works. Of the major nutrients, NO_3-N levels were low, both above and below the effluent, PO_4-P and NO_2-N were high, and very significantly increased below the sewage works. NH_4-N consistently during the survey reached very high levels below the sewage works, and was almost twice as high as the next highest site in the Tweed Basin; i.e. below Selkirk Sewage Works in the Ettrick.

EDEN WATER: This tributary was harder than the Jed, but levels of Na and K were lower. The nutrient status of the Eden was comparable with the lowest stretches of the Teviot, and Cl and Si means were also almost identical.

LEET WATER: This tributary and the smaller Lambden Burn were by far the hardest tributaries of the Tweed. Even at its foot, after mixing with water from the Tweed that comes from a mill-lade, the water of the Leet was still hard. The single sample taken of the Leet above Leithen (km -12.3) had conductivity of 750 micro-mhos and Ca of 129 mg l^{-1}. Na and K were also high, with the former being lower than in the Jed. Cl was high, and in the upper stretches higher than in any other site in the Tweed. PO_4-P, NO_2-N and NO_3-N were the highest of all the tributaries surveyed for macrophytes, but NH_4-N was no higher than in the lowest stretches of the Tweed.

RIVER TILL: If one site on the Till (km -1.5) may be taken as representative of the chemistry of the whole river, it can be regarded as of average hardness, yet slightly harder than the lowest stretches of the Tweed. Na and K were also higher. All the major nutrients were lower than in the lower stretches of the Tweed. Si on the other hand, was higher than in the lower stretches of the Tweed, and also higher than in any other large tributaries.

BLACKADDER WATER: This was the hardest and most nutrient rich large tributary. At its foot it was very hard, with Mg levels at 23.5 mg l^{-1} and Ca at 50 mg l^{-1}. Na and K were high too. Cl and Si were at similar levels as at the foot of the Teviot, but all nutrients except NO_2-N were higher, PO_4-P in particular was higher than at any site except Leet Foot. Phosphate, however, as the samples of the river on 22.V.73 show, were not high throughout the river's length. High values were confined to below Langton Burn which carried the effluent of the town of Duns. NH_4-N was not particularly high, but NO_3-N was higher than all others except the Eden and Leet. This too, was due to the Langton.

WHITEADDER WATER: Above Blackadder Foot the Whiteadder was of average hardness, with Mg higher, and Ca lower than in the Tweed below Teviot Foot. Conductivity, Na and K were only marginally higher. Its nutrient status was equivalent to the Tweed above Teviot Foot in all but its PO_4-P, which was 60% lower.

The mixing of the two Adder Waters resulted in conductivity, K, Mg and Ca at the foot of the river being almost exactly half the total of the two affluents above their confluence. This resulted in the water being classed as hard. The Blackadder increased PO_4-P and NH_4-N levels in the Whiteadder, but NO_2-N and NO_3-N were not greatly affected, the former increasing, and the latter decreasing on passing downstream. Nutrient levels were generally similar to those in the lowest stretches of the Tweed, but Cl was higher.

6. PRIMARY MACROPHYTE DATA

6.1 Introduction

The primary data of the two rivers which were surveyed throughout their entire lengths, and also the 10 tributaries which received only partial surveys, are given in full in this chapter.

As the Tweed is the major river of the catchment area it was studied throughout its entire length. Because the Teviot is the largest tributary, and since greatest changes in the recipient river occurred immediately below Teviot Foot, that river was also surveyed throughout its entire length. Lack of survey time limited the number, and also the extent to which other tributaries could be surveyed. The following tributaries were selected for macrophyte surveys for the reasons outlined below (see fig. 2.2a).

(i) Biggar Water: although the most upstream tributary surveyed, this tributary had a typical physical characteristics (see 3.2).

(ii) Lyne Water: this was the largest tributary in the upper one-third of the catchment area, and in hardness characteristics it most resembled the lower stretches of the Tweed (see 5.4).

(iii) Yarrow Water: tributary of the Ettrick that has a history of being devoid of "weed" growths (Steven, 1916), but reported by Mr J. C. Currie, 1971, personal communication) to support extensive attached algal growths during the summer months.

(iv) Ettrick Water: one of the four largest tributaries of the Tweed

(v) Jed Water: tributary of the Teviot that has moderately hard water, and its water chemistry is, and has in the past been effected greatly by the effluent of Jedburgh (see 3.56 and 5.4).

(vi) Eden Water: a hard water , small, rocky, relatively fast flowing tributary that had physical characteristics more akin to streams in higher reaches, although flowing at low altitude (see 3.2).

(vii) Leet Water: a small, very slow flowing affluent that was harder

and more nutrient rich than any other tributary of the Tweed (see 5.4).
(viii) River Till; one of the largest tributaries of the Tweed, which drains a flat alluvial plain and is thus very slow flowing (see 3.2).
(ix) Blackadder Water: tributary of the Whiteadder, and is slow flowing, hard and nutrient rich (see 3.2, 5.4).
(x) Whiteadder Water: large tributary that discharges into the tidal reaches of the Tweed. It was thus very useful as a control river in ascertaining the importance of donor tributaries providing inocula to recipient rivers.

Macrophyte data for the Tweed are expressed from left to right from km 0.0 at the source of the river in descending order downstream to km 149.5 in the tidal reaches. Conversely, tributary data are given in reverse order from their confluence with the Tweed (km -0.0), to ascending kilometer reference points higher upstream. In the case of the Yarrow and Blackadder, large tributaries of the Ettrick and Whiteadder respectively, the point at which they joined their respective tributaries are expressed as the distance from which they are from the Tweed. Yarrow Foot is thus designated km -7.5 and Blackadder Foot km -17.5 (see Fig. 2.2a). This has been done because the Ettrick and Yarrow at their confluence are of near comparable size, as are the Blackadder and Whiteadder at their confluence. As the Jed was such a small tributary in comparison with the Teviot, the foot of that tributary was designated km -0.0.

The presence or absence of each macrophyte within 0.5 km lengths is indicated by the presence or absence of a figure in the tables. A blank shows that the species was absent, and a figure between 1 and 5 indicates the presence of the species, as well as its abundance within each 0.5 km length (see 2.2). For rivers surveyed throughout, (6.2), the number of times a species was recorded, and its total abundance within every 10 km is summarized to the right of each page With an * indicating absence from 10km. Where the length of partially surveyed tributaries exceeded 10 km, (e.g. 6.37), the datahave been separated into 10 km stretches in order to facilitate ease of comparison with similar stretches of the main river and other tributaries. It also makes back reference to the raw data easier when considering the simulated data in histograms 8.62 and 8.63.

In 6.41,the distribution of species in the Tweed have been summarized in histogram form. The presence or absence from twenty 0.5 km has been plotted for 15 consecutive 10 km stretches from km 0.0 - 9.5 to 140.0 - 149.5. The overall distribution of each species in the whole catchment areahave been summarized in 6.42. Both completely and partially surveyed rivers have been divided into 10 km stretches, and the presence or absence of each species within them plotted. Where a species was absent in a river above a tributary, but common below, and probably inoculated into it by the tributary (e.g. Myriophyllum spicatum in the Tweed at Teviot Foot, km 108.5), only the stretch below the confluence has been shaded. In all other cases, if the species was present, albeit only once in a 10 km stretch, the whole stretch was shaded.

In 6.5 the merit of including an abundance value,in addition to merely recording the presence of the species is illustrated with reference to data given in 6.2 and 6.3.

The presentation of the following primary data section is clarified below by summarizing the sequence in which the material is tabulated.

6.21	Primary macrophyte data from Tweed	pp. 136 - 166
6.22	Primary macrophyte data from Teviot	pp. 167 - 180
6.3	Primary macrophyte data from tributaries	pp. 181 - 199
6.41	Distribution patterns of the species listed in 6.21 in successive 10 km stretches of the Tweed	pp. 200 - 208
6.42	Summary diagrams of the whole Tweed Basin for all species recorded at least five times from either the Tweed or its tributaries	pp. 209 - 220

The text continues on p. 221 with a discussion and comparison of two recording methods.

species	km down River Tweed																				0.5 km total (max. 20)	abundance total (max.100)
	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5		
Nostoc parmelioides																					*	*
Nostoc other sp(p).																					*	*
Phormidium spp.	1	1	1	1	1	1	1	1	1	1	1	1		1			1				13	13
Hildenbrandia rivularis																					*	*
Lemanea fluviatilis		1		1		1			1	1	1					1	1		1		9	9
Botrydium granulatum																					*	*
Vaucheria sp(p).			1																		1	1
Didymosphenia geminata			1	1	3	3	1	1		1	1	1	1	1	2		1	3	1	2	16	24
Heribaudiella fluviatilis		1	1				1			1		1		1		1	1	1		1	10	10
Cladophora glomerata																					*	*
Cladophora sp.'A'																					*	*
Enteromorpha sp(p).																					*	*
Haematococcus viride			1			1		1	1			1			1	1			1		8	8
Monostroma bullosum																					*	*
Oedogonium spp.	1	2	3	3	2	2	1	2	3	3	2	1	3	2	1	4	1	2	3	2	20	43
Tetraspora sp(p).																					*	*
Stigeoclonium tenue									1		1	1				2	2		1	1	7	9
Ulothrix zonata				1		1	1	2			2	1				2	2		2	2	10	17
Prasiola crispa			1		1			1				1	1				1	1	1		8	8
Spirogyra spp.													1		1			1	1		4	4
Collema flaccidum																					*	*
C. fluviatile																					*	*
Dermatocarpon fluviatile																					*	*
Verrucaria praetermissa										1		1	1	1			1			1	6	6
Verrucaria other spp.								1	1		1		1			1	1	1	1		8	8
Acrocladium cuspidatum	2	2	1	3	3	1	1	3	3	3	1	1	1	1	2	1	1	1	1	1	20	33
Amphidium mougeotii			1	1	1				1	1						1	1				7	7
Brachythecium plumosum	4	3	5	3	3	3	2	3	3	2	2	3	4	1	4	4	5	4	1	5	20	64
B. rivulare	2	2	1	1	2	2	1	2		1	2	1	1		2	1	1		1		16	23
B. rutabulum																1		2		1	4	5
Bryum pseudotriquetrum	1	2	2	2	2	2	2	2	3	3	2	1	3	1	1	2	1	2	2	2	20	38
Chiloscyphus polyanthos																					*	*
Cinclidotus fontinaloides	3	3	3	3	4	3	3	3	3	3	3	3	2		1		1				15	41
Climacium dendroides	1	1	1	1				1					1	2		1	1	1		1	11	12
Conocephalum conicum	2	1	1	1	2	2	2	2	1	1	1	2	2	2	1	2	2	1	2	1	20	31
Cratoneuron filicinum	1	1		1	1		1	1		1	1	1	1	1	1	1			1	1	15	15
Dichodontium pellucidum	2	3	2	2	2	2	2	3	4	8	2	3	2	2	1	3	1	2	2	2	20	45
Eurhynchium riparioides	2	1	1	1	1	1	1	2	2	2	2	2	1	1	1	1	1	1	1	1	20	26
Fissidens adianthoides																					*	*
F. crassipes																					*	*
Fontinalis antipyretica	3	3	1	3	3	3	3	3	3	1	4	3	3	3	2	3	3	3	5	3	20	58
F. ant. var. gracilis		1													1						2	2
Funaria hygrometrica						1				1										1	3	3
Grimmia alpicola	2	3	3	3	3	2	1	4	4	5	3	5	2	2	4	1	1	2	2	2	20	54
Hygroamblestegium fluviat	2	2	3	2	2	3	1	3	2	3	3	3	2	1	1	4	1	1	2	4	20	45
Hygrohypnum luridum (ilo	4	2	4	1	3	2	3	3	3	4	4	2	5	5	3	3	3	1	2	5	20	62
H. ochraceum	2	2	1	2	3	1		1				1	1				3				10	17
Leptodictyum riparium																					*	*
Leskea polycarpa																					*	*
Marchantia polymorpha													1	1	1	1	1	1		1	7	7
Mnium longirostrum																	1			1	2	2
M. punctatum	1	1			1		1	1			1			1	1			1	1		10	10
Orthotrichum rivulare																1					1	1

species	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Pellia endiviifolia													1	1	1						3	3
P. epiphylla	2	2	1											1	1	2	2	1	2	1	10	15
Philonotis fontana	2	2	1	1	2	2	1	2	2	2	2	1	3	2	3	2	2	2	2	2	20	38
Scapania undulata	1	1			1	1			1	1	1		1			1	1				10	10
Solenostoma triste	2	3	1	2			1	2	1		3	3	3	1	1	3	2	1	1	2	17	32
Thamnium alopecurum																					*	*
Tortula mutica																					*	*
Rhacomitrium acicularis		1		1	1	1	1	1			1										7	7
R. aquaticum							1	1					1		1				1		5	5
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1		1				16	17
Caltha palustris		1				1	1	1	1	1	1		1						1		9	9
Carex nigra								1	2	1	1		1		1	1	1		1		9	10
C. rostrata														1					1	1	3	3
Carex other spp.										1			1			1			1		4	4
Cochlearia alpina	1	1		1		1		1	1	1	1				1	1		1	1	1	13	13
Eleocharis palustris																					*	*
Elodea canadensis																					*	*
Equisetum fluviatile																					*	*
Filipendula ulmaria		1					1				1					1			1	1	6	6
Glyceria fluitans					1				1	1					1		1				5	5
Iris pseudacorus																					*	*
Juncus acutiflorus	1	1		1	1		1	1		1	1	1			1				1		11	11
J. effusus	1		1	1	1	1	1	1	1	1	1		1	1	1	2	1	1	1		17	18
J. inflexus																					*	*
Mentha aquatica																		1			1	1
Mimulus guttatus	1	1		1			1	1	1	3	2	2	1	1	1	1	1	1	1	1	17	21
Myosotis scorpioides	1	1			1	1	1				1			1	1		1			1	10	10
Myriophyllum alterniflorum	2	1	1	1	4	1	1	1	1	3	3		1	3	3	1	1	1	4		18	33
M. spicatum																					*	*
Phalaris arundinacea																					*	*
Polygonum amphibium																					*	*
Potamogeton crispus																					*	*
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus																					*	*
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.																					*	*
R. flammula		1					1		1		1						1	1			6	6
R. fluitans x ?																					*	*
R. penicillatus var. calcareus																					*	*
Rorippa amphibia																					*	*
R. nasturtium-aquaticum					1	1					1								1		4	4
Scirpus sylvaticus																					*	*
Sparganium erectum																					*	*
Veronica beccabunga	1				2	1			1					1				1	1	1	8	9
Zannichellia palustris																					*	*
sewage fungus (obvious)																					*	*

species	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Nostoc parmelioides																					*	*
Nostoc other sp(p).													1								1	1
Phormidium spp.		1	1			1		1	1												5	5
Hildenbrandia rivularis		1							1						1					1	4	4
Lemanea fluviatilis		2				1			1					1	1			1			6	7
Botrydium granulatum																					*	*
Vaucheria sp(p).						1					1		1	1							4	4
Didymosphenia geminata	2	1	1	1	1	3	4	1	1	2	3	3	3	2	1	3	5	1	3	5	20	46
Heribaudiella fluviatilis	1	1		1	1			1		1			1	1		1		1	1	1	12	12
Cladophora glomerata		1																			1	1
Cladophora sp.'A'																					*	*
Enteromorpha sp(p).																					*	*
Haematococcus viride	1		1										1				1				4	4
Monostroma bullosum																					*	*
Oedogonium spp.	1	2	1	1	1	1	2	2	1	1	1	1	1	2	1		1	2	1	1	19	24
Tetraspora sp(p).																					*	*
Stigeoclonium tenue	1	2	1	1	2	2	3	1	1		1	1	1	1	2	1	1	2	1	1	19	26
Ulothrix zonata	2	2	3	1	2	1	3	2	1	1	1		2		1	2		1	1	1	17	27
Prasiola crispa	1		1	1					1		1						1	1		1	8	8
Spirogyra spp.			1		2			1						1	1	1	2		1	2	9	12
Collema flaccidum													1								1	1
C. fluviatile																					*	*
Dermatocarpon fluviatile																					*	*
Verrucaria praetermissa				1									2				1			1	4	5
Verrucaria other spp.	2	1			3	1		1		1	1	1	2		1	2	1	2	2	1	15	22
Acrocladium cuspidatum	2	2	3	4	2	2	2	2	1	1	2	2	2	1	1	1	1	1	1	2	20	35
Amphidium mougeotii		1	1	1					1				1	1							6	6
Brachythecium plumosum	4	4	5	4	4	4	3	1	1	3	3	2	3	3	2	2	2	3	1	1	20	55
B. rivulare		1	1	1		1	1		1	1		2	1	1	1	1	2	1	1		15	17
B. rutabulum																1			1		2	2
Bryum pseudotriquetrum	2	3	2	2	2	1		2	1	2	2	2	2	1	2	2	2		1	2	18	33
Chiloscyphus polyanthos		1				1					1		1	1							5	5
Cinclidotus fontinaloides	2	2					3	1	3	1	1	1	1	1	3	2	1	1	1	2	16	26
Climacium dendroides		1							2	2	1	1	1			1		2		2	9	13
Conocephalum conicum		1				1	1	1								1			1	1	7	7
Cratoneuron filicinum	1	2			1					1	1	1	2	1	2	2	1	1	1	3	14	20
Dichodontium pellucidum			1	1		1	1	1	1	2	2	2	2	1	2	1	1		1	1	16	21
Eurhynchium riparioides	2	2	1	1	2	1	2	1	1	1	2	2	3	1	1	3	2	2	1	1	20	32
Fissidens adianthoides												1			1				1		3	3
F. crassipes																					*	*
Fontinalis antipyretica	3	4	5	3	3	1	3	4	3	3	3	1	3	3	3	3	2	2	3	3	20	58
F. ant. var. gracilis																					*	*
Funaria hygrometrica							1				1			1				1	1		5	5
Grimmia alpicola	2	3	2	2	2	2	2	3	2	1	2	2	3	2	2	2	2	1	1	2	20	40
Hygroamblystegium fluviat	4	3	2	3	3	2	4	1	2	3	2	2	3	2	1	4	2	2	2	4	20	51
Hygrohypnum luridum (ile	2	3	3	3	2	2	5	2	5	2	4	4	2	1	4	4	2	3	2	4	20	59
H. ochraceum		1	1	1	1	1	4		3				1		1				1		10	15
Leptodictyum riparium																					*	*
Leskea polycarpa																					*	*
Marchantia polymorpha		1	1			1	1		1			1	1						1		8	8
Mnium longirostrum	2			1	1					2	1	1	2	1	1		1	1			11	14
M. punctatum	1	1	1	1			1						1	1			1	1			9	9
Orthotrichum rivulare							1								1				1		3	3

species	km down River Tweed 10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	0.5 km total (max. 20)	abundance total (max.100)
Pellia endiviifolia																					*	*
P. epiphylla	1	2	1			2			1	1	1			1		2					9	12
Philonotis fontana	2	2		1			1	2	1	2	2	1	2	2	1	1			3	1	15	24
Scapania undulata	1	3		1								1			1						5	7
Solenostoma triste	1	1		1				1			1	1	1				1	1			9	9
Thamnium alopecurum		2											2								2	4
Tortula mutica																					*	*
Rhacomitrium acicularis																					*	*
R. aquaticum					1	1									1	1	1				5	5
Rhytidiadelphus squarrosus	1										1						1				3	3
Callitriche spp.	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1		1	1	17	17
Caltha palustris	1	1	1	1	1		1	1		1	1	1	1	1	1	1	1	1		1	17	17
Carex nigra	1		1	1	1	1	2	1	1	1	1	1	1	1		1		1	1	1	17	18
C. rostrata				1			1				1					1		1			5	5
Carex other spp.			1							1		1						1			4	4
Cochlearia alpina	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	19	19
Eleocharis palustris									1			1			1	2	1			1	6	7
Elodea canadensis																					*	*
Equisetum fluviatile									1	1	1	1		1	1	1	1	1	1	1	11	11
Filipendula ulmaria	1	1	1	1	2	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	20	22
Glyceria fluitans	1			1			1														3	3
Iris pseudacorus																					*	*
Juncus acutiflorus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	20	21
J. effusus	1	1	1	1	1		1	1		1	1	1	2	1	1	1	1	2	1	1	18	20
J. inflexus																					*	*
Mentha aquatica		1	1	1					1	1		2	2	1		1	2	1		2	12	16
Mimulus guttatus	1	1	1	3	1	1	2	2	1	1	1	2	1	1	1	1	2	1	1	1	20	26
Myosotis scorpioides	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20	20
Myriophyllum alterniflorum	3		1	1	4	1	1	1			2	3	1		1	3	1	1	1	1	16	26
M. spicatum																					*	*
Phalaris arundinacea				1	1		1	1	1	1	1	1	1	1	1	1	2	1	1	1	16	17
Polygonum amphibium																					*	*
Potamogeton crispus																					*	*
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus																					*	*
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.																					*	*
R. flammula					1				1		1	1		1			1	1	1		8	8
R. fluitans x ?																					*	*
R. penicillatus var. calcar (eus																					*	*
Rorippa amphibia													1		1						2	2
R. nasturtium-aquaticum	1			1		1	1	1	1		1	1	1		1	1	1	1	1		14	14
Scirpus sylvaticus													1								1	1
Sparganium erectum																					*	*
Veronica beccabunga	1		1	1	1	1	1	1	1			1		1	1	1	1	1	1	1	16	16
Zannichellia palustris																					*	*
Sewage fungus (obvious)																					*	*

species	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0	28.5	29.0	29.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Nostoc parmelioides																					*	*
Nostoc other sp(p).																					*	*
Phormidium spp.					1					1		1			1		1		2	2	7	9
Hildenbrandia rivularis			1	1	1			1	1		1	1		1	2	1	2	2			12	15
Lemanea fluviatilis		2					1		1	1			1				2		1	1	8	10
Botrydium granulatum																					*	*
Vaucheria sp(p).																					*	*
Didymosphenia geminata	4	3	1	1	5	5	5	5	1	1											10	31
Heribaudiella fluviatilis		1	1		1	1		1	1	1	1		1	1	1	1	1		1	1	15	15
Cladophora glomerata												1		1			1	2	1	1	6	7
Cladophora sp.'A'																					*	*
Enteromorpha sp(p).																					*	*
Haematococcus viride							1									1					2	2
Monostroma bullosum																					*	*
Oedogonium spp.	1	1	2	1	1	2	1	1	1	1	1	1	2	1	1	1	2	1	3	1	20	26
Tetraspora sp(p).																					*	*
Stigeoclonium tenue	2	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	1	1	1	2	20	24
Ulothrix zonata	1	3	1		1	2	3	1	2	3	1	1		1	2	4	3	1	1	1	18	32
Prasiola crispa			1			1			1	1		1			1		1				7	7
Spirogyra spp.			1					1					1	1			1	1	1	1	8	8
Collema flaccidum																					*	*
C. fluviatile																					*	*
Dermatocarpon fluviatile		1									1								2		3	4
Verrucaria praetermissa		1								1						1			2	1	5	6
Verrucaria other spp.	1	1	1		1	2		1	1	1	1	2	1	2	1	2	2	1	1		17	22
Acrocladium cuspidatum	1		2	2			1	1						1	1		1	1	1	1	11	13
Amphidium mougeotii											1										1	1
Brachythecium plumosum	2	2		2		1					1			1				1		1	8	11
B. rivulare	2	2	4	1		1	1	2	2	2		1	2	1	1	1	2	2	1	4	18	32
B. rutabulum																			1		1	1
Bryum pseudotriquetrum	2	1	2		2	2	1	2		1	1		1		1		2	1	2		14	21
Chiloscyphus polyanthos		1	1	1	1	1	1	1						1	1	1			1	1	12	12
Cinclidotus fontinaloides	1	2	1	2	3	3	2			1		2		1	2	3	1	1	3	3	16	31
Climacium dendroides			1			1															2	2
Conocephalum conicum			2	2		1							1			1	1	1	1	1	9	11
Cratoneuron filicinum	2	1	2	1		1	2	2	1	1	1	1	1	1	1	1	1	2	1	1	19	24
Dichodontium pellucidum	1	1	1	2		2		1	1		2	1	1	1		1	2	1	1	1	16	20
Eurhynchium riparioides	3	3	1	3	4	3	2	1	1	3	1	3	4	3	2	4	3	3	3	1	20	51
Fissidens adianthoides				1		1										1					3	3
F. crassipes																					*	*
Fontinalis antipyretica	4	3	4	3	3	3	2	1	1	1	1	3	2	2	3	3	3	3	3	3	20	51
F. ant. var. gracilis																					*	*
Funaria hygrometrica						1			1							1					3	3
Grimmia alpicola	2	1	2	2	2	1	2		1	1		1	1	1	1	1		1	2	2	17	24
Hygroamblestegium fluviat	3	1	3	3	2	4	2	1	1		1	1	4	1	2	4	2	2	3	3	19	43
Hygrohypnum luridum (ile	5	3	5	2	2	2					1			2		1			1	2	11	26
H. ochraceum		2		2	1	1	1	2		1				2							8	12
Leptodictyum riparium																					*	*
Leskea polycarpa																		3	1		2	4
Marchantia polymorpha								1		1				2		1	1			1	6	7
Mnium longirostrum		1		1	1	1				1				1			1		1		8	8
M. punctatum	1	1				1															3	3
Orthotrichum rivulare						1	1													1	3	3

km down River Tweed

species	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0	28.5	29.0	29.5	0.5 km total (max. 20)	abundance total (max.100)
Pellia endiviifolia		1	1				1														3	3
P. epiphylla		1	1			1	1		1				1			1					7	7
Philonotis fontana	2	1	4	2	2	2				1	1					1		1	1	1	12	19
Scapania undulata	1												1	1		2	2	2	1		7	10
Solenostoma triste			1			1	1							1	1	1				1	7	7
Thamnium alopecurum					1	2										1				1	4	5
Tortula mutica												1		1			1	1			4	4
Rhacomitrium acicularis				1																	1	1
R. aquaticum																					*	*
Rhytidiadelphus squarrosus						1															1	1
Callitriche spp.	1		1	1	1	1			1	1		1	1	1	1	3	1	1	2	1	16	19
Caltha palustris	1	1	1	1	1	1			1			1	1	1	2	1	1	1			14	15
Carex nigra	1	1		1						1						1					5	5
C. rostrata			1	2		1		1		1		1				3	1	1	1	1	11	14
Carex other spp.											1					1					2	2
Cochlearia alpina		1				1															2	2
Eleocharis palustris			1		1									1	1	1			1	1	7	7
Elodea canadensis							1		1	1		1	1		1	3		1	2	4	10	16
Equisetum fluviatile	1		1	1	1	1	1		1	1			2			2			1		11	13
Filipendula ulmaria	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1			1		16	16
Glyceria fluitans			1		1		1									1			1		5	5
Iris pseudacorus				1	1							1									3	3
Juncus acutiflorus	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	2	1	20	22
J. effusus	1	1	1	1	1	2	1	1	2	1	1	1	2	1	1	1	1	1	1	1	20	23
J. inflexus																					*	*
Mentha aquatica					1	2	1	1	1	1		1	1	1	2	1	1			1	13	15
Mimulus guttatus	1	1	1		1	1	1	1	1	1	1	2	1	1	1	1	1	1	2	1	19	21
Myosotis scorpioides	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	1	1	1	20	22
Myriophyllum alterniflorum	3	1	2	4	2	3	1	1	1	1	2	2	1	1	2	3	3	2	3	1	20	39
M. spicatum																					*	*
Phalaris arundinacea	1		1		1	1	1	1	2	1	3	1	1	2	1	2	1	1	1	1	18	23
Polygonum amphibium		1									1			1					1		4	4
Potamogeton crispus													3	1	1	3		1	1	1	7	11
P. lucens																					*	*
P. natans				1												2					2	3
P. x olivaceus									1		1	1	3		1	1	1	1	1	1	10	12
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.			1	1	1	1	1		1	2		1	1			2	1	2	2	1	14	18
R. flammula		1			1																2	2
R. fluitans x ?																					*	*
R. penicillatus var. calcar					1					3	1			1	2	3	3	3	3	1	10	21
Rorippa amphibia (eus																					*	*
R. nasturtium-aquaticum	1		1	1	1	1		1	1		1			2	1	1	1	1	1	1	15	16
Scirpus sylvaticus							1														1	1
Sparganium erectum				3					1		1	1		1	1	1	1		1		9	11
Veronica beccabunga	1	1				1	1	1	1	1		1	1	1			1	1			12	12
Zannichellia palustris																					*	*
sewage fungus (obvious)																					*	*

species	km down River Tweed																				0.5 km total (max. 20)	abundance total (max.100)
	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0	35.5	36.0	36.5	37.0	37.5	38.0	38.5	39.0	39.5		
Nostoc parmelioides																					*	*
Nostoc other sp(p).																1					1	1
Phormidium spp.		1			1			1	1	1								2			6	7
Hildenbrandia rivularis		1	1	2	1	1	1	2	2	1	1	2	1	1	4	2	2	1	2	1	19	29
Lemanea fluviatilis					1	1	1	1			1	1				1					7	7
Botrydium granulatum																					*	*
Vaucheria sp(p).											1	1			1						3	3
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	1	1	1	2	1	1	1	1	2	1	1		1	1	2	1			1	1	17	20
Cladophora glomerata		1		1	2	1		1	2	2	1	1	2	1	1	1	1	1	2	1	17	22
Cladophora sp.'A'															1						1	1
Enteromorpha sp(p).																					*	*
Haematococcus viride									1												1	1
Monostroma bullosum																					*	*
Oedogonium spp.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20	20
Tetraspora sp(p).																					*	*
Stigeoclonium tenue	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	19	19
Ulothrix zonata	2	1	2	1	1	1	2	1	1	1	2	1	1	1	1	1	2	1	2		19	25
Prasiola crispa			1					1			1				1						4	4
Spirogyra spp.		1	1	1			1			1										1	6	6
Collema flaccidum																					*	*
C. fluviatile													3	1	3					3	4	10
Dermatocarpon fluviatile		1	1					1	1	1		1		1			1	1	1	1	11	11
Verrucaria praetermissa	1	1	1	1	1	1	1		1	1		1	1				1		1	1	14	14
Verrucaria other spp.	1	1	1	1	1	1	1	2	3	1	1	2	1	1	3	2	2	1	2	1	20	29
Acrocladium cuspidatum		1				2	1			1		1	1	2					1		8	10
Amphidium mougeotii					1																1	1
Brachythecium plumosum		1		1	1	1	1		1			1									7	7
B. rivulare		1	2	1	1	2	3	1		1	1	1	1	1		2	2	2	1	2	17	25
B. rutabulum	1		1	1	1		1	1	1		1	1	1		1		1				12	12
Bryum pseudotriquetrum				1	2	1	2	1		1			1	1		1	2	1	2		12	16
Chiloscyphus polyanthos	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1		2	1	18	19
Cinclidotus fontinaloides	1	1	1	2	3	1	3	3	2	1	1	5	1	2	1	1	3	3	3	3	20	41
Climacium dendroides																					*	*
Conocephalum conicum	2	2	1	1	1	1		1	3	1	1	1	3	3	1	1		1	1	1	18	26
Cratoneuron filicinum	2	3	3	1	2	3	1	3	1	1	2	2	1	1	1	1	2	3	3	1	20	37
Dichodontium pellucidum	1	2		2	3	2	1		1	2			1	2		1	2	2	1	2	15	25
Eurhynchium riparioides	1	3	5	3	3	5	4	4	3	4	4	3	3	3	4	3	4	3	5	1	20	68
Fissidens adianthoides								1				2	1	2				1	1		6	8
F. crassipes																					*	*
Fontinalis antipyretica	2	3	3	3	3	1	1	3	2	1	1	1	2	3	2	3	2	2	3	1	20	42
F. ant. var. gracilis																	1				1	1
Funaria hygrometrica			1			1			1				1						1		5	5
Grimmia alpicola	2	1	1	1	1		1				1		1	1	1			1		1	12	13
Hygroamblystegium fluviat	4	3	2	2	2	3	2	3	3	3	1	2	3	2	1	2	3	3	1	3	20	48
Hygrohypnum luridum (ile					2					1											2	3
H. ochraceum	1		2		2		1			1	1							1	2		8	11
Leptodictyum riparium																					*	*
Leskea polycarpa	3	2	1	1	1		1		1					1					3	1	10	15
Marchantia polymorpha		1	1					1				1	1	1	1			1	1	1	10	10
Mnium longirostrum			1			1	2				1	2	1	1	1	1		1			10	12
M. punctatum				1									1								2	2
Orthotrichum rivulare			1			1		1				1						1	1		6	6

species	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0	35.5	36.0	36.5	37.0	37.5	38.0	38.5	39.0	39.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Pellia endiviifolia	1			1	1								1					1			5	5
P. epiphylla				1			1		1		1		2			2		1			7	9
Philonotis fontana						3			2						1		2	2	2		6	12
Scapania undulata				1	1								1								3	3
Solenostoma triste	1	1		1			1		1										1		6	6
Thamnium alopecurum					1	1							1								3	3
Tortula mutica		1		2											1	1		1	1		6	7
Rhacomitrium acicularis			1			1															2	2
R. aquaticum							1														1	1
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.	1		1		1			1	1		1					1			1		8	8
Caltha palustris	1	1	1	1	1	1	1	1	1	1		1	1	1		1	1	1	1	1	18	18
Carex nigra			1						1												2	2
C. rostrata						1	1						1				1				4	4
Carex other spp.																					*	*
Cochlearia alpina																					*	*
Eleocharis palustris	1	1			1	1	1								1		2		1		8	9
Elodea canadensis		1	2	1	1		1	1		1	1	1	3	3	1	3	2	2	3	2	17	29
Equisetum fluviatile		1	1		2	2		1									1		1		7	9
Filipendula ulmaria		1	1		1	2		1	1	1	2	1	1	1	1	2		2	1	1	16	20
Glyceria fluitans	1										1	1			1	3	3		1		7	11
Iris pseudacorus														1							1	1
Juncus acutiflorus		1	1	1		2	1	2		1	1	1			1		1	2	1	1	14	17
J. effusus				1		2	1	2	1	1	1						1		1		9	11
J. inflexus																					*	*
Mentha aquatica	1	1	1					1	1			1			1	1			1	1	10	10
Mimulus guttatus	1	1	1	1	1	1	1	1	1	1	2	1	1	1	3	3	1	2	2	1	20	26
Myosotis scorpioides	1	1	1	1	1	1	1	1	1	2	2	1	1	1	3	3	1	2	2	1	20	28
Myriophyllum alterniflorum	1	1	3	3	4	1	4	3	1	2	3	3	1	3	2	3	3	2	3	2	20	48
M. spicatum																					*	*
Phalaris arundinacea		2	2	1	1	1	3	1	1	2	2	1	2	3	3	2	3	2	2	2	19	38
Polygonum amphibium										1	1		1		1	1					5	5
Potamogeton crispus	1	1			1				1		1	1		1		1	1	1	1		11	11
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus		1		1	1	1		1	1	1	1	3	3	2	3	4	1	1	2	2	17	29
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.	1	1	2	3		1	1	1	1	2	2	1			1		2	2	1	1	16	23
R. flammula																					*	*
R. fluitans x ?																					*	*
R. penicillatus var. calcar (eus			2	2	1			2		2	2	1	1	1	1	2	2	2		2	14	23
Rorippa amphibia																					*	*
R. nasturtium-aquaticum	1	1	1	1	1	1				1	1	1							1		10	10
Scirpus sylvaticus									1	1			1		1						4	4
Sparganium erectum										1	2	1	3	3	3	1	2		3		9	19
Veronica beccabunga	1		1	1		1				1					1	1	1		1	1	10	10
Zannichellia palustris																					*	*
sewage fungus (obvious)																					*	*

species	km down River Tweed 40.0	40.5	41.0	41.5	42.0	42.5	43.0	43.5	44.0	44.5	45.0	45.5	46.0	46.5	47.0	47.5	48.0	48.5	49.0	49.5	0.5 km total (max. 20)	abundance total (max.100)
Nostoc parmelioides																2					1	2
Nostoc other sp(p).						1					1							2		1	4	5
Phormidium spp.	1	1	1		1	1	1			1				1	1			2	1		11	12
Hildenbrandia rivularis	2	1	1	2	2	2	1	1	1	1	1	3	3	3	1	3	2	2	1	1	20	34
Lemanea fluviatilis					1			1		1		1						1			5	5
Botrydium granulatum																					*	*
Vaucheria sp(p).		1	1	1	2	1	1	1					1	1				1	1	1	12	13
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	2	1	1		1	1	1	2	1	1	1	1	1	1	2	2	1	1	2	1	19	24
Cladophora glomerata	1	1	1	1	3	1	1	1			1	2	1		1	1	1	2	1		16	20
Cladophora sp.'A'	1	1																			2	2
Enteromorpha sp(p).																					*	*
Haematococcus viride																					*	*
Monostroma bullosum																					*	*
Oedogonium spp.	1	1	1	1	3	3	1	1		1	1	1	3	2	1	3	2	2	1	1	19	28
Tetraspora sp(p).																					*	*
Stigeoclonium tenue	1	1	1	2	2	1	1	2	1	1	1	1	2	1	1	1	2	1	1	1	20	25
Ulothrix zonata	1	2	2	1	1	2	2	1	1	1	2	2	2	1	1				1		16	23
Prasiola crispa	1			1		1		1	1												5	5
Spirogyra spp.							1													1	2	2
Collema flaccidum																			1		1	1
C. fluviatile	2	1				1			1			2								1	6	8
Dermatocarpon fluviatile		1			1		1														3	3
Verrucaria praetermissa		1	1	1					1	1				1			1	1	1		9	9
Verrucaria other spp.	3	3	2	3	3	5	2	2	2	2	2	3	4	1	2	3	3	4	2	2	20	53
Acrocladium cuspidatum		1	1	1		1		1							2				1	1	8	9
Amphidium mougeotii																					*	*
Brachythecium plumosum		2			1							1							1		4	5
B. rivulare	1	2	1	2	1	1		3		1		1	1	1	1	2	1	2	1	1	17	23
B. rutabulum	1	2	1	1								1			2	1		1	1	1	10	12
Bryum pseudotriquetrum		2		1		1		1				1		2							6	8
Chiloscyphus polyanthos		1		1	1	1							1	1				1		1	8	8
Cinclidotus fontinaloides		1	1	1	3	4	3	2					2	2	1	3		2	1		13	26
Climacium dendroides																					*	*
Conocephalum conicum	1	2	2	2	1	3	1	3	1		1		1	3	1			2		1	15	25
Cratoneuron filicinum	1	1		2	2	1								2	1	1			1	1	10	13
Dichodontium pellucidum		1	1		1	1						2	2			1	2		1		9	12
Eurhynchium riparioides	5	3	3	4	3	5	3	4	3	4	4	2	3	3	3	3	1	3	3	3	20	65
Fissidens adianthoides				1	2														2		3	5
F. crassipes																					*	*
Fontinalis antipyretica	1	3	2	4	3	1	2	3	2	1	2	2	3	1	3	1	1	2	3	3	20	43
F. ant. var. gracilis																					*	*
Funaria hygrometrica																1					1	1
Grimmia alpicola		1	1		2	1	1	2			1		1	1		1			1		11	13
Hygroamblestegium fluviat	1	3	2	4	3	3	3	3	3	4	2	3	3	2	2	2	1	1	2	2	20	49
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium								2	1	2	1					1					5	7
Leskea polycarpa					1							2	1								3	4
Marchantia polymorpha		1	1		1	1	1		1	1			1	2			1	2	1	1	13	15
Mnium longirostrum		2		1	1			1						1					1		6	7
M. punctatum																		1			1	1
Orthotrichum rivulare						1	1														2	2

species	40.0	40.5	41.0	41.5	42.0	42.5	43.0	43.5	44.0	44.5	45.0	45.5	46.0	46.5	47.0	47.5	48.0	48.5	49.0	49.5	0.5 km total (max. 20)	abundance total (max. 100)
	km down River Tweed																					
Pellia endiviifolia		1	1										1								3	3
P. epiphylla			2		1					1					1	1		1			6	7
Philonotis fontana					1								1	1							3	3
Scapania undulata					1																1	1
Solenostoma triste		2	1	1	1									1	1						6	7
Thamnium alopecurum																					*	*
Tortula mutica	1								1						2	1	1		1	2	7	9
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus									1				1								2	2
Callitriche spp.		1	1		1			1		1		1	1		1	1	1	1	1		12	12
Caltha palustris	1	1	1	1	1			1	1	1	1	1	1	1	1	1			1		15	15
Carex nigra															1						1	1
C. rostrata	1										1	1			2		2			1	6	8
Carex other spp.									1												*	*
Cochlearia alpina																					*	*
Eleocharis palustris			1					1		1	1	1			3	1	3	1	1	1	11	15
Elcdea canadensis	4	1	2	1	3	3	4	1	3	3	3	2	4	4	3	3	3	4	4	3	20	58
Equisetum fluviatile			1		1						1			1				1	1	1	7	7
Filipendula ulmaria		1	2	1	1	2	1	1	1	1		1		1	2	1	1	1	1	1	17	20
Glyceria fluitans	2	1			1	1		1	1	1	1	2	2		1	1		2	1	1	15	19
Iris pseudacorus												1	1								2	2
Juncus acutiflorus			1					1	1	1			2	1	2		1	1	1		10	12
J. effusus			1							1		1	1	1	2	1		1		1	9	10
J. inflexus																					*	*
Mentha aquatica	1					1	1		1		1		1	1	1	1	1	1	1	1	13	13
Mimulus guttatus	1	1	2	1	2	3	3	1	1	2	1	1	3	3	2	1	1	1	1		19	31
Myosotis scorpioides	1	1	2	1	2	3	3	1	1	2	2	2	2	2	2	1	1	2	1	1	20	33
Myriophyllum alterniflorum	3	2	3	3	3	3	3	3	3	3	2	3	3	2	1	3	4	4	3	3	20	57
M. spicatum																					*	*
Phalaris arundinacea	3	2	3	2	2	3	3	3	1	2	3	2	3	3	3	3	2	3	1	2	20	49
Polygonum amphibium			3				3				1					1				1	5	9
Potamogeton crispus	1				1		3		1	1		1	2		1		1	3	1		11	16
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus	4	1	2	1	1	1	5	3	3	3	2	1	2	1		1	2	2	3		18	38
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.	1	2	2	1	2	1	5	3	3	4	4	5	5	4	1	4	3	4	2	4	20	60
R. flammula																					*	*
R. fluitans x ?																					*	*
R. penicillatus var. calc	2	3	3	3	3		3	4	3	3	3	3	3	3	1	2	2	1	3	2	19	50
Rorippa amphibia (arcua								1		1											2	2
R. nasturtium-aquaticum	1	1	1		1		1	1				1			1		1	1	1	1	12	12
Scirpus sylvaticus								1			1										2	2
Sparganium erectum	2						1	1	1		2	1	4	1	1	1	2	2	1	1	14	21
Veronica beccabunga	2	1				1	1	1		1	1		1	1	3	1	1	1	1	1	15	18
Zannichellia palustris																					*	*
sewage fungus (obvious)		1					1	5	1	1	1			1							7	11

species	50.0	50.5	51.0	51.5	52.0	52.5	53.0	53.5	54.0	54.5	55.0	55.5	56.0	56.5	57.0	57.5	58.0	58.5	59.0	59.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Nostoc parmelioides														1		1			1	1	4	4
Nostoc other sp(p).							1						1								2	2
Phormidium spp.	2		2			1		1		1		2		2				2			9	14
Hildenbrandia rivularis	3	3	1	1	1	2	2	1		1	2	1	2	2	2	3	3	3	3	3	19	39
Lemanea fluviatilis					1				1				1				1				4	4
Botrydium granulatum																					*	*
Vaucheria sp(p).										1			1				1			1	4	4
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	1		1	1	1	1	1	2	1	1		1	1	1	2	1	1	1		1	17	19
Cladophora glomerata	3	3		1			1	2	1	2	1	2	2	1	1	1	1	1	1	1	17	23
Cladophora sp.'A'																		1			1	1
Enteromorpha sp(p).																					*	*
Haematococcus viride				1																	1	1
Monostroma bullosum																					*	*
Oedogonium spp.	2	1	2	3	4	1	1	2	1	3	1	2	3	2	1		1	2		2	18	34
Tetraspora sp(p).																					*	*
Stigeoclonium tenue	1	1	2	1	1	1		1	1	1	1	1	1	1		1	1	1	1	1	18	19
Ulothrix zonata	1	2	1	2	3	1	1		1	1	2	1		1		1	1				14	19
Prasiola crispa																					*	*
Spirogyra spp.					1					2	1						1				4	5
Collema flaccidum																					*	*
C. fluviatile							1		1	1		1			1			1		1	7	7
Dermatocarpon fluviatile			1					1					1						1		4	4
Verrucaria praetermissa			1	1		1	1	1		2	1	2	1	1			2	1	1	1	14	17
Verrucaria other spp.	3	4	1	2	1	1	2	2	3	1	3	2	2	2	1	2	4	3	2	2	20	43
Acrocladium cuspidatum					1			1					1	1					1		5	5
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare						1	1						1			1					4	4
B. rutabulum	2		1	1			1	1	1	1	1	2	1	2	2	1	1	1	2	1	17	22
Bryum pseudotriquetrum																					*	*
Chiloscyphus polyanthos				1				2			1		1		1		1		3	1	8	11
Cinclidotus fontinaloides					1		1	1	1	1	2	1	1			1	1	2	1	1	13	15
Climacium dendroides																					*	*
Conocephalum conicum				1		3	1	1		1				1	1			1	1	1	10	12
Cratoneuron filicinum		1	1					1			1		1						1		6	6
Dichodontium pellucidum	1				1		1				1	1				1			1		7	7
Eurhynchium riparioides	1	5	1	2	4	1	3	3	1	2	5	3	1	3	3	4	4	4	2	3	20	55
Fissidens adianthoides						2	1					1					1	1			5	6
F. crassipes																					*	*
Fontinalis antipyretica	1	3	1	3	1	1	3	1	1	2	3	3	3	3	2	4	5	2	3	3	20	48
F. ant. var. gracilis																					*	*
Funaria hygrometrica									1							1					2	2
Grimmia alpicola	1				1	1	1				1	1	1			1				1	9	9
Hygroamblystegium fluviat		3	2	1	3	1	1	2		2	1		3		1	1	2	1	1	1	16	26
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium									1	1											2	2
Leskea polycarpa																					*	*
Marchantia polymorpha	1	1		1		1	1	1		1					1			1	1	1	11	11
Mnium longirostrum							1	1					1		1						4	4
M. punctatum																					*	*
Orthotrichum rivulare																		1			1	1

species	50.0	50.5	51.0	51.5	52.0	52.5	53.0	53.5	54.0	54.5	55.0	55.5	56.0	56.5	57.0	57.5	58.0	58.5	59.0	59.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Pellia endiviifolia															1			1			2	2
P. epiphylla								1			1		1					1			4	4
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum																					*	*
Tortula mutica			1	1			1	1					1	1			1	1		1	9	9
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.					1			1			2		1			1					5	6
Caltha palustris			1		1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	16	16
Carex nigra																					*	*
C. rostrata	3		1										1				1				4	6
Carex other spp.	1																				1	1
Cochlearia alpina																					*	*
Eleocharis palustris			2	4				1	3	3				3	1	1	1	1		1	11	21
Elodea canadensis	3	3	4	2	4	4	3	4	5	5	2	4	5	4	2	4	3	3	1	1	20	66
Equisetum fluviatile		1	1					2		1	2	1			3	1		1			9	13
Filipendula ulmaria			3			1	1			1		1	1	1	1	1	1		1	1	12	14
Glyceria fluitans	1			2		1		2	3	1	1								1	1	9	13
Iris pseudacorus																					*	*
Juncus acutiflorus	1	1	3	2	2	1			1	1	1			1		1		1			12	16
J. effusus	1	1	3	1	2	1		1	1	1				1		1	1	1			13	16
J. inflexus																					*	*
Mentha aquatica					1					2	1	1									4	5
Mimulus guttatus	1	1	2	2	2	1	1	1		2	1	2	2	1	1	1	1	1	1	1	19	25
Myosotis scorpioides	2	1	2	2	2	1	1	2	2	2	1	2	2	1	1	1	1	1	1	1	20	29
Myriophyllum alterniflorum	3	4	3	4	2	1		2	3	2	1	2	3	3	3	4	1	2	1	1	19	45
M. spicatum																					*	*
Phalaris arundinacea	3	3	3	3	1	2	2	3	3	2	1	3	3	3	3	2	2	2	1	1	20	46
Polygonum amphibium	1																1				2	2
Potamogeton crispus			1	1							1	1		1		3	1	1	1		9	11
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus	3	3	5	2	1		2	3					3	4		5	2	1	1		13	35
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.	1	2	1	1	2	1	1	1	2	1	1	1	2	3	2	1	2	2	1	2	20	30
R. flammula																					*	*
R. fluitans x ?																					*	*
R. penicillatus var. calcareus	2	4	3	2	4	2	1	3	4	2	1	3	4	4	4	4	2	4	3	3	20	59
Rorippa amphibia				1						1	1		1				1		1		6	6
R. nasturtium-aquaticum								1	1	1	1	1			1			1			7	7
Scirpus sylvaticus												1				1		1	1		4	4
Sparganium erectum	2	2	4	1		1	1	1	3	3	1		3	4	3	3	1		1	1	17	35
Veronica beccabunga			1		2	1		1	1	1	1	1									8	9
Zannichellia palustris																					*	*
sewage fungus (obvious)														2	1						2	3

species	60.0	60.5	61.0	61.5	62.0	62.5	63.0	63.5	64.0	64.5	65.0	65.5	66.0	66.5	67.0	67.5	68.0	68.5	69.0	69.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Nostoc parmelioides				1			2			1				3	3				1	1	7	12
Nostoc other sp(p).												1									1	1
Phormidium spp.	1	1	1		2	2		1	1	1	2	1		1	2	1	2	1	2		16	23
Hildenbrandia rivularis	2	1	1	2	1	1	3	2	1	1	2	1	1	2	2	2	3	2	3	3	20	36
Lemanea fluviatilis		1					1				1		1	1				1	1		7	7
Botrydium granulatum																					*	*
Vaucheria sp(p).															1						1	1
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis		1	1	1	2	1	1	2	1	1	1	2	1	1	2	1	2	1	2	1	20	26
Cladophora glomerata				1	1	1	1	1	1	1	1	1	1	1			1	1	2	1	15	16
Cladophora sp.'A'								1				1				1			1		4	4
Enteromorpha sp(p).																					*	*
Haematococcus viride																					*	*
Monostroma bullosum																					*	*
Oedogonium spp.	2	2					1								1						4	6
Tetraspora sp(p).																					*	*
Stigeoclonium tenue	1	1		1	1	1	1			1		1	1	1		1	1	1	1	1	15	15
Ulothrix zonata		1	1		1		1			1				1	1	1	1		1	1	11	11
Prasiola crispa											1										1	1
Spirogyra spp.			1						1		1			1					1	1	6	6
Collema flaccidum																			1		1	1
C. fluviatile		2												2				2	3		4	9
Dermatocarpon fluviatile										1			1		1		1		2	1	6	7
Verrucaria praetermissa	2		1	1	1		1	1	1		1	1	1	1	1	1	1	1	1	1	17	18
Verrucaria other spp.	3	1	3	2	3	1	3	3	2	4	2	3	3	2	4	3	2	3	4	3	20	54
Acrocladium cuspidatum			1	1			1	1	1			1				1		1	1	1	10	10
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare																			1		1	1
B. rutabulum	2	1	1	2	1		1	2	1		1	1	1	1	1				1	1	15	18
Bryum pseudotriquetrum																					*	*
Chiloscyphus polyanthos	1		2			1	2	1			1		2	1	1	1	1	2	1	1	14	18
Cinclidotis fontinaloides	3	1	3	1		1		1	1	1	1			1		1	1	2	3	1	15	22
Climacium dendroides																					*	*
Conocephalum conicum	1	2	1	1		1	1	1		2	1	1	2	1	1	1	1	1	1	1	18	21
Cratoneuron filicinum							1						1						1		3	3
Dichodontium pellucidum				1								1						1			3	3
Eurhynchium riparioides	3	1	3	3	4	4	3	2	2	1	5	5	2	2	5	3	2	4	4	3	20	61
Fissidens adianthoides	1	1																			2	2
F. crassipes																					*	*
Fontinalis antipyretica	3	1	3	4	1	1	3	1	1	3	3	1	3	1	2	2	2	1	3	2	20	41
F. ant. var. gracilis																			2		1	2
Funaria hygrometrica							1								1				1		3	3
Grimmia alpicola				1		1			1		1		1					1	1		7	7
Hygroamblestegium fluviat	1	2	2	1	1			1	2	2		1			2		1		3	1	13	20
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium										1											1	1
Leskea polycarpa																					*	*
Marchantia polymorpha					1								1						2		3	4
Mnium longirostrum		1	1	1		1				1	1	1		1		1	1		1	1	12	12
M. punctatum																					*	*
Orthotrichum rivulare			1																		1	1

km down River Tweed

species	60.0	60.5	61.0	61.5	62.0	62.5	63.0	63.5	64.0	64.5	65.0	65.5	66.0	66.5	67.0	67.5	68.0	68.5	69.0	69.5	0.5 km total (max. 20)	abundance total (max. 100)
Pellia endiviifolia																					*	*
P. epiphylla	1	1	1		1	1		1			1		1			1	1		1	1	12	12
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum																			1		1	1
Tortula mutica	2	2	1	1		2	1		2	1	2		1	1	2	1	2	1	1	1	17	24
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.				1				1									1				3	3
Caltha palustris	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	19	19
Carex nigra																					*	*
C. rostrata										1											1	1
Carex other spp.		1																			1	1
Cochlearia alpina																					*	*
Eleocharis palustris		2	1	1		1					1	1	1	1		1	1	1		1	12	13
Elodea canadensis	2	2	1	3	2	4	2	1	3	1	2	1	1	2	2	1	4	1	2	2	20	39
Equisetum fluviatile				1									1	1	1		1	1	1		7	7
Filipendula ulmaria	1		1		1	1				1	1					1			1	1	9	9
Glyceria fluitans											1		1				1	1			4	4
Iris pseudacorus		1	1								1										3	3
Juncus acutiflorus			1		1		1			1		1		1		1		1	1		9	9
J. effusus							1			1				1			1				4	4
J. inflexus																					*	*
Mentha aquatica																1		1		1	3	3
Mimulus guttatus	1		1				1		1		1	1	1		1	1	1	1	2	1	13	14
Myosotis scorpioides	1	1	1		1	1			1		1	1	1	1	1	1	1	1	2	1	16	17
Myriophyllum alterniflorum	2	1	3	3	2	1	3	2	3	1	2	3	1	1	3	3	2	1	1	1	20	39
M. spicatum																					*	*
Phalaris arundinacea	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	20	40
Polygonum amphibium						1					1		1			1	1			1	6	6
Potamogeton crispus	1		1		1	3	1		1	3	1	1	1	3	1		1	1	1		15	21
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus		1						1								2				1	4	5
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.	1		1	1	2	2	1					1	1			1	1	1		1	12	14
R. flammula																					*	*
R. fluitans x ?																					*	*
R. penicillatus var. calc.	2	1	3	3	4	3	3	2	2	1	2	3	3	2	1	3	2	3	1	3	20	47
Rorippa amphibia (+reus	1	1	1					1	1							1		1	1		8	8
R. nasturtium-aquaticum				1			1	1													3	3
Scirpus sylvaticus				1		1	1	1	1	1		1					1		1	1	10	10
Sparganium erectum	1	2	2	1	1	1			2		1	1	1	1	2	1	2	2	2	1	17	24
Veronica beccabunga																					*	*
Zannichellia palustris																					*	*
sewage fungus (obvious)										1											1	1

species	km down River Tweed																				
	70.0	70.5	71.0	71.5	72.0	72.5	73.0	73.5	74.0	74.5	75.0	75.5	76.0	76.5	77.0	77.5	78.0	78.5	79.0	79.5	0.5 km total (max. 20)	abundance total (max.100)
Nostoc parmelioides	1				1		2	2		2			1	1		1		2	2	1	11	16
Nostoc other sp(p).											1				1				1		3	3
Phormidium spp.	1	1	1	3	1		3	1							1	1				1	10	14
Hildenbrandia rivularis	1	1	2	3	2	1	2	1	1	1	1	1	1	1	1	2	1	1	2	1	20	27
Lemanea fluviatilis			1									1				1		1	2		5	6
Botrydium granulatum																					*	*
Vaucheria sp(p).												1				1	1	1	2	1	6	7
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	2	1	2	2	1			1		1	1	1	1	1	1	2	1	1	1	1	17	21
Cladophora glomerata		1	2	1	2	1	1	1	2		1	2	1	1	2	1	1	1	1	1	18	23
Cladophora sp.'A'				1							1						1	1	1		5	5
Enteromorpha sp(p).																					*	*
Haematococcus viride																					*	*
Monostroma bullosum																					*	*
Oedogonium spp.																1			1		2	2
Tetraspora sp(p).																					*	*
Stigeoclonium tenue	1	1		1	1			1			1	1				1		1	1	1	11	11
Ulothrix zonata	1	1	1	1						1	1	1						1	1		9	9
Prasiola crispa				1												1					2	2
Spirogyra spp.			1		1			1				1	1	1				1	1		8	8
Collema flaccidum																1					1	1
C. fluviatile			1		1	1	1			1	1	1			1	2	2	1	2	1	13	16
Dermatocarpon fluviatile	1	1	1		1			1				1	1				1	2	2		10	12
Verrucaria praetermissa	1		1	1		1		1				1	1	1	1	1	1	1	1	1	14	14
Verrucaria other spp.	1	2	3	1	2	1	2	1	1	4	2	1	1	1	2	4	2	1	2	1	20	35
Acrocladium cuspidatum				1	1			1	1	1					1	1	1		1		9	9
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare																					*	*
B. rutabulum					1	1		1	1			1	1	1	1		1	1	1		11	11
Bryum pseudotriquetrum													1								1	1
Chiloscyphus polyanthos		1	1	1	1					1	2	1				1	1	1			10	11
Cinclidotus fontinaloides					2	2		1		1		1	2	1		1	2	2	1		11	16
Climacium dendroides																					*	*
Conocephalum conicum	1	1	1	2		1	2			1	1	1	2	1	1		1	1	2		15	19
Cratoneuron filicinum												1									1	1
Dichodontium pellucidum				1															1		2	2
Eurhynchium riparioides	1	3	2	2	3	1	1	1	2	1	1	2	1	1	2	1	1	3	3	3	20	35
Fissidens adianthoides															1						1	1
F. crassipes																					*	*
Fontinalis antipyretica	1	1	2	1	2	2	2	1	1	1	1	1	2	2	1	1	2	3	2	3	20	32
F. ant. var. gracilis																			1		1	1
Funaria hygrometrica			1									1									2	2
Grimmia alpicola	1	1	1										1				1		1		6	6
Hygroamblestegium fluviat	1		1	2	1	2	1	1	1	1	2	2	1	2	1	1	2	2	2	2	19	28
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium												1				1			1		3	3
Leskea polycarpa																					*	*
Marchantia polymorpha	1					1	1	1				1			1	1	1			1	9	9
Mnium longirostrum		1				1			1			1			1		1		1		7	7
M. punctatum																					*	*
Orthotrichum rivulare				1								1					1				3	3

species	70.0	70.5	71.0	71.5	72.0	72.5	73.0	73.5	74.0	74.5	75.0	75.5	76.0	76.5	77.0	77.5	78.0	78.5	79.0	79.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Pellia endiviifolia																					*	*
P. epiphylla		1				1	1						1	1						1	6	6
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum																					*	*
Tortula mutica			1	2	2	1	1		1	2	1	1	2			1	2	1	1		14	19
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.				1				1					1							1	4	4
Caltha palustris			1		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	16	16
Carex nigra																					*	*
C. rostrata	1	1	1	1				1													5	5
Carex other spp.																					*	*
Cochlearia alpina																					*	*
Eleocharis palustris	1		1	1	1	1		1	3		1		1	1		1	1	1	2	1	15	18
Elodea canadensis	4	4	2	1	2	2	2	3	1	3	3	3	3	2	1	2	3	2	2	3	20	48
Equisetum fluviatile					1	1				1					1			1	1	1	7	7
Filipendula ulmaria			1				1			1	1	1	1			1	1			1	9	9
Glyceria fluitans	1	1		1								1	1	1				1	1	1	9	9
Iris pseudacorus			1													1	1				3	3
Juncus acutiflorus								1		1			1	1			1	1	1		7	7
J. effusus																1		1			2	2
J. inflexus																					*	*
Mentha aquatica		1	1													1			1		4	4
Mimulus guttatus	1	1		1					1		1					1	1	1		1	9	9
Myosotis scorpioides	1	1	1	1		1	1	1	1			1	2	1		1	1	1	1	1	16	17
Myriophyllum alterniflorum	2	2	2	3	1	2	4	1	1	1	1	1	1	1	1	2	2	1	2	1	20	32
M. spicatum																					*	*
Phalaris arundinacea	2	2	2	2	2	2	2	2	3	2	3	3	2	2	2	2	2	2	2	2	20	43
Polygonum amphibium	1					1	1		1			1	2	1		1		1	1		10	11
Potamogeton crispus	2	4	2	1		1	1	2	1	1	1	1	1			1	1	2	2	1	17	25
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus	1																1		1	1	4	4
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.		1					2	2				2	1		2				1	1	8	12
R. flammula																					*	*
R. fluitans x ?																					*	*
R. penicillatus var. calc	2	3	3	3	2	3	4	4	3	4	4	4	4	2	4	4	3	2	3	4	20	65
Rorippa amphibia (areus	1	1	1			1	1	1	1	1						1	1	1	1		12	12
R. nasturtium-aquaticum				1		1									1				1	1	5	5
Scirpus sylvaticus	1	1	2	1	1		2	1			1	1	2	1							11	14
Sparganium erectum	1	2	1	1	2	1	1			1	1		2		1	1	1	2	1	1	16	20
Veronica beccabunga																					*	*
Zannichellia palustris																					*	*
sewage fungus (obvious)						1	1						1		1						4	4

species	km down River Tweed																				0.5 km total (max. 20)	abundance total (max. 100)
	80.0	80.5	81.0	81.5	82.0	82.5	83.0	83.5	84.0	84.5	85.0	85.5	86.0	86.5	87.0	87.5	88.0	88.5	89.0	89.5		
Nostoc parmelioides							1	1	1							1	1		1	1	7	7
Nostoc other sp(p).															1						1	1
Phormidium spp.	1	2			1					1				1			1	1			7	8
Hildenbrandia rivularis	1	3	1	2	1	2	3	1	4	2	1	3	1	2	1	1	2	2	2	1	20	36
Lemanea fluviatilis															1				1		2	2
Botrydium granulatum																					*	*
Vaucheria sp(p).			1								1	1	1	1		1	2	1			8	9
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	2	1	1			1		1	1	1	1	1	1	1	1	1	2	1	2	1	17	20
Cladophora glomerata	1	3	1	1	1			2	1					1	1	1	1	1	1	1	14	17
Cladophora sp.'A'	1		1			1		2	1	1		1		1	1	1	1	1	1	2	14	16
Enteromorpha sp(p).																					*	*
Haematococcus viride																					*	*
Monostroma bullosum																					*	*
Oedogonium spp.	2	1	3	1	3							1	1	2	1	1	3	1		1	13	28
Tetraspora sp(p).																					*	*
Stigeoclonium tenue	1	2	1		1		1						1		1		1	1			9	10
Ulothrix zonata	1		1			1			1	1				1	1						7	7
Prasiola crispa		1																1			2	2
Spirogyra spp.								1				2								1	3	4
Collema flaccidum																					*	*
C. fluviatile	1			1					1		1		1					1	1		7	7
Dermatocarpon fluviatile									1	1	1			1		1					5	5
Verrucaria praetermissa			1		1			1	1	1	2	1	1	2	1		1	2	1		13	16
Verrucaria other spp.	1	2	1		1	1	1	1	2	1	1	2	1	2	1	1	2	2	1	1	19	25
Acrocladium cuspidatum				1		1		1		1	1							1			6	6
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare													1				2	1			3	4
B. rutabulum			1	1	1	2	1		1	1	2	2		3	1	1	1	1	1	1	16	21
Bryum pseudotriquetrum																					*	*
Chiloscyphus polyanthos											1					1	1				3	3
Cinclidotus fontinaloides	2	1	1			1	1	2	1	3	3	2	1	3	1	1	1	2	3	1	18	30
Climacium dendroides																					*	*
Conocephalum conicum	1	1			1	1	1			1	2			1	1		1	1	1	1	13	14
Cratoneuron filicinum											1						1		1		3	3
Dichodontium pellucidum				1								1					1	1			4	4
Eurhynchium riparioides	3	1	3	2	2	3	3	2	3	3	1	5	3	3	1	1	2	4	3	3	20	51
Fissidens adianthoides	1									1	1	1			1						5	5
F. crassipes																					*	*
Fontinalis antipyretica	1	2	1	1		2		2	1	1	3	3	2	2	1	2	3	3	3	3	18	36
F. ant. var. gracilis																					*	*
Funaria hygrometrica									1								1		1		3	3
Grimmia alpicola	1			1			1			1				1			2	1		1	8	9
Hygroamblestegium fluviat	1			1	1	1		2	3		2		1	2	1	2	2	1	1		14	21
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium	1		1																		2	2
Leskea polycarpa																					*	*
Marchantia polymorpha							1		1			1		1			1	1			6	6
Mnium longirostrum						1					1						1		1		4	4
M. punctatum																					*	*
Orthotrichum rivulare																	1		1		2	2

Species	80.0	80.5	81.0	81.5	82.0	82.5	83.0	83.5	84.0	84.5	85.0	85.5	86.0	86.5	87.0	87.5	88.0	88.5	89.0	89.5	0.5 km total (max. 20)	abundance total (max. 100)
	km down River Tweed																					
Pellia endiviifolia																					*	*
P. epiphylla	1		1					1							1						4	4
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum										1	1		1					1			4	4
Tortula mutica		1		1	1	1			1	1	1	1				1				1	10	10
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.													1				1			1	3	3
Caltha palustris	1	1	1		1		2	1	1	1	1			1		1	1	1	1		14	15
Carex nigra																					*	*
C. rostrata																		2			1	2
Carex other spp.	1						1	1										1			4	4
Cochlearia alpina																					*	*
Eleocharis palustris	1	2	2	2	1		2	1	1	1		1	1			1		2		1	14	19
Elodea canadensis	5	1	3	3	3	1	3	3	1	3	3	2	3	3	2	3	2	2	1	3	20	50
Equisetum fluviatile			1		1			1		1		2	1								6	6
Filipendula ulmaria								1		1	1								1		4	4
Glyceria fluitans						1					1					1				1	4	4
Iris pseudacorus																					*	*
Juncus acutiflorus	1	1	2	1	1			2	1	1			1	1				1	1		12	14
J. effusus	1		1					1					1	1					1		6	6
J. inflexus																					*	*
Mentha aquatica																					*	*
Mimulus guttatus			1	1	1	1	2	1	1	2	1	1		1				1	1	1	14	16
Myosotis scorpioides	1	1	2	1	1	1	1	1	1	2	1	1	1	2		2	2	2	1		18	24
Myriophyllum alterniflorum	2	1	2	1	1	2	1	2	1	1		1	2	1	2		1	1	1	1	18	24
M. spicatum																					*	*
Phalaris arundinacea	2	3	1	3	2	2	3	3	2	2	2	2	1	1	2	3	3	2	1	2	20	42
Polygonum amphibium	3		1	1				1					1	1			1	1		1	9	11
Potamogeton crispus	3	1	1	1	2	1			2		2		1	1						1	11	16
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus			1				1				1										3	3
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.	1	1		1		1															4	4
R. flammula																					*	*
R. fluitans x ?									3	1	2	3	3	2	3	3	5	5	3	3	12	38
R. penicillatus var. calc	3	1	2	5	3	3	3	2	2	3	4	5	4	2	3	3	3	4	3	3	20	61
Rorippa amphibia (areus	1	1	1	1	1	1	2	2	1	2	1	1	1	1	1	1	1	3	1	1	20	25
R. nasturtium-aquaticum		1						1	1	1			1	2	1			2			8	10
Scirpus sylvaticus								1					1				1	1	1		5	5
Sparganium erectum	1			1			2	1		1		1		1		1		2	1	1	11	13
Veronica beccabunga									1				1					1			3	3
Zannichellia palustris																					*	*
sewage fungus (obvious)	1	1														1					3	3

Species	km down River Tweed 90.0	90.5	91.0	91.5	92.0	92.5	93.0	93.5	94.0	94.5	95.0	95.5	96.0	96.5	97.0	97.5	98.0	98.5	99.0	99.5	0.5 km total (max. 20)	abundance total (max.100)
Nostoc parmelioides			1			1				2		2	2	1	1		3	1	3		10	17
Nostoc other sp(p).																					*	*
Phormidium spp.							1								1				2		3	4
Hildenbrandia rivularis	2	1		2	1	2	1	3	2	3	1	3	2	2	2	1	2	2	2	1	19	35
Lemanea fluviatilis			1	1	1	1															4	4
Botrydium granulatum																					*	*
Vaucheria sp(p).			1			1	1	1			2	1				1	1	1	1	1	11	12
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	2	1	1		1	1	2	1	1		1		1		2	1	1	1	1	2	16	20
Cladophora glomerata		1	1	1	1	2	3	2	2	1	1	1	2	1	1	1		1		1	17	23
Cladophora sp.'A'	1			1	1		1	2		1	1	1	3	1			3		1		12	17
Enteromorpha sp(p).																					*	*
Haematococcus viride				1																	1	1
Monostroma bullosum																					*	*
Oedogonium spp.	1		1	2	3	3	3	2	2	1	2	2	3	2	1	3		2	3	1	18	37
Tetraspora sp(p).													1							1	2	2
Stigeoclonium tenue		1	1		1			1					1	1	1	1			1		9	9
Ulothrix zonata	1		1		1								1								4	4
Prasiola crispa		1	1															1			3	3
Spirogyra spp.									1								1				2	2
Collema flaccidum																					*	*
C. fluviatile	1								1	1		2					2		1		6	8
Dermatocarpon fluviatile			1					1											1		3	3
Verrucaria praetermissa	1		1	1	1	1	1	2	1		1	1	1		1		3	1		1	15	18
Verrucaria other spp.	1		2	1	2	1	2	2	1	2	1	2	1	2		2	1	1	2		17	36
Acrocladium cuspidatum								1							1						2	2
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare				1				1					1						1		4	4
B. rutabulum	1	1	2	2	1	1	1	2	2	2	2	1	1	1	1	1	1	2	2	2	20	29
Bryum pseudotriquetrum																					*	*
Chiloscyphus polyanthos				1				1		1	1						1				5	5
Cinclidotus fontinaloides	2		2	4	1	3	3		1	3	2		1				1		3	1	13	27
Climacium dendroides																					*	*
Conocephalum conicum	1		1	1		1	1	1	1	1	3	2	1	1	1	1		1	2	1	17	21
Cratoneuron filicinum									1								1				2	2
Dichodontium pellucidum			1												1						2	2
Eurhynchium riparioides	1	1	3	3	3	4	4	1	3	3	2	3	2	1	2	1	1	2	2	1	20	43
Fissidens adianthoides			1								1						2				3	4
F. crassipes																					*	*
Fontinalis antipyretica	1	1	2	2	3	2	3	1	3	3	1	3	1	1		1	1			1	17	30
F. ant. var. gracilis			1																		1	1
Funaria hygrometrica															1						1	1
Grimmia alpicola				2			1		1									1			4	5
Hygroamblystegium fluviatl			1	1	1	1			1	1	1	1	2	1			1	1		1	14	15
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium									1												1	1
Leskea polycarpa																					*	*
Marchantia polymorpha	1				1					1					1						4	4
Mnium longirostrum						1									1	1					3	3
M. punctatum																					*	*
Orthotrichum rivulare			1	2			1			1					1		1				6	7

species	km down River Tweed																				0.5 km total (max. 20)	abundance total (max.100)
	90.0	90.5	91.0	91.5	92.0	92.5	93.0	93.5	94.0	94.5	95.0	95.5	96.0	96.5	97.0	97.5	98.0	98.5	99.0	99.5		
Pellia endiviifolia																					*	*
P. epiphylla							1				1				1			1	1		5	5
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum						1			1		1										3	3
Tortula mutica			1		1					1	1				1	1					6	6
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.																			1		1	1
Caltha palustris		1	1			1	1					1					1				6	6
Carex nigra																					*	*
C. rostrata																					*	*
Carex other spp.																					*	*
Cochlearia alpina																					*	*
Eleocharis palustris		2	3	2	1	1	2	1	1		1		3	1	2	3	2	1	1		16	27
Elodea canadensis	1	2	3	2	1	3	3	2	3	2	2	2	3	3	3	5	3	5	3-	1	20	52
Equisetum fluviatile							1					1		1		1	2	1		1	7	8
Filipendula ulmaria							1	1			1	2	1				2		1		7	9
Glyceria fluitans								1				1					1				3	3
Iris pseudacorus													1								1	1
Juncus acutiflorus				1		2	1		1	1	1	1	1	1	1	3	1	1	1		14	17
J. effusus						2							1	1	1	2	1	1	1		8	10
J. inflexus															1						1	1
Mentha aquatica			1								1		1				2	1		1	6	7
Mimulus guttatus	1				1	3		1	1	1	3	1		1			1	1	1	1	13	17
Myosotis scorpioides		1	1		1	3	3	1	1	1	1	2	2	1	2	1	2	1	1	1	18	26
Myriophyllum alterniflorum	1	1	3	1		2	2	1	1	3	1	1	3	2	2	2	1	2	1	1	19	31
M. spicatum																					*	*
Phalaris arundinacea	3	1	1	2	2	2	3	2	1	2	1	1	2	2	3	3	2	1	1	1	20	36
Polygonum amphibium		1						1				1	2	1		1	2	1	1		9	11
Potamogeton crispus			2			1	2		1	1	2	2	1		2	1	2	2	1		13	20
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus												1	1								2	2
P. pectinatus																					*	*
P. perfoliatus																					*	*
P. pusillus																					*	*
P. x salicifolius																					*	*
P. x suecicus																					*	*
Ranunculus aquatilis agg.	1						1						1								3	3
R. flammula																					*	*
R. fluitans x ?	3	5	5	1	3	5	3	2	5	4	1	2	1	1	2	4	2	2	3	1	20	55
R. penicillatus var. calc	3	3	4	2	2	4	3	2	3	4	1	2	1	3	3	3	2	2	3	2	20	52
Rorippa amphibia (areus	1	1	1	1	1	3	2	1	1	1	1	2	2	1	1	2	2	1	1	1	20	27
R. nasturtium-aquaticum		1			1	3	2	1	1		1	2	2	1		2	2	1	1	1	15	22
Scirpus sylvaticus								1					1	1		1	2				5	6
Sparganium erectum			1					2			1			1							4	5
Veronica beccabunga													1						1		2	2
Zannichellia palustris																					*	*
sewage fungus (obvious)																					*	*

species	km down River Tweed 100.0	100.5	101.0	101.5	102.0	102.5	103.0	103.5	104.0	104.5	105.0	105.5	106.0	106.5	107.0	107.5	108.0	108.5	109.0	109.5	0.5 km total (max. 20)	abundance total (max.100)
Nostoc parmelioides	1	3	3	1				1				1	3	2	2						9	17
Nostoc other sp(p).						1								1							2	2
Phormidium spp.			1	1		1															3	3
Hildenbrandia rivularis	1	1	2	1	1	1	2	1	4	4	1	1	3	2	2	1	2		2	2	19	34
Lemanea fluviatilis	2																				1	2
Botrydium granulatum																					*	*
Vaucheria sp(p).	1	1	2		1					1	2	1	2	1	1	1	3	1		1	14	19
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	2		1		1	1		2	1		1	2	1	1	1		1		1	1	14	17
Cladophora glomerata	1	1	2	1	2	2	2		1	1		1	3		3	1	2		1	4	15	27
Cladophora sp.'A'		1	1	1	1		2					1	4	1	1				1		10	14
Enteromorpha sp(p).																	1	5	3	1	4	10
Haematococcus viride																					*	*
Monostroma bullosum														1							1	1
Oedogonium spp.	2	1	1	2	2	2	2	2	2	3	3	3	3	4	3	2	3	3	4	3	20	50
Tetraspora sp(p).					1				2		1			2			2			1	6	9
Stigeoclonium tenue	1	1		1	2		2	1	1	1		1	1	2	1	1		1	1		15	18
Ulothrix zonata																					*	*
Prasiola crispa						1			1					1				1			4	4
Spirogyra spp.		1						1									2		1		4	5
Collema flaccidum																		1			1	1
C. fluviatile	1	3	3	2			2					3	4	4	3		1				10	26
Dermatocarpon fluviatile		1	1	1	2	2	2					1									7	10
Verrucaria praetermissa	2	1	1		2	2	2			2	1	2	1		2	1	1			1	14	21
Verrucaria other spp.	1	1	1	1	1	1	2	1	2	1		1	2	1	1		2		1	1	17	21
Acrocladium cuspidatum																					*	*
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare																				2	1	2
B. rutabulum	1	1	1	1	1	2	2	1	1	1	1	1	2	1	1	1	2	2	1	1	20	25
Bryum pseudotriquetrum																					*	*
Chiloscyphus polyanthos					1	1															2	2
Cinclidotus fontinaloides	1	1	1			3	4	1		1	3	2	2	2	1		3	1		1	15	27
Climacium dendroides																					*	*
Conocephalum conicum		2	1	1		1	1	1	1			1	1	1			1	1	1	1	14	15
Cratoneuron filicinum								1					1				1	1			4	4
Dichodontium pellucidum					1					1					1	1					4	4
Eurhynchium riparioides	1	2	1	1	1	1	3	1	1	3	2	3	3	1	1	1	3	3	3	1	20	36
Fissidens adianthoides		1		1			2			1	2	3	1			1				1	9	13
F. crassipes																					*	*
Fontinalis antipyretica		1		1	1	1			1		1	1	1	1	1		1			1	12	12
F. ant. var. gracilis																					*	*
Funaria hygrometrica															1	1					2	2
Grimmia alpicola				1		1			1		1		1	1			1				7	7
Hygroamblestegium fluviat	1	2	1	1	1	2	1	1		2	1	1	2	1	1	1	2	1	1		18	23
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium																	1		1		2	2
Leskea polycarpa																					*	*
Marchantia polymorpha			1	1			1								1	1				1	6	6
Mnium longirostrum					1	1	1	1			2	1	1		1	1	1				10	11
M. punctatum																					*	*
Orthotrichum rivulare						1	2				1		1				2			1	6	8

species	km down River Tweed																				0.5 km total (max. 20)	abundance total (max.100)
	100.0	100.5	101.0	101.5	102.0	102.5	103.0	103.5	104.0	104.5	105.0	105.5	106.0	106.5	107.0	107.5	108.0	108.5	109.0	109.5		
Pellia endiviifolia																					*	*
P. epiphylla		1						1									1	1	1	1	6	6
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum																					*	*
Tortula mutica										1				1					1	1	4	4
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.						1												1			2	2
Caltha palustris		1		1	1		1		1	1		1	1		1		1	1		1	12	12
Carex nigra																					*	*
C. rostrata							1							1							2	2
Carex other spp.						1	1			1											3	3
Cochlearia alpina																					*	*
Eleocharis palustris	1		1	1	1	2		1	1	1	2	2	2	1	4	3	2	1	1	1	18	28
Elodea canadensis	2	2	2	3	1	3	3	3	2	3	1	2	2	2	2	5	2	2	3	1	20	46
Equisetum fluviatile	1				1	3	1	1	1		1	1		1	1	1	1	1	1	1	15	17
Filipendula ulmaria	1	1	1	1	1	1		1	1	2		1	1	1			2				13	14
Glyceria fluitans		1										1					1	1		1	5	5
Iris pseudacorus								1	1	1											3	3
Juncus acutiflorus	1			1	1	1	1		1	1	1	1		1	1	1	2				13	14
J. effusus						1	1			1		1				1					5	5
J. inflexus							1			1		1				1					4	4
Mentha aquatica			1	1						1			1								4	4
Mimulus guttatus	1	1	1	1		1		1	1	2	1	1	1	1		1	1	1	1		16	17
Myosotis scorpioides	2	2	1	1	1	2	2	1	1	2	1	2	2	1	2	1	2	2	1	1	20	30
Myriophyllum alterniflorum	2	1	1	1	2		1	3	3	3	1	1	2	1	2	1	1	1			17	27
M. spicatum																		2	2	1	3	3
Phalaris arundinacea	2	2	1	2	2	2	2	1	2	2	2	2	1	1	2	2	2	1	1	1	20	33
Polygonum amphibium					1	3	2	1		2				1	2	1	1	1	3		11	18
Potamogeton crispus		1	1	1		1		1		1		1	1	1					1	1	11	11
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus																		1			1	1
P. pectinatus																		2	1	1	3	4
P. perfoliatus																		2			1	2
P. pusillus																		2	1		2	3
P. x salicifolius																		3	1		2	4
P. x suecicus																					*	*
Ranunculus aquatilis agg.																					*	*
R. flammula																					*	*
R. fluitans x ?	2	1	1	2	1	1	2	1	1	2	2	3	2	1	2	1	3	3	1	4	20	36
R. penicillatus var. calc	2	3	3	2	1	2	3	1	3	3	3	2	3	2	2	1	2	3	3	1	20	45
Rorippa amphibia (arcus	1	1	1	1	1	2	2	1	1	1	2	2	2	1	1	1	1	1	1	1	20	25
R. nasturtium-aquaticum						2	2	1		1	2	2	1	1	1	1			1		11	15
Scirpus sylvaticus						1	2	1		1											4	5
Sparganium erectum		1	1			1				1					1		3	5	3	1	9	17
Veronica beccabunga						1										1		1			3	3
Zannichellia palustris													1					2	1	2	4	5
Sewage fungus (obvious)																					*	*

species	km down River Tweed 110.0	110.5	111.0	111.5	112.0	112.5	113.0	113.5	114.0	114.5	115.0	115.5	116.0	116.5	117.0	117.5	118.0	118.5	119.0	119.5	0.5 km total (max. 20)	abundance total (max.100)
Nostoc parmelioides	1								1		1					4			1		5	8
Nostoc other sp(p).																					*	*
Phormidium spp.		1																			1	1
Hildenbrandia rivularis	1	2	2	2	1	3	1	2	3	2	2	2	2	2	3	3	2	1	2	1	20	39
Lemanea fluviatilis																					*	*
Botrydium granulatum	1	1								1						1					4	4
Vaucheria sp(p).	1			1																1	3	3
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	1	1	1		2				2	2	1	2	1		2	2	2	1	1	1	15	22
Cladophora glomerata	2	1	2	1	2	3	1	1	2	1	2	2	3	1	1	3	1	1	2	2	20	34
Cladophora sp.'A'	2		1						2			1	2	2		2		1		1	9	14
Enteromorpha sp(p).	1			2		1	1		1	2				3	3	3		1	2	2	12	22
Haematococcus viride																					*	*
Monostroma bullosum				1										1							2	2
Oedogonium spp.	3	5	3	5	5	5	5	3	1	3	2	3	5	5	5	2	3	3	3	2	20	71
Tetraspora sp(p).			1	1			1					1				1					5	5
Stigeoclonium tenue			1		3	3		1	1	3	3	3	3	1	1	2	4	3	1	4	16	37
Ulothrix zonata																					*	*
Prasiola crispa																					*	*
Spirogyra spp.																					*	*
Collema flaccidum																					*	*
C. fluviatile	1		1	3	1	3		2	1					1	1	4		1	1	1	13	21
Dermatocarpon fluviatile	1										1								1		3	3
Verrucaria praetermissa	1		1								1										3	3
Verrucaria other spp.	1	1	2	2	1	3	2	1	2		3	3	2	2	1		2	1	2	1	18	32
Acrocladium cuspidatum																					*	*
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare	1		1		1				2	1						1					6	7
B. rutabulum	1	1	1	1	1	1			1	1	1	1		1	1	1		1	1	1	16	16
Bryum pseudotriquetrum									1												1	1
Chiloscyphus polyanthos																				1	1	1
Cinclidotus fontinaloides	1		2	1	1	1	1		1	1	1		1			3	3	1	1	3	15	22
Climacium dendroides																					*	*
Conocephalum conicum			1			1			1						1						4	4
Cratoneuron filicinum												1							1		2	2
Dichodontium pellucidum				1					1								1				3	3
Eurhynchium riparioides	1	1	1			1	1		2		1		1	1		2	2		1	1	13	16
Fissidens adianthoides																					*	*
F. crassipes	3	1	2	1			1	2				1	1			1	1	1		2	12	17
Fontinalis antipyretica		1	1	1		1			1			1			1						7	7
F. ant. var. gracilis									1												1	1
Funaria hygrometrica													1								1	1
Grimmia alpicola		1			1			1	1								1	1			6	6
Hygroamblestegium fluviat	1	1	1					1	1					1	1	1	1	1			10	10
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium			1						1					1		1					4	4
Leskea polycarpa																					*	*
Marchantia polymorpha	1									1			1								3	3
Mnium longirostrum				1				1	1						1						4	4
M. punctatum																					*	*
Orthotrichum rivulare				1					1												2	2

species	km down River Tweed																				
	110.0	110.5	111.0	111.5	112.0	112.5	113.0	113.5	114.0	114.5	115.0	115.5	116.0	116.5	117.0	117.5	118.0	118.5	119.0	119.5	0.5 Km total (max. 20)	abundance total (max. 100)
Pellia endiviifolia	3																				1	3
P. epiphylla	3							1						1	1				1		5	7
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum																					*	*
Tortula mutica		1														1					2	2
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.									1	1								1	1		4	4
Caltha palustris					1	1	1		2	1			1	1			1	1		1	10	11
Carex nigra																					*	*
C. rostrata						1			1						1						3	3
Carex other spp.									2						1					1	3	4
Cochlearia alpina																					*	*
Eleocharis palustris		1	2	2	1	3	3	1	2	3	2	1	2	1	3	2	1		1	1	18	32
Elodea canadensis	1	2	2	4	2	3	1	1	3	2	1	1	2	3	2	2	1	1	1	2	20	31
Equisetum fluviatile	1					1	1										1				4	4
Filipendula ulmaria				1		1	1	1	2	1				1	1						.8	9
Glyceria fluitans			1	1		1		1		2			1			1		2	1	1	10	12
Iris pseudacorus									1				1								2	2
Juncus acutiflorus		1		1					1		2					1			1		6	7
J. effusus									3												1	3
J. inflexus									3												1	3
Mentha aquatica								1	1	1											3	3
Mimulus guttatus	1		2	1			1	1	2	1	1		1	1		1	1		1		13	15
Myosotis scorpioides	1	1	2	1	1	1	1		2	1	1	1	1	1	1	1	1	1	1	1	19	21
Myriophyllum alterniflorum			1																		1	1
M. spicatum	1		2	1	4	3	3	1	3	2	3	1	2	1	2	2	1	1	1	1	19	35
Phalaris arundinacea	1	1	2	1	2	1	1	1	3	1	1	1	1	1	2	1	1	1	2	2	20	27
Polygonum amphibium		1	2	1	2	1	1		1	1	2	1	1	1	3	1	1				15	20
Potamogeton crispus		3	2	2					1		1				2	2		1		1	9	15
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus																	1				1	1
P. pectinatus	2	2	3	4	4	4	4	1	3	3	4	3	4	3	3	3	2	3	3	2	20	58
P. perfoliatus											2										1	2
P. pusillus	1		1	1		1	1				1		1	1			1	1	1		11	11
P. x salicifolius		3	3	4	4	3	4	1	4	3	3	3	1	3	3	1			3		16	46
P. x suecicus																					*	*
Ranunculus aquatilis agg.																					*	*
R. flammula																					*	*
R. fluitans x ?	3	1	4	2	4	2	1	1	4	2	4	2	3	3	1	4	4	3	3	1	20	52
R. penicillatus var. calc	3	1	4	2	4	2	2	3	4	2	3	2	3	3	1	4	4	3	3	3	20	56
Rorippa amphibia (areus	1		1	1	1	1	1	1	1	1	1		1	1	1	1	2	1	1		17	18
R. nasturtium-aquaticum			1						1		1						1				4	4
Scirpus sylvaticus									1	1		1	2								4	5
Sparganium erectum	1	4	1	1	1			3	3	1			3		1				1		11	20
Veronica beccabunga			1			1									1			1			4	4
Zannichellia palustris	1		1	1	1		1		1	1	1	2	2			1	1	1	1		14	16
Sewage fungus (obvious)					1								1								2	2

species	km down River Tweed																				0.5 km total (max. 20)	abundance total (max.100)
	120.0	120.5	121.0	121.5	122.0	122.5	123.0	123.5	124.0	124.5	125.0	125.5	126.0	126.5	127.0	127.5	128.0	128.5	129.0	129.5		
Nostoc parmelioides		2				1		1						1			1	1			6	7
Nostoc other sp(p).																					*	*
Phormidium spp.						1			1					1	1	1		1			6	6
Hildenbrandia rivularis	1	2	1	1	1	2	1		1	1	1	1	2	1	3	1	1		1		17	22
Lemanea fluviatilis																					*	*
Botrydium granulatum	1								1						1					1	4	4
Vaucheria sp(p).						1	1			1						1	1		1		6	6
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	1	1	1	3				1	1		1	1	2	2	3			1		1	13	19
Cladophora glomerata	1	1	2	2	1	1	1	2	4	3	1	2	1	2	3	1	3	1	1	3	20	36
Cladophora sp.'A'		2					1				1										3	4
Enteromorpha sp(p).			2	1	1	2	2	3	3	2	3		1					2	3	2	13	27
Haematococcus viride																					*	*
Monostroma bullosum			1												1						2	2
Oedogonium spp.	1	1	3	3	4	5	5	1	3	3	3	3	2	1	1	1	2	3	5	5	20	55
Tetraspora sp(p).	1	1		1		1	1						1	1			1	1			9	9
Stigeoclonium tenue		1	4	1		1		1		2		2	2	3	3	2		1	3	1	14	27
Ulothrix zonata																					*	*
Prasiola crispa																					*	*
Spirogyra spp.							1								1						2	2
Collema flaccidum																					*	*
C. fluviatile											1								2	1	3	4
Dermatocarpon fluviatile																					*	*
Verrucaria praetermissa		1	1		1						1	1									5	5
Verrucaria other spp.		1			1			1		1	1				1		1	1			8	8
Acrocladium cuspidatum																					*	*
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare																					*	*
B. rutabulum	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1		1		17	17
Bryum pseudotriquetrum																					*	*
Chiloscyphus polyanthos			1													1					2	2
Cinclidotus fontinaloides	1		1		1				1	2	1	1	1	1		3	1		1		12	15
Climacium dendroides																					*	*
Conocephalum conicum							1			1						2	3				4	7
Cratoneuron filicinum												1									1	1
Dichodontium pellucidum																					*	*
Eurhynchium riparioides	1		2	1	2	1		1	1	2	1	2		1	1	3	1		1	1	16	22
Fissidens adianthoides																					*	*
F. crassipes	1	1	1			1	1	1			1					2	1		1		10	11
Fontinalis antipyretica		1		1		1	1			1	2			1		2	1		1	1	11	13
F. ant. var. gracilis																					*	*
Funaria hygrometrica									1												1	1
Grimmia alpicola					1					1	1						1				4	4
Hygroamblystegium fluviat							1			1	1			1		1	1		1		7	7
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium			1										1						1		3	3
Leskea polycarpa																					*	*
Marchantia polymorpha			1				1				1	1			1	1	1	1			8	8
Mnium longirostrum				1					1					1							3	3
M. punctatum																					*	*
Orthotrichum rivularo											1				1						2	2

species	km down River Tweed																				0.5 km total (max. 20)	abundance total (max.100)
	120.0	120.5	121.0	121.5	122.0	122.5	123.0	123.5	124.0	124.5	125.0	125.5	126.0	126.5	127.0	127.5	128.0	128.5	129.0	129.5		
Pellia endiviifolia								1			1					2					3	4
P. epiphylla			1							2						1		1			4	5
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum																1					1	1
Tortula mutica								1								1			1		3	3
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.					1					1				1	1				1		5	5
Caltha palustris	1							1			1				1	1			1		6	6
Carex nigra																					*	*
C. rostrata								1													1	1
Carex other spp.		1						1											1		3	3
Cochlearia alpina																					*	*
Eleocharis palustris		1	1	1	3			1	2	1	1	1	1	1	1	1	1	1	1		16	19
Elodea canadensis	1	2	1	1	3	1	1	2	1	1	1	2	1	1	1	1	1	1	3	3	20	29
Equisetum fluviatile	1				1			1		1	1		1		1		1	1	3		10	12
Filipendula ulmaria				1							1								1		3	3
Glyceria fluitans	1	1		1				2		1	2	1	2		1	1		1	1	1	13	16
Iris pseudacorus																					*	*
Juncus acutiflorus	1	1			1					1	1		1	1			1	1	1		10	10
J. effusus	1									1											2	2
J. inflexus																					*	*
Mentha aquatica																					*	*
Mimulus guttatus		1	1		1			1			1	1		1		1	1				9	9
Myosotis scorpioides	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20	21
Myriophyllum alterniflorum																						*
M. spicatum	2	3	1	2	1	2	1	1	1	3	2	4	2	1	1	1	1	1	1	4	20	35
Phalaris arundinacea	1	1	2	1	3	1	1	1	2	1	1	2	1		1	1	1	2	1	1	19	25
Polygonum amphibium		1	2	1	2			1	1	2	1	1						1	1	1	12	15
Potamogeton crispus	1	2		1	1					1	1	1			1	1	1		1	2	12	14
P. lucens																					*	*
P. natans																					*	*
P. x olivaceus																					*	*
P. pectinatus	1	3	3	2	3	5	4	2	2	3	1	2	2	1	2	3	3	3	3	4	20	52
P. perfoliatus								1		1											2	2
P. pusillus		1		1	1	1	1	1		1	1	1	1	1			1		1	1	14	14
P. x salicifolius	2	4	1	3	3	5	4	2	1	1		2	1		1	1	2	3	1	1	18	39
P. x suecicus																					*	*
Ranunculus aquatilis agg.																					*	*
R. flammula																					*	*
R. fluitans x ?	1	2	3	4	4	3	3	3	3	3	2	2	2	2	3	2	3	3	1	3	20	52
R. penicillatus var. calc	1	2	3	4	4	3	3	3	3	3	3	3	2	3	3	2	3	3	2	3	20	56
Rorippa amphibia (arcus	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20	21
R. nasturtium-aquaticum		1							1	1							1				4	4
Scirpus sylvaticus		1						1	1	1											4	4
Sparganium erectum		1	2	1	1				1	1			1					1		1	9	10
Veronica beccabunga	1	1			1			1	1										1		6	6
Zannichellia palustris		2	1		1		1		1	1	1	1				1	1	1	1		12	13
Sewage fungus (obvious)																					*	*

species	130.0	130.5	131.0	131.5	132.0	132.5	133.0	133.5	134.0	134.5	135.0	135.5	136.0	136.5	137.0	137.5	138.0	138.5	139.0	139.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Nostoc parmelioides				1						1											2	2
Nostoc other sp(p).																					*	*
Phormidium spp.			1	1							1					1					4	4
Hildenbrandia rivularis	1	1	2	3	1	1		2	1	1	1	2	1	2	3	2	1		1		17	26
Lemanea fluviatilis																					*	*
Botrydium granulatum				1										1							2	2
Vaucheria sp(p).		1		1	1				1				1	1		1			1		8	8
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis	1	2		2	1	2		2	1	2	1		1	3	2			2	3		14	25
Cladophora glomerata	1	1	1	2	1	1	1	1	1	1	1	3	1	1	1	1	1	1		1	19	22
Cladophora sp.'A' .		1		2				1													3	4
Enteromorpha sp(p).	2	3		1	1	1	5			3	3			2	1		1		1	3	13	27
Haematococcus viride																					*	*
Monostroma bullosum													1								1	1
Oedogonium spp.	3	3	4	2	1	1	1	1	1	3	1	3	1	1	1	1	3	5	4	4	20	44
Tetraspora sp(p).	1			1	3					1			1			1	2		1		8	11
Stigeoclonium tenue	2	4	1	1	2	1	1	2	1	2	4	5	1		1	1		1	3	1	18	34
Ulothrix zonata																					*	*
Prasiola crispa																					*	*
Spirogyra spp.																1			1	4	3	6
Collema flaccidum																					*	*
C. fluviatile				1		1															2	2
Dermatocarpon fluviatile																					*	*
Verrucaria praetermissa					1	1											1				3	3
Verrucaria other spp.	1		2	2	1	1				1		2			2			1			9	13
Acrocladium cuspidatum																					*	*
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare																					*	*
B. rutabulum	1			1	1	1	1	1	1	1			1	1	2					1	12	13
Bryum pseudotriquetrum																					*	*
Chiloscyphus polyanthos																					*	*
Cinclidotus fontinaloides	1			1		1							1						2	1	6	6
Climacium dendroides																					*	*
Conocephalum conicum						1		1	1				1			1					5	5
Cratoneuron filicinum				1						1			1								3	3
Dichodontium pellucidum								1													1	1
Eurhynchium riparioides	1	1		2	1	1	3				1	1	1		1				1		11	14
Fissidens adianthoides																					*	*
F. crassipes		1	1	2	2	2	1	2	1		1		2			1	1			1	13	18
Fontinalis antipyretica		1				2		1				1			1						5	6
F. ant. var. gracilis																					*	*
Funaria hygrometrica																					*	*
Grimmia alpicola								1						1							2	2
Hygroamblystegium fluviat				2	1	1	2	1	1	1			1	1				1			9	11
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium	1	1		2	1				1		1	1					1				8	9
Leskea polycarpa																					*	*
Marchantia polymorpha				1		1	1					1			1			1			6	6
Mnium longirostrum						1										1					2	2
M. punctatum																					*	*
Orthotrichum rivulare	1					1													1		3	3

species	km down River Tweed 130.0	130.5	131.0	131.5	132.0	132.5	133.0	133.5	134.0	134.5	135.0	135.5	136.0	136.5	137.0	137.5	138.0	138.5	139.0	139.5	0.5 km total (max. 20)	abundance total (max.100)
Pellia endiviifolia				1						1					1				1		4	4
P. epiphylla						1			1	1	1						1	1		1	7	7
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum																					*	*
Tortula mutica										1	1			1					1		4	4
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.			1		1							1						1			4	4
Caltha palustris				1			1							1	1	1			1		6	6
Carex nigra																					*	*
C. rostrata		1					1	3													3	5
Carex other spp.																					*	*
Cochlearia alpina																					*	*
Eleocharis palustris	1	1	2	1	2		1		1	1	1	2	2	1	2	1	1	1	1	2	18	24
Elodea canadensis	2	3	1	1	3	1	4		1	2		2	2	4	4	3	2	2	2	1	18	40
Equisetum fluviatile			2	1	1		1			1		1			2		1		1		9	11
Filipendula ulmaria						1			1												2	2
Glyceria fluitans				1		1				1	1			1			1	1	1		8	8
Iris pseudacorus								1	1												2	2
Juncus acutiflorus	1	1	1	1	1	1	1	1	1	2	1	1	1		1		1	1	1		17	18
J. effusus							1						1		1						3	3
J. inflexus			1		1	1									1						4	4
Mentha aquatica					1																1	1
Mimulus guttatus	1	1		1		1	1		1	1			1		2			1	1	1	12	13
Myosotis scorpioides	1	1	1	2	1	1	1	1	1	1	2	1	2	2	2	1	1	2	1	1	20	26
Myriophyllum alterniflorum																					*	*
M. spicatum	2	2	2	3	2	3	2	2	1	4	3	4	3	1	2	1	2	2	2	1	20	44
Phalaris arundinacea	2	2	1	3	1	1	2	1	2	2	1	2	1	1	1	1	1	2	1	1	20	29
Polygonum amphibium	2	2	1	2	2	1	1	1	1	1			1	1		1	1	2	1		16	21
Potamogeton crispus	1	1		1	2			1		1	1	1			2	1		2	1	1	13	16
P. lucens				2																	1	2
P. natans					1																1	1
P. x olivaceus					1																1	1
P. pectinatus	2	2	1	3	4	2	3	2	2	3	3	3	2	3	2	2	2	3	2	1	20	47
P. perfoliatus	2				5	1	4	3	3	3	3	3	3	3	5	4	4	4	3	1	17	54
P. pusillus	1			1	1	1			1	1		1		1		1	1		1		11	11
P. x salicifolius	1		3	3	3	2	4	2	3	3	1		3	1	1	1		2	1	1	17	35
P. x suecicus					1					1					1			2	1		5	6
Ranunculus aquatilis agg.																					*	*
R. flammula																					*	*
R. fluitans x ?	3	3	2	4	3	3	1	5	3	3	4	3	4	2	3	3	2	4	3	1	20	59
R. penicillatus var. calc	1	3	1	3	4	2	1	4	3	3	4	4	4	1	3	2	3	4	3	1	20	54
Rorippa amphibia (areus	1		1	2	2	2	1	1	1	1	2	2	2		1	1	1	1	1	1	18	24
R. nasturtium-aquaticum									1				1			1			1		4	4
Scirpus sylvaticus		1						1	1												3	3
Sparganium erectum		1		1	1	1	5	3				1				1	4				9	18
Veronica beccabunga		1		1	1		1			1	1		1		3			1	1	1	11	13
Zannichellia palustris		1		2	1	1	1	2		1		1	1		1		2	3	1		13	18
sewage fungus (obvious)													1					2			2	3

species	km down River Tweed 140.0	140.5	141.0	141.5	142.0	142.5	143.0	143.5	144.0	144.5	145.0	145.5	146.0	146.5	147.0	147.5	148.0	148.5	149.0	149.5	0.5 km total (max. 20)	abundance total (max.100)
Nostoc parmelioides																					*	*
Nostoc other sp(p).																					*	*
Phormidium spp.			1		1						1		1								4	4
Hildenbrandia rivularis		1		2		1	1	1			1	2	3	2	1	1					11	16
Lemanea fluviatilis																					*	*
Botrydium granulatum																					*	*
Vaucheria sp(p).					1				1		1	1			1	3	1	1	2	2	10	14
Didymosphenia geminata																					*	*
Heribaudiella fluviatilis					2	1		2	1			5		1	1	3	4	1	4	3	12	28
Cladophora glomerata	1	1	1	3	1	1		3	1	1	1	4	1	1	4	5	4	4	4	5	19	46
Cladophora sp.'A'																					*	*
Enteromorpha sp(p).	1	4	2	3	2	2	2	1	2	1	2	2	1	1	2	3	4	5	5	5	20	50
Haematococcus viride																					*	*
Monostroma bullosum																					*	*
Oedogonium spp.	1	5	5	5	4	3	1	1	1	1	1	4	1	1	3	1					16	38
Tetraspora sp(p).	1		1			1		1													4	4
Stigeoclonium tenue		1				1						1									3	3
Ulothrix zonata																					*	*
Prasiola crispa																					*	*
Spirogyra spp.	1		3	1					3	1	1	1	1								8	12
Collema flaccidum																					*	*
C. fluviatile																					*	*
Dermatocarpon fluviatile																					*	*
Verrucaria praetermissa																					*	*
Verrucaria other spp.	1	1		2	1		1	1	1		1	2	1		1	1					12	14
Acrocladium cuspidatum																					*	*
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B. rivulare																					*	*
B. rutabulum	1		1	2		1	1	1		1	2	3	1	1	1	2	1	1			15	20
Bryum pseudotriquetrum																					*	*
Chiloscyphus polyanthos																					*	*
Cinclidotus fontinaloides			1					1									1				3	3
Climacium dendroides																					*	*
Conocephalum conicum		1				1						1			1				1	1	6	6
Cratoneuron filicinum			1				1														2	2
Dichodontium pellucidum																					*	*
Eurhynchium riparioides	1		1		1	1					1	1		1							7	7
Fissidens adianthoides																					*	*
F. crassipes	1				1	1															3	3
Fontinalis antipyretica					1			1			2										3	4
F. ant. var. gracilis																					*	*
Funaria hygrometrica																					*	*
Grimmia alpicola			1																		1	1
Hygroamblystegium fluviat	1		1			1	1		1		1										6	6
Hygrohypnum luridum (ile																					*	*
H. ochraceum																					*	*
Leptodictyum riparium	1			1			1		1	1	1										6	6
Leskea polycarpa																					*	*
Marchantia polymorpha			1					1													2	2
Mnium longirostrum		1		1			1			1			1								5	5
M. punctatum																					*	*
Orthotrichum rivulare																					*	*

species	140.0	140.5	141.0	141.5	142.0	142.5	143.0	143.5	144.0	144.5	145.0	145.5	146.0	146.5	147.0	147.5	148.0	148.5	149.0	149.5	0.5 km total (max. 20)	abundance total (max.100)
	km down River Tweed																					
Pellia endiviifolia																					*	*
P. epiphylla				1					1												2	2
Philonotis fontana																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum																					*	*
Tortula mutica						1						1									2	2
Rhacomitrium acicularis																					*	*
R. aquaticum																					*	*
Rhytidiadelphus squarrosus																					*	*
Callitriche spp.			1		2		1	2		2	1					1	2	1	1		10	14
Caltha palustris	1					1	1				1	2	1		1	1	1	2	1	1	12	14
Carex nigra																					*	*
C. rostrata	3	1	1	3	1		3		4	3	3	2		1						1	12	26
Carex other spp.																					*	*
Cochlearia alpina																					*	*
Eleocharis palustris	3	1		1	2	1	1	1	1	1	1	3		1	1				3	2	15	23
Elodea canadensis	3	5	3	4	4	3	3	3	4	3	1	3	4	3	1	3					16	50
Equisetum fluviatile	1								1							1					3	3
Filipendula ulmaria												1									1	1
Glyceria fluitans		2		1				2													3	5
Iris pseudacorus				1																	1	1
Juncus acutiflorus	1	1	1	1				1	1	1		1	1	1	1	1	1	1			14	14
J. effusus												1		1							2	2
J. inflexus																					*	*
Mentha aquatica												1									1	1
Mimulus guttatus	1		1					1	1	1	1	2		1	1	3	1				11	14
Myosotis scorpioides	1	1	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1			18	20
Myriophyllum alterniflorum																					*	*
M. spicatum	1	2	2	1	2	1	2	2	1	2	3	3	3	3	2	3	2	3			18	33
Phalaris arundinacea	1	1	1	1	2	1	2	1	1	1	2	3	1	3	1	1	1	1	4	3	20	32
Polygonum amphibium					1		1		1	1	3	1				1					7	9
Potamogeton crispus		1	1	1	1	1	1				1	1			1	1	1				11	11
P. lucens							1				3	3									3	7
P. natans												3									1	3
P. x olivaceus																					*	*
P. pectinatus	1		4	3	3	2		1	1	1	1	1	2	1	1	3	4	2			16	31
P. perfoliatus	1	1	4	3	3	5	2	1	3	3	3	3	3	3	3	3	3	2			18	49
P. pusillus	1		1		1	1	1		1	1			1		1			1			10	10
P. x salicifolius							1				4	4					1				4	10
P. x suecicus						2					1										2	3
Ranunculus aquatilis agg.																					*	*
R. flammula																					*	*
R. fluitans x ?	3	3	3	2	5	5	4	2	3	3	3	2	2	1	1	2	2	1			18	47
R. penicillatus var. calc	1	2	1	2	4	5	3	2	2	2	1	3	2	1	1		1				16	33
Rorippa amphibia (areus	1	1	2	1	1	1	1	1		1	1	2	1	1	1	1	1	1	1		18	20
R. nasturtium-aquaticum								1			1						1				3	3
Scirpus sylvaticus																					*	*
Sparganium erectum				1	3	1	1			1		1									6	8
Veronica beccabunga		1			1		1			2		1	1	1			1	1			9	10
Zannichellia palustris			1		1	1	1		1				1		1	1	1	1	1		11	11
sewage fungus (obvious)																					*	*

km up the River Teviot

(from Teviot Foot at Kelso)

species	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	0.5 km total (max. 20)	abundance total (max.100)
hamaesiphon spp. (obvious)																					*	*
ostoc parmelioides					2																1	2
hormidium spp.		1								2				1							3	4
ildenbrandia rivularis	3	3	2	4	3	2	3	2	2	2		3	4	4	4	3	2	2		2	18	50
emanea fluviatilis	1	2		1						1			1					1			6	7
aucheria sp(p).										1						1					2	2
elosira varians	1			1				2	4	3	5	1	2	2	1	3					11	25
oribaudiella fluviatilis	2	2	2	1			1		1			3	2	2	2	1	1			1	13	21
ladophora glomerata	3	3	1	1	1	2	1		2	2	1	1	1	1	1	1	2	2	3	1	19	30
nteromorpha sp(p).	3	3	2	3	2	1	2	2	3	2	3	3	3	1	2	2	3	2	3	2	20	47
ongrosira incrustans	4	3	2	2	2	4	2	2	2	2	1	2	1	2	1	1	1	1		1	19	36
aematococcus viride																					*	*
onostroma bullosum		2		1	1	2		1		1			1								7	9
edogonium spp.	1					1		1	2	1	1	1	1	2		1	1		1		12	14
etraspora sp(p).	2	2	1	1		2	2	3	2	2	1	1		2			1	2	1		16	26
tigeoclonium tenue											1										1	1
lothrix zonata																					*	*
rasiola crispa		1			1	1		2	1	2			2	2	1			2			10	15
pirogyra spp.	1							1		1		1	2	1			2		1		8	10
haraphyta sp.																					*	*
ollema flaccidum																					*	*
.fluviatile													2		1						2	3
ermatocarpon fluviatile																					*	*
errucaria praetermissa					1	1							2			1					4	5
errucaria other spp.	1	1	1	2	2	2	2	1	2	1		2	2	3	1	2	2	2		1	18	30
crocladium cuspidatum																					*	*
mphidium mougeotii																					*	*
rachythecium plumosum																					*	*
.rivulare																1					1	1
. rutabulum	1	1					1							1	1	1					6	6
ryum pseudotriquetrum						1			1		1			1		1					5	5
inclidotus fontinaloides		1	2	2	2			3	3	1	1		1	1	1						11	18
limacium dendroides																					*	*
onocephalum conicum	2	1		1							1		2		1	1			1		8	10
ratoneuron filicinum																2					1	2
ichodontium pellucidum		1									1		2	1	1	1			1		7	8
urhynchium riparioides	4	5	4	4	5	3	4	3	4	3	1	3	5	4	5	3	2	5	1	3	20	71
issidens adianthoides																					*	*
.crassipes	2			2	1			1	1	1	1		3		1	2					10	15
ontinalis antipyretica	3	1		2	2	1	1	2	1	1	3	1	2		1	4	2	4	3	4	18	38
unaria hygrometrica																					*	*
rimmia alpicola				1	2																2	3
ygroamblystegium fluviat		1		1	2								2	1	1	1	1	2		1	10	13
ygrohypnum luridum (ile																					*	*
.ochraceum																					*	*
eptodictyum riparium											2	2	1		1			1	2		6	9
eskea polycarpa																					*	*
archantia polymorpha	1	1		1	2						1		1	1	1	1			1		10	11
nium longirostrum										1			1	1	1				1		5	5
.punctatum																					*	*
rthotrichum rivulare					2											1					2	3
ellia endiviifolia	1									1						1					3	3
.epiphylla	2									1					1	1			2		5	7

km up the River Teviot

(from Teviot Foot at Kelso)

species	0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	5 km total (max. 20)	undance total (max.100)
hilonotis fontana,																					*	*
capania undulata																					*	*
olenostoma triste																					*	*
hamnium alopecurum				1	1			1					1		1	1		1			7	7
ortula mutica		1									1	3	1								4	6
hacomitrium acicularis																					*	*
.aquaticum																					*	*
hytidiadelphus squarrossus																					*	*
allitriche hermaphroditica																				1	1	1
allitriche other sp(p).																					*	*
altha palustris	1	2	1	1	1		1	1	1	2		1	1	1	1			1	1		15	17
arex acutiformis																					*	*
.hirta																					*	*
C.nigra																					*	*
C.ovalis																					*	*
C.rostrata												1									1	1
Cochlearia alpina																					*	*
Eleocharis palustris	2	3	3	3		3		4	1	2	2	4	3	1			2	2	1	1	14	34
Elodea canadensis	3	1	3	2	1		1	1	3	1	3	3	2	1	1	1	3	1	1	1	19	33
Equisetum fluviatile		1			1							1		1							4	4
Filipendula ulmaria	1		2	1		1		1			1			1	1	2		1			10	12
Glyceria fluitans	1							1		1			1	1							5	5
Iris pseudacorus					1	2	1	1	3	1					1						7	10
Juncus acutiflorus		1									1	1								1	4	4
J.effusus					1	1					1			1							4	4
J.inflexus		1	2	2	1					1	1	1	1								8	10
Lemna minor	1	1	2	1	1					2											6	8
Mentha aquatica		1	1	2	1	1		1		1	1	1	1								10	11
Mimulus guttatus	1	1	1	1	2	1	1	1	2	3	1	1	1	1	1	1	1	1	1	1	20	24
Myosotis scorpioides	1	1	1	1	2	1	1	1	1	3	1	2	1	1	1	1	2	1	1	1	20	25
Myriophyllum alterniflorum																					*	*
M.spicatum	4	2	5	4	3	3	3	3	4	3	3	3	2	3	5	5	3	3	2	3	20	66
Phalaris arundinacea	3	1	1	1	2	1	2	1	1	1	1	1	1	1	2	1	1	1	2	1	20	26
Phragmites communis																					*	*
Polygonum amphibium	1	1	1	1	2	1	1	1	1	3	1	2	1	1	1	1	2	1	1	1	20	24
Potamogeton crispus	2	2	1	1	2	1	1		2	1	1	1	1	1	1	2	2	2	1	3	19	28
P.lucens			3																3		2	6
P.natans		1	3																3		3	7
P.pectinatus	3	3	2	2	3	2	3	4	3	3	3	3	3							1	14	38
P.perfoliatus			3							1		1	1						3		5	9
P.pusillus	1			1													1		1	1	5	5
P. x salicifolius	3	3	5	4	3		2	2	5	5	5		3						2		12	42
Ranunculus aquatilis																					*	*
R.flammula																					*	*
R.fluitans x ?	4	4	3	5	5	4	3	3	3	1	1	1	2	5							14	44
R.penicillatus var.calcar	4	5	5	3	3	5	4	5	5	3	3	5	5	4	5	4	5	4	1	3	20	81
Rorippa amphibia (eus		1	1								1	1	1				1		1	1	8	8
R.nasturtium-aquaticum					1		1											1		1	4	4
Scirpus sylvaticus		1	1	1	1	3		1	1		1	1	1		2		1				12	15
Sparganium erectum	1	5	4	5	3	3	4	3	4	5	4	4	3	2	1	2	3	1		3	19	60
Veronica beccabunga			1		1				3	1	1	1	1		1	1	1	1	1	1	13	15
Zannichellia palustris	3	3	2	1	2	2	3	2	3		2	4	2		2	2	2	3	2	3	18	43
sewage fungus (obvious)																					*	*

km up the River Teviot

(from Teviot Foot at Kelso)

species	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	0.5 km total (max. 20)	abundance total (max.100)
Chamaesiphon spp. (obvious)																					*	*
Nostoc parmelioides						1															1	1
Phormidium spp.																			1		1	1
Hildenbrandia rivularis	1	2	2	1	1	3	2		1	2	2	2	1	3	2		2		3	2	17	32
Lemanea fluviatilis																					*	*
Vaucheria sp(p).																				1	1	1
Melosira varians		2				1	1	4	2	2	3	1	4				1	3			11	24
Heribaudiella fluviatilis		2	1	1	2	1	1	1			1	1		1	1	1	1		1		14	16
Cladophora glomerata	3	4	3	3	3	1	2	2	1	1	2	3	4	4	2		1	2	1	1	19	43
Enteromorpha sp(p).	1	4	1	3	3	1	3	4	1	3	4	1	1	3	3	2	1	2	2		19	43
Gongrosira incrustans	1	3	2	2		1	1		3	1	2	2	2	1	3	1	2	4		2	17	33
Haematococcus viride																					*	*
Monostroma bullosum			1		1																2	2
Oedogonium spp.		1		1		2	3	5	2	2	2	2	1	1		1	1	1	2	1	16	28
Tetraspora sp(p).	1			1					1				1								4	4
Stigeoclonium tenue																					*	*
Ulothrix zonata																					*	*
Prasiola crispa			1													1		1			3	3
Spirogyra spp.				1		1	1	2	1		1					1			1		9	10
Charaphyta sp.																					*	*
Collema flaccidum					1														1		2	2
C.fluviatile						1						1							2		3	4
Dermatocarpon fluviatile																					*	*
Verrucaria praetermissa						1				1				1							3	3
Verrucaria other spp.	1	2	1	2		1	2		1	1	1	2	2	3	2	1	2	1	2	1	18	28
Acrocladium cuspidatum					1																1	1
Amphidium mougeotii																					*	*
Brachythecium plumosum																					*	*
B.rivulare																	1				1	1
B. rutabulum	1	2	1		1					1		1		1							7	8
Bryum pseudotriquetrum							1														1	1
Cinclidotus fontinaloides										2		1		1		1			1	3	6	9
Climacium dendroides																					*	*
Conocephalum conicum	1	1		1			1		1			1					1	1	1		9	9
Cratoneuron filicinum											1	1	1								3	3
Dichodontium pellucidum		1					1		1						1		1		2	1	6	7
Eurhynchium riparioides	1	2	1	2	1	5	1	2	1	3	3	5	1	3	4	1	1	2	2	4	20	40
Fissidens adianthoides																		1			1	1
F.crassipes																	1		1		2	2
Fontinalis antipyretica	3	1		1		1		1	2	3	2	1	1	4	4	1	1	1	3	3	17	33
Funaria hygrometrica															1						1	1
Grimmia alpicola		1								1		2						1			4	5
Hygroamblystegium fluviat	1	1		1		1		1	1	2	1	2	1	1	1	1	1	1	2	3	17	22
ygrohypnum luridum (ile																					*	*
.ochraceum																					*	*
Leptodictyum riparium							1								1	2			1		4	5
Leskea polycarpa																				1	1	1
Marchantia polymorpha		1			1			1	1	1		1					1	1			8	8
Mnium longirostrum			1				1						1				1				4	4
.punctatum																					*	*
rthotrichum rivulare												1									1	1
ellia endiviifolia			1					1						1	1						4	4
.epiphylla										1					1						2	2

species	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	0.5 km total (max. 20)	abundance total (max. 100)
	km up the River Teviot (from Teviot Foot at Kelso)																					
Philonotis fontana,																					*	*
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum																					*	*
Tortula mutica									1			1					1				3	3
Rhacomitrium acicularis																					*	*
R.aquaticum																					*	*
Rhytidiadelphus squarrossus																					*	*
Callitriche hermaphroditica																					*	*
Callitriche other sp(p).						1															1	1
Caltha palustris							1	1	1	2			1					1	1	1	8	9
Carex acutiformis																					*	*
C.hirta																					*	*
C.nigra																					*	*
C.ovalis																					*	*
C.rostrata																					*	*
Cochlearia alpina																					*	*
Eleocharis palustris			1	1			1	1	2	2	1	3	2				2	2	1	2	13	21
Elodea canadensis	3	1		1	1	1	3	1	1	2	3	1	1	3	5	5	3	1	3	2	19	41
Equisetum fluviatile										1		1		1			1	1		1	6	6
Filipendula ulmaria		2	1	1	1	1				1	1			1	2	3	2	1			12	17
Glyceria fluitans	1	1							1			1									4	4
Iris pseudacorus																					*	*
Juncus acutiflorus						1	1		1		1	1									5	5
J.effusus								1	1				1								3	3
J.inflexus							2		1												2	3
Lemna minor																					*	*
Mentha aquatica						1				1	2										3	4
Mimulus guttatus	1	2	1	1	1	1	1	1	1	1	2	1	1	3	2	1	2	1	1	1	20	26
Myosotis scorpioides	1	2	1	1	1	1	1	1	1	1	2	1	1	1	2	1	2	1	1		19	23
Myriophyllum alterniflorum																					*	*
M.spicatum	3	4	5	3	2	3	3	4	2	3	3	1	3	4	5	4	5	5	3	3	20	68
Phalaris arundinacea	1	1	3	2	1	1	1	1	2	3	2	1	1	1	5	1	2	1	2	1	20	33
Phragmites communis															2				2	1	3	5
Polygonum amphibium						1	3		1	1	2	1				1			2	1	9	13
Potamogeton crispus		1		1		1	2	2	3	1	3	2	1	1	1		3	2	2	1	16	27
P.lucens																					*	*
P.natans																			1		1	1
P.pectinatus																					*	*
P.perfoliatus																					*	*
P.pusillus				1					1					1	1		1	1	1	1	8	8
P. x salicifolius																					*	*
Ranunculus aquatilis																					*	*
R.flammula																					*	*
R.fluitans x ?																					*	*
R.penicillatus var.calcar	4	4	3	1	2	5	4	2	4	4	5	4	5	5	5	3	5	5	3	4	20	77
Rorippa amphibia (eus	1	1	1	1	1		1	1		1		1	1	1			1	1	1		14	14
R.nasturtium-aquaticum	1	2		1													1	1		1	6	7
Scirpus sylvaticus				1		1															2	2
Sparganium erectum	3		2	2	1			1	1	2	3		2	1	4	4	4		1		14	31
Veronica beccabunga					1	1	2	1		1	1	1		1	1	1	1		1		12	13
Zannichellia palustris	4	2	3	4	2	2	3	3	4	3	3	3	3	4	4	1	5	3	4	2	20	62
sewage fungus (obvious)																					*	*

species	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0	28.5	29.0	29.5	.5 km total (max. 20)	undance total (max.100)
	km up the River Teviot (from Teviot Foot at Kelso)																					
hamaesiphon spp. (obvious)																					*	*
ostoc parmelioides	1																				1	1
hormidium spp.		1	2										2		1			3		1	6	10
ildenbrandia rivularis	2		2	1	1	3	1		2	3	2		1	1	2		2	1	1	1	16	26
emanea fluviatilis				2																	1	2
aucheria sp(p).		2	1	2							1		2	2	3		1	1		1	10	16
elosira varians					4	3			1					1			1				5	10
eribaudiella fluviatilis	1	1	1	1	1	2		1	1	1	1	1	2	1	1	1	1	1	1	1	19	21
ladophora glomerata	2	1	2	3	2	3	3	5	2	3	3	4	3	3	3	2	2	2	3	1	20	52
nteromorpha sp(p)			2	2																	2	4
ongrosira incrustans	1	1	2	2	2	1	1	2	2	2	4	4	1	2	1	1	2	1	1	2	20	35
aematococcus viride																					*	*
onostroma bullosum																					*	*
edogonium spp.		1	1	2		1	2		1		2	1	2		1	2	1	3	1	2	15	23
etraspora sp(p).																					*	*
tigeoclonium tenue																					*	*
lothrix zonata																					*	*
rasiola crispa					1	1			1				1								4	4
pirogyra spp.	1		1	3		2	2	1	2		3	3			2	1			1	1	13	23
haraphyta sp.																					*	*
ollema flaccidum											1										1	1
.fluviatile			2																		1	2
ermatocarpon fluviatile								1					1		1						3	3
errucaria praetermissa					1								1	1	1						4	4
errucaria other spp.	1		2	1	1	1	1	2	1	2	2	1	2	1	1	1	2	2	1	1	19	26
crocladium cuspidatum																					*	*
mphidium mougeotii																					*	*
rachythecium plumosum																					*	*
.rivulare								1	1				1				1			1	5	5
. rutabulum					1				1			1						1			4	4
ryum pseudotriquetrum																1					1	1
inclidotus fontinaloides	1		3	1	2	1					1		2		1			1			9	13
limacium dendroides																					*	*
onocephalum conicum		1			1				1	1				1		1					6	6
ratoneuron filicinum				1			1	1		2		1									5	6
ichodontium pellucidum	1	1	1		1	1	1	1			1	1	1		1		1				12	12
urhynchium riparioides	3	1	3	2	2	3	1	1	1	2	1	2	3	2	2	2	2	3	3	3	20	42
issidens adianthoides							1					1									2	2
.crassipes																					*	*
ontinalis antipyretica	4	1	3	2	4	3	2	1	1	3	1	1	2	1	1	1	3	3	3	1	20	41
unaria hygrometrica								1					1								2	2
rimmia alpicola	1	1	1	2	2	1	1			1			1	2	1						11	14
ygroamblystegium fluviat	1	1	4	2	2	1	1	1	1	1	1	2	1	1	2	1	1	1	2	1	20	28
ygrohypnum luridum (ile																					*	*
.ochraceum																					*	*
eptodictyum riparium			1		2																2	3
oskea polycarpa		1						1		1					1			1			5	5
archantia polymorpha		1									1		1			1					4	4
nium longirostrum									1												1	1
.punctatum																					*	*
rthotrichum rivulare		1			1	1								1							4	4
ellia endiviifolia						1															1	1
.epiphylla												1									1	1

km up the River Teviot

(from Teviot Foot at Kelso)

species	20.0	20.5	21.0	21.5	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	26.0	26.5	27.0	27.5	28.0	28.5	29.0	29.5	.5 km total (max. 20)	bundance total (max.100)
hilonotis fontana																					*	*
capania undulata																					*	*
olenostoma triste																					*	*
hamnium alopecurum																					*	*
ortula mutica	1	1	2	1	2	2	1	1	1	1	1	1	1	1		1		1	1	1	18	21
hacomitrium acicularis																					*	*
.aquaticum																					*	*
hytidiadelphus squarrossus																					*	*
allitriche hermaphroditica																					*	*
allitriche other sp(p).				1																	1	1
altha palustris	1													3	2	1	1		1		6	9
arex acutiformis																					*	*
.hirta																					*	*
C.nigra																					*	*
C.ovalis																					*	*
C.rostrata																					*	*
Cochlearia alpina																					*	*
Eleocharis palustris			1		1					1	1	1	2	3	2		3	1	3	2	12	21
Elodea canadensis	3	3	1	3	2	3		2	2	1	3		2	3	3	1	3	2	4	1	18	42
Equisetum fluviatile	1			1									1	2	1	1		1		1	8	9
Filipendula ulmaria							1							1	1	1					4	4
Glyceria fluitans	1		1	1	1	1		1	1	1		1		2			1	1			12	13
Iris pseudacorus																					*	*
Juncus acutiflorus			1	1	1		1	1	1				1	1	1	2	2	1		1	13	15
J.effusus			1	1	1				1							1		1			6	6
J.inflexus	1		1		1					1	1				1	1	2	1	1		10	12
Lemna minor																					*	*
Mentha aquatica														2		1	1	1			4	5
Mimulus guttatus	2	1	1	1	2	1	1	2	2	2	2	1	1		2	2	2	1	1	1	19	28
Myosotis scorpioides	2	1	1	1	2	1	1	2	2	1	2	1	1	1	1	1	2	1	1	1	20	26
Myriophyllum alterniflorum														1					1		2	2
M.spicatum	4	3	3	3	4	3	1	3	1	1	1	1	2	1	3	1	3	2	3	1	20	44
Phalaris arundinacea	1	1	1	2	1	1	1	1	1	1	2	1	2	2	2	1	1	1	2	2	20	27
Phragmites communis	:																				*	*
Polygonum amphibium	1	2	2	1	1				1	1				1		1	1				10	12
Potamogeton crispus	1	1	1	1	1	2		2	1	1	2	1	1	2	2		3	3	3	2	18	30
P.lucens																					*	*
P.natans																					*	*
P.pectinatus																					*	*
P.perfoliatus																					*	*
P.pusillus			1	1			1	1		1			3		1						7	9
P. x salicifolius																					*	*
Ranunculus aquatilis																					*	*
R.flammula																					*	*
R.fluitans x ?																					*	*
R.penicillatus var.calcar	4	4	4	3	5	4	4	4	5	4	4	3	4	4	4	5	5	5	1	1	20	77
Rorippa amphibia (cus	1	1		1																	3	3
R.nasturtium-aquaticum			1				1	1		1	1	1	2	2	1	1	1	1			12	14
Scirpus sylvaticus																					*	*
Sparganium erectum									1					1	2					2	4	6
Veronica beccabunga	1	1	1	1	1	1		1	1	1		1	2	2	1	1	2	1			16	19
Zannichellia palustris	3	2	3	3	4	2	2	4	3	2	4	2	3	2	2		2	2	3	4	19	52
sewage fungus (obvious)																					*	*

km up the River Teviot

(from Teviot Foot at Kelso)

species	-30.0	-30.5	-31.0	-31.5	-32.0	-32.5	-33.0	-33.5	-34.0	-34.5	-35.0	-35.5	-36.0	-36.5	-37.0	-37.5	-38.0	-38.5	-39.0	-39.5	.5 km total (max. 20)	bundance total (max.100)
hamaesiphon spp. (obvious)																	1		1	1	3	3
ostoc parmelioides																					*	*
hormidium spp.		1		2															1		3	4
ildenbrandia rivularis	2	1	2	1	3	3	2	2	2	2	3	1	1	1	1	1	1	2	1	2	20	35
emanea fluviatilis						1						1			1	1	1			2	6	7
aucheria sp(p).						1	1	1	2	2	2										6	9
elosira varians						1							3		1					1	4	6
eribaudiella fluviatilis	2	2	1	1	3	2	1	1	2	1	1	2	2	2	2	1	2	2	1	1	20	32
ladophora glomerata	3	3	3	3	3	3	3	2	2	4	1	3	4	3	1					1	16	42
nteromorpha sp(p)																					*	*
ongrosira incrustans	1	1	2	1	2	1	1	2	3	1	2	3	2	4	1	2		1	1	2	19	33
aematococcus viride																			1		1	1
onostroma bullosum																					*	*
edogonium spp.	1			1	3	4	1		1	2	1	1	1	1	1	1	1	1	3	2	17	26
etraspora sp(p).																					*	*
tigeoclonium tenue				1		4	1		1												4	7
lothrix zonata																					*	*
rasiola crispa	1					2		1	1	1											5	6
pirogyra spp.						1	1			1					1	1	2	2	1	3	9	13
haraphyta sp.																	2		2		2	4
ollema flaccidum																					*	*
.fluviatile				2										1			1				3	4
ermatocarpon fluviatile			1																		1	1
errucaria praetermissa					1	1								1	1	1		1	1	1	8	8
errucaria other spp.	2		3	3	3	3	1	1	2	1	1	1		1	1	1		1		1	16	26
crocladium cuspidatum									1								1			1	3	3
mphidium mougeotii																					*	*
rachythecium plumosum																		1		2	2	3
.rivulare																1	2		2	3	4	8
. rutabulum		1			1			1			2		1					2			6	8
ryum pseudotriquetrum									1										1		2	2
inclidotus fontinaloides		2	1	3	2	3			1	3	1	1	1	1	2	3	3	2	4	3	17	38
limacium dendroides																					*	*
onocephalum conicum		2	1	1	1		1	2	1		1	1	1	1		1	1	3	2	2	16	22
ratoneuron filicinum	1	1		1				1	1		1		1		1	1	3	1	2	1	13	16
ichodontium pellucidum	1	1		1		1		1		2	1	1	1	1	1	1	1	1	1	2	16	18
urhynchium riparioides	4	5	5	4	4	4	3	5	4	2	3	4	3	3	3	3	3	5	2	4	20	73
issidens adianthoides		1						1						1	1				1		5	5
.crassipes		1					1							1							3	3
ontinalis antipyretica	3	3	3	3	4	3	2	1	1	3	1	1	1	2	1	3	1	3	4	2	20	45
unaria hygrometrica													1					1		1	3	3
rimmia alpicola			1				1		1	1		1		1						2	7	8
ygroamblystegium fluviat	1	3	2	1	2	4	1	1	3	3	1	1	1	1	1	3	2	1	2	2	20	36
ygrohypnum luridum (ile				1				1			1	2	2	2	2	4	4	3	3	3	12	28
.ochraceum																					*	*
eptodictyum riparium																1					1	1
eskea polycarpa			1				1					1			1						4	4
archantia polymorpha		1	1	1			1	1	1		1	1	1		1	1	1		1		13	13
nium longirostrum		1								1	1				1			1		1	6	6
.punctatum														1				3		1	3	5
rthotrichum rivulare							1			1	1										3	3
ellia endiviifolia											1	1							1		3	3
.epiphylla																		1			1	1

km up the River Teviot

(from Teviot Foot at Kelso)

species	30.0	30.5	31.0	31.5	32.0	32.5	33.0	33.5	34.0	34.5	35.0	35.5	36.0	36.5	37.0	37.5	38.0	38.5	39.0	39.5	0.5 km total (max. 20)	abundance total (max. 100)
Philonotis fontana																				1	1	1
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum						1.		3										2	2	3	5	11
Tortula mutica	1			1			1				1										4	4
Rhacomitrium acicularis																					*	*
R.aquaticum																					*	*
Rhytidiadelphus squarrossus																					*	*
Callitriche hermaphroditica																					*	*
Callitriche other sp(p).												1									1	1
Caltha palustris		1	1			1				1	1				1				1	1	8	8
Carex acutiformis																			1		1	1
C.hirta																					*	*
C.nigra																					*	*
C.ovalis																					*	*
C.rostrata																			1		1	1
Cochlearia alpina																				1	1	1
Eleocharis palustris	1				1																2	2
Elodea canadensis	4	1	2	2	2	3			1	5	3		2	2	2	2	5				14	36
Equisetum fluviatile		2				1	3		1			1	1		1	1		1		1	10	13
Filipendula ulmaria	1			1						1	1	1	1			1		1	1	1	10	10
Glyceria fluitans	1		1		1	1					1	1	1	1	1	1	1	1	2		13	14
Iris pseudacorus					1																1	1
Juncus acutiflorus		1		1	1								1					1		1	6	6
J.effusus												1									1	1
J.inflexus																					*	*
Lemna minor																					*	*
Mentha aquatica			2			1			1					1		1		1		1	7	8
Mimulus guttatus		1	1	1	1		1		1	1	1	1	1	1	1			1	1	1	15	15
Myosotis scorpioides	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	20	21
Myriophyllum alterniflorum	1										3		1	2	1	1	5	3	2	1	10	20
M.spicatum	2	2	3	2	3	3	1		1	2	2		1	2							12	24
Phalaris arundinacea	2	1	1	1	2	1	1	1	3	1	1	1	1	1	1	1	1	1	1	1	20	24
Phragmites communis																					*	*
Polygonum amphibium	1				2	1					1	1		1		1					7	8
Potamogeton crispus	3	2	4	2	4	4	2	1	5	5	4	1	1	1	1	1	5				17	46
P.lucens																					*	*
P.natans																	1				1	1
P.pectinatus																					*	*
P.perfoliatus																					*	*
P.pusillus																					*	*
P. x salicifolius																					*	*
Ranunculus aquatilis																					*	*
R.flammula																					*	*
R.fluitans x ?																					*	*
R.penicillatus var.calcar	1			1	1									1			2				5	6
Rorippa amphibia (eus									1		1	1		1					1		5	5
R.nasturtium-aquaticum				1	2	1	1		1		1		1		1						8	9
Scirpus sylvaticus																					*	*
Sparganium erectum	1				1					1	1						1	1	1		7	7
Veronica beccabunga										1							1			1	3	3
Zannichellia palustris	3					2	1			1	1										5	8
sewage fungus (obvious)											1	1	2								3	4

Km up the River Teviot (from Teviot Foot at Kelso)

species	40.0	40.5	41.0	41.5	42.0	42.5	43.0	43.5	44.0	44.5	45.0	45.5	46.0	46.5	47.0	47.5	48.0	48.5	49.0	49.5	0.5 km total (max. 20)	Abundance total (max.100)
Chamaesiphon spp. (obvious)			2		1	1	2			2	3			1	1		2	1	1	2	12	20
Nostoc parmelioides																					*	*
Phormidium spp.			1	1	2	1		1			1	2	2	3	2	1	2	2	3	1	15	25
Hildenbrandia rivularis	2	2	1		1		1	1				1									7	9
Lemanea fluviatilis	1	1	1	3	1	1		2			1					3					9	14
Vaucheria sp(p).		1																			1	1
Melosira varians	1	1	1	2		1	3	1				2									8	12
Heribaudiella fluviatilis	1	1	1	1	1	1	1	1	1		2	1			1			1			13	14
Cladophora glomerata		1	1	1		4	2							4							6	13
Enteromorpha sp(p).																					*	*
Gongrosira incrustans	2	1	2	2	3	3	2	1	2	2			1	4	2	3	3				15	33
Haematococcus viride												1									1	1
Monostroma bullosum																					*	*
Oedogonium spp.	1		2	2	1	3	1	2		2	2		1		1			1			12	19
Tetraspora sp(p).																					*	*
Stigeoclonium tenue																					*	*
Ulothrix zonata									1	1		1			2	1	3	5	3	1	9	18
Prasiola crispa										1			1								2	2
Spirogyra spp.	2	2	1	2		1	1	2	2		1	1			1						11	16
Charaphyta sp.	1																				1	1
Collema flaccidum																					*	*
C. fluviatile	1			1																	2	2
Dermatocarpon fluviatile																					*	*
Verrucaria praetermissa	1	1	1				1	1	1	2	1	1	1	3	2			2	3	1	15	22
Verrucaria other spp.					1	1		1													3	3
Acrocladium cuspidatum	1		1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	2	3	19	26
Amphidium mougeotii								1					1				1		1	1	5	5
Brachythecium plumosum		1	2		1		1	2	2	3	1	3	1	1	1		2	1	1	1	16	24
B. rivulare				2		1		1	2	2	3	2	1	3			1				10	18
B. rutabulum	1						2			1		1			1		1		1		7	8
Bryum pseudotriquetrum	2	2	1	1	1	1	1	1	2	2	1	1	1	2		1	2	1	2	1	19	26
Cinclidotus fontinaloides	3	4	3	4	3	2	3	4	3	5	3	2	4	2	1	1	1				17	48
Climacium dendroides																					*	*
Conocephalum conicum	2	1	2	1	1		2	2	1		1	1	1		1	1	1	2	1		16	21
Cratoneuron filicinum	1	1	1	2	1	1	2	2	2	3	2	2	1	2	3		3		1	1	18	30
Dichodontium pellucidum	1	1	2	3	1	1	2	2	1	2	1	1	1	2	1	1	1	2	2	2	20	30
Eurhynchium riparioides	5	5	3	5	5	4	4	5	4	4	4	3	3	4	4	3	5	4	4	3	20	81
Fissidens adianthoides		1	1			1					1		1								5	5
F. crassipes								1													1	1
Fontinalis antipyretica	4	2	2	1	1	1	1	2	2	2	1	1	1	1	1	1	2	1	2	1	20	30
Funaria hygrometrica	1			1				1						1							4	4
Grimmia alpicola	1	1	1	4	1	1	1	2	3	3	4	2	2	2	1	1	2	2	1	2	20	37
Hygroamblystegium fluviat		1					2	1			1	1	2	1			1		1	1	10	12
Hygrohypnum luridum (ile	2	3	2	3	3	2	3	5	2	3	3	2	4	4	3	3	3	1	1	1	20	53
H. ochraceum				1	1	1		1			1										5	5
Leptodictyum riparium																					*	*
Leskea polycarpa	1			1																	2	2
Marchantia polymorpha																					*	*
Mnium longirostrum	1		1	1		1	2	1	1	1		1	1	1			1	1	1		14	15
M. punctatum			2				1										1				3	4
Orthotrichum rivulare			1	1																	2	2
Pellia endiviifolia		1	1		1		1														4	4
P. epiphylla		1						1	1		1	1		2		1		1	1	1	10	11

km up the River Teviot

(from Teviot Foot at Kelso)

species	40.0	40.5	41.0	41.5	42.0	42.5	43.0	43.5	44.0	44.5	45.0	45.5	46.0	46.5	47.0	47.5	48.0	48.5	49.0	49.5	0.5 km total (max. 20)	abundance total (max. 100)
Philonotis fontana,								1									4		2	1	4	8
Scapania undulata																					*	*
Solenostoma triste																					*	*
Thamnium alopecurum	2	3	3					3													4	11
Tortula mutica																					*	*
Rhacomitrium acicularis																					*	*
R.aquaticum																					*	*
Rhytidiadelphus squarrossus																					*	*
Callitriche hermaphroditica																					*	*
Callitriche other sp(p).					1																1	1
Caltha palustris		1	1	2	1	1	1	1	1				2				1			1	11	13
Carex acutiformis			3					3		2		1						1			5	10
C.hirta																					*	*
C.nigra			2	1			1		1			1	1	1			1		2		9	11
C.ovalis																	1			1	2	2
C.rostrata																	2	4	3	1	4	10
Cochlearia alpina					1												1				2	2
Eleocharis palustris		1	3		2					1		1					1	2		1	8	12
Elodea canadensis																						
Equisetum fluviatile	1	1	1	1	1	1	1	2	1	1	1	2	2	1			1		1	1	17	20
Filipendula ulmaria	1	1	1	2	1	1	1	1	1	1	2	1	3	3	3	3	3	1	2	1	20	33
Glyceria fluitans		1	1			1	1		1	1	2	3		1	3	3	2		3	2	14	25
Iris pseudacorus	1																				1	1
Juncus acutiflorus	2	2	1	2			1	1	1	2	1	1			2	2	1	1	2	2	16	24
J.effusus								1			1	1					1			1	5	5
J.inflexus																					*	*
Lemna minor																					*	*
Mentha aquatica	1		1	1	1	1	1			1	1	1			2	1	3	1	2	2	15	20
Mimulus guttatus	1	1	1		1	1	1	2	2				2	1		1	1	1	1	1	15	18
Myosotis scorpioides	1	1	2	1	1		1	1	1		1	2		1	1	1	1	1	1	1	17	19
Myriophyllum alterniflorum	1	2	2	2				2	1									1			7	11
M.spicatum																					*	*
Phalaris arundinacea	1	1	1					1							1	1	1				7	7
Phragmites communis																					*	*
Polygonum amphibium	1													3							2	4
Potamogeton crispus																					*	*
P.lucens																					*	*
P.natans																					*	*
P.pectinatus																					*	*
P.perfoliatus																					*	*
P.pusillus																					*	*
P. x salicifolius																					*	*
Ranunculus aquatilis																					*	*
R.flammula																			1		1	1
R.fluitans x ?																					*	*
R.penicillatus var.calcar			1																		1	1
Rorippa amphibia (eus	1													1	1	1	1				5	5
R.nasturtium-aquaticum	1			1	1				1		1	1		1	1	1					9	9
Scirpus sylvaticus																					*	*
Sparganium erectum		1																			1	1
Veronica beccabunga		1	1					1													3	3
Zannichellia palustris																					*	*
sewage fungus (obvious)			1																		1	1

species	km up the River Teviot (from Teviot Foot at Kelso) 50.0	50.5	51.0	51.5	52.0	52.5	53.0	53.5	54.0	54.5	55.0	55.5	56.0	56.5	57.0	57.5	58.0	58.5	59.0	59.5	0.5 km total (max. 20)	abundance total (max.100)
Chamaesiphon spp. (obvious)	1		2	1		1	2	2		1	1			1	1	1		2	2	1	14	19
Nostoc parmelioides																					*	*
Phormidium spp.	1	1	1	2	2	3	2	1	2	2	1	1	2	3	2	1	2	1	1	1	20	32
Hildenbrandia rivularis								1											1		2	2
Lemanea fluviatilis		1						1													2	2
Vaucheria sp(p).													1						1		2	2
Melosira varians																					*	*
Heribaudiella fluviatilis		1					1					1				1					4	4
Cladophora glomerata																					*	*
Enteromorpha sp(p).																					*	*
Gongrosira incrustans	1	1	1	2		1	2			1		1	1	2	1	3				2	13	19
Haematococcus viride			2			1										1				1	4	5
Monostroma bullosum																					*	*
Oedogonium spp.																					*	*
Tetraspora sp(p).																					*	*
Stigeoclonium tenue																					*	*
Ulothrix zonata	1	2	1	2	2	2	2	2	1	1	3	1	2	4	3	2	2	1	1	3	20	38
Prasiola crispa																					*	*
Spirogyra spp.																					*	*
Charaphyta sp.	3																				1	3
Collema flaccidum																					*	*
C.fluviatile																					*	*
Dermatocarpon fluviatile																					*	*
Verrucaria praetermissa	1						1	1	1	1		2	1	2	1	2	3	1	1	1	14	19
Verrucaria other spp.								1	1										1		3	3
Acrocladium cuspidatum	2	2	3	3	3	3	2	1	2	2	1	2	2	2	2	4	3	4	2	3	20	48
Amphidium mougeotii						1					1				1					1	4	4
Brachythecium plumosum	1	2	2	3	3	3	1	2	1		1	1		1	1	2	2	4	3	1	18	34
B.rivulare	1	2	2	3	3	3	1	3	1	1	1	1	1			2	1	2	1	1	18	30
B.rutabulum		1	1		1					1											4	4
Bryum pseudotriquetrum	2	2	2	2	2	2	1	2	1	2	2	1	2	2	2	2	2	3	3	3	20	40
Cinclidotus fontinaloides								1						1		1					3	3
Climacium dendroides												1							1	1	3	3
Conocephalum conicum	1	1	2	1	2	1	1	1	1	1	1	1		1	2	1	3	2	4	2	19	29
Cratoneuron filicinum	2	2	2	3	2	1	2	1	2	2	1	1	1	1	1	2	2	1	2	3	20	34
Dichodontium pellucidum	1	2	1	2	1	1	1	1	2	1	1	1	2	1	1	2	1	1	1	1	20	25
Eurhynchium riparioides	4	5	3	3	3	2	3	2	2	3	3	4	3	3	4	4	4	5	5	4	20	69
Fissidens adianthoides	1	1	1	1			1		1										1		7	7
F.crassipes																					*	*
Fontinalis antipyretica	2	1	3	2	2	2	1	2	1	1	2		1	1	1	1	2	3	2	2	19	32
Funaria hygrometrica	1											1									2	2
Grimmia alpicola	1	3	2	2	4	1	3	2	2	1	1	1	2	3	1	3	2	5	2	2	20	43
Hygroamblystegium fluviat		1	1	1	2	2	1					1			1		1		2		10	13
Hygrohypnum luridum (ile	1	2	2	2	2	2	3	2	2	1	1	2	1	2	1	1	2	2	2	2	20	35
H.ochraceum																					*	*
Leptodictyum riparium																					*	*
Leskea polycarpa																					*	*
Marchantia polymorpha																					*	*
Mnium longirostrum	1	1	1	2	2	2	1		1		1	1	1		2				1	1	14	18
M.punctatum				1		1							1						1	1	5	5
Orthotrichum rivulare											1							1			2	2
Pellia endiviifolia																					*	*
P.epiphylla	1	1	1	1	1	1	1	1	1	1		1	1	1	1	2	1	1	1	1	19	20

km up the River Teviot

(from Teviot Foot at Kelso)

species	50.0	50.5	51.0	51.5	52.0	52.5	53.0	53.5	54.0	54.5	55.0	55.5	56.0	56.5	57.0	57.5	58.0	58.5	59.0	59.5	0.5 km total (max. 20)	abundance total (max. 100)
Philonotis fontana,	2	1	2	2	2	3	1	2	2	1	1	1	2	1	4	2	2	3	2	4	20	40
Scapania undulata										3				1				1			3	5
Solenostoma triste															1					1	2	2
Thamnium alopecurum																					*	*
Tortula mutica																					*	*
Rhacomitrium acicularis													1			1			2		3	4
R.aquaticum			1				1			3					1		1				5	7
Rhytidiadelphus squarrossus				2							2						1				3	5
Callitriche hermaphroditica																					*	*
Callitriche other sp(p).	2	2						1													3	5
Caltha palustris			1	1	1	1	1											1	1	2	8	9
Carex acutiformis	2				4	4					2										4	12
C.hirta		1	1																1	2	4	5
C.nigra		1	1		2	2		1	1		4	4	2	1			1			2	12	22
C.ovalis					1					1	1		2	2					1	1	7	9
C.rostrata		2	4	4	2	2			3	2		2			2					3	10	26
Cochlearia alpina		1	1		1									1				1		1	6	6
Eleocharis palustris				1		2					1	1		1			1	3		1	8	11
Elodea canadensis																					*	*
Equisetum fluviatile	2	1	1	1		1	2	1	1			1	1		1	1	1	1	1	1	16	18
Filipendula ulmaria	2	2	1	2	2	1	2	2	1	2	1	3		1		2		1	1	2	17	28
Glyceria fluitans	2		1		1		1	1	2	2	3	2	2	3	3	2	3	1	1	2	17	32
Iris pseudacorus								2													1	2
Juncus acutiflorus	2	2	2	3	2	2	1	2	2	3	1	2	2	1	3	2	3	2	4	4	20	45
J.effusus	1	1	1	1	1	1		1	2	3	1	2	1	2	1	2	2	1	2	2	19	28
J.inflexus																					*	*
Lemna minor																					*	*
Mentha aquatica	2	2	2	1	1	1			1			2	2	1	1	2	1	1		1	15	21
Mimulus guttatus	1	1	2	2	1	2	1	1	1	1			1				1	2	2	3	15	22
Myosotis scorpioides	1	1	1	1	1	1	1	1	1	1	2		1			1	1	1	1	1	17	18
Myriophyllum alterniflorum								1													1	1
M.spicatum																					*	*
Phalaris arundinacea	1	1	1	2	1			1													6	7
Phragmites communis																					*	*
Polygonum amphibium																					*	*
Potamogeton crispus																					*	*
P.lucens																					*	*
P.natans																					*	*
P.pectinatus																					*	*
P.perfoliatus																					*	*
P.pusillus																					*	*
P.x salicifolius																					*	*
Ranunculus aquatilis	2														2				1	2	4	7
R.flammula					1								1				1		1	1	5	5
R.fluitans x ?																					*	*
R.penicillatus var.calcar																					*	*
Rorippa amphibia (eus			1						1					1							3	3
R.nasturtium-aquaticum	1		1						1	1	1		1	1	1		1				9	9
Scirpus sylvaticus																					*	*
Sparganium erectum																				1	1	1
Veronica beccabunga	1	1	2	1	1	2	1											1	1	1	10	12
Zannichellia palustris																					*	*
sewage fungus (obvious)																					*	*

km up the River Teviot

(from Teviot Foot at Kelso)

Species	60.0	60.5	61.0	61.5	0.5 km total (max. 4)	abundance total (max. 20)
:hamaesiphon spp. (obvious)	1	1	2	1	4	5
!ostoc parmelioides					*	*
'hormidium spp.	1		2		2	3
Iildenbrandia rivularis					*	*
,emanea fluviatilis				1	1	1
'aucheria sp(p).					*	*
Ielosira varians					*	*
Ieribaudiella fluviatilis					*	*
:ladophora glomerata					*	*
:nteromorpha sp(p)					*	*
;ongrosira incrustans					*	*
Iaematococcus viride	1	1		1	3	3
Ionostroma bullosum					*	*
)edogonium spp.					*	*
'etraspora sp(p).					*	*
;tigeoclonium tenue					*	*
Ilothrix zonata	1	1	2	2	4	6
'rasiola crispa					*	*
;pirogyra spp.					*	*
:haraphyta sp.					*	*
;ollema flaccidum					*	*
:.fluviatile					*	*
)ermatocarpon fluviatile					*	*
'errucaria praetermissa	1	1	2		3	4
'errucaria other spp.					*	*
\crocladium cuspidatum	2	3	3	3	4	11
\mphidium mougeotii	1		1	1	3	3
;rachythecium plumosum	1	1	1	2	4	5
;.rivulare	1	1	1	1	4	4
;. rutabulum					*	*
;ryum pseudotriquetrum	4	5	2	3	4	14
:inclidotus fontinaloides					*	*
:limacium dendroides		1		1	2	2
:onocephalum conicum	1	1	2	1	4	5
:ratoneuron filicinum	2	3	3	5	4	13
)ichodontium pellucidum	1	2	2	2	4	7
:urhynchium riparioides	2	3	5	4	4	14
'issidens adianthoides					*	*
'.crassipes					*	*
'ontinalis antipyretica	2	2	3	2	4	9
'unaria hygrometrica		1			1	1
;rimmia alpicola	2	2	4	1	4	9
Iygroamblystegium fluviat	1				1	1
Iygrohypnum luridum (ile	1	3	3	2	4	9
:.ochraceum					*	*
,eptodictyum riparium					*	*
;eskea polycarpa					*	*
archantia polymorpha					*	*
nium longirostrum	1	2	2	1	4	6
I.punctatum		1		1	2	2
'rthotrichum rivulare					*	*
'ellia endiviifolia					*	*
'.epiphylla		1	2	2	3	5

species	km up the River Teviot (from Teviot Foot at Kelso) 60.0	60.5	61.0	61.5	0.5 km total (max. 4)	abundance total (max. 20)
Philonotis fontana,	4	5	4	4	4	17
Scapania undulata					*	*
Solenostoma triste		1	1		2	2
Thamnium alopecurum					*	*
Tortula mutica					*	*
Rhacomitrium acicularis		1		1	2	2
R.aquaticum		1		1	2	2
Rhytidiadelphus squarrossus	1			1	2	2
Callitriche hermaphroditica					*	*
Callitriche other sp(p).	1				1	1
Caltha palustris		1	1	1	3	3
Carex acutiformis					*	*
C.hirta					*	*
C.nigra	2	3	2		3	7
C.ovalis	1	1	1	1	4	4
C.rostrata	1	2	1		3	4
Cochlearia alpina	2	1	1	1	4	5
Eleocharis palustris		1	1		2	2
Elodea canadensis					*	*
Equisetum fluviatile	2	2	2	2	4	8
Filipendula ulmaria	1	2	1	2	4	6
Glyceria fluitans	2	2	1	1	4	6
Iris pseudacorus					*	*
Juncus acutiflorus	5	4	4	4	4	17
J.effusus	2	2	2	1	4	7
J.inflexus					*	*
Lemna minor					*	*
Mentha aquatica	1	2	1	1	4	5
Mimulus guttatus	2	2	2	3	4	9
Myosotis scorpioides	1	2	1	1	4	5
Myriophyllum alterniflorum					*	*
M.spicatum					*	*
Phalaris arundinacea					*	*
Phragmites communis					*	*
Polygonum amphibium					*	*
Potamogeton crispus					*	*
P.lucens					*	*
P.natans					*	*
P.pectinatus					*	*
P.perfoliatus					*	*
P.pusillus					*	*
P. x salicifolius					*	*
Ranunculus aquatilis					*	*
R.flammula	1	2			2	3
R.fluitans x ?					*	*
R.penicillatus var.calcar					*	*
Rorippa amphibia (eus					*	*
R.nasturtium-aquaticum					*	*
Scirpus sylvaticus					*	*
Sparganium erectum					*	*
Veronica beccabunga	2	2	1	1	4	6
Zannichellia palustris					*	*
sewage fungus (obvious)					*	*

species	km up Biggar Water 0.0	3.5	6.0	6.5	7.0	9.5	km up Lyne Water 0.0	0.5	1.0	4.0	4.5
Callitriche spp.	1	1			2	2	1	2			
Caltha palustris	1	1	1	1	1	1	1	1	1		
Carex acuta								3			
C.acutiformis								2			
C.nigra	1	1							1	1	
C.rostrata	2							1	1		
Cochlearia alpina						1		1		1	1
Eleocharis palustris	1	1	1	1		1	1	2	1		1
Elodea canadensis	3	4	5	4	4	3	2	1	1		
Filipendula ulmaria	1	2		1		1	1		1	1	
Glyceria fluitans	2	1			1		1	1			1
Iris pseudacorus	1						1	1			
Juncus acutiflorus	1	1				2	1	1	1	1	1
J.effusus					1	1		1	1		
Mentha aquatica	1			1			1	2	1	1	1
Mimulus guttatus	1	1	1		1				1	1	1
Myosotis scorpioides	1	1	1	1	1	1	1	1	1	1	1
Myriophyllum alterniflorum	3	4	3	2	2	2	2	1	2	1	1
Phalaris arundinacea	3	5	5	5	5	4	2	3	2	1	1
Polygonum amphibium	1						1				
Potamogeton crispus	2	2	3	3	2	1	2	2	1	1	
P. x olivaceus							1	1			
P.natans	1	4	5	5	5						
Ranunculus aquatilis agg.	1	1			1	2					
R.flammula						1			1	1	1
R.penicillatus var.calcareus	3	5	5	4	4	3					
Rorippa nasturtium-aquaticum	2	1	1			1	1	1		1	
Sparganium erectum	1	1			1	2	1	1	1		
Veronica beccabunga	1	1	1		1	2	1	1		1	1
sewage fungus (obvious)						2					

species	km up Biggar Water						km up Lyne Water				
	0.0	3.5	6.0	6.5	7.0	9.5	0.0	0.5	1.0	4.0	4.5
Chamaesiphon spp.(obvious)									2	1	2
Phormidium spp.	1	1	2	1	2	2	1		1		
Tolypothrix penicillata											2
Hildenbrandia rivularis	1	1	1				5	3	2	1	1
Lemanea fluviatilis	1						2	3	1		1
Vaucheria sp(p).	2	2	1	2		1	1			1	
Didymosphaenia							1		1	1	1
Heribaudiella fluviatilis	1	1	1				1	1	1	1	1
Chaetophora sp.									1		1
Cladophora glomerata	2	3	2	1	1	1	2	3	2	3	2
Haematococcus viride										1	
Oedogonium spp.	1				1		2	1	1		1
Prasiola crispa								1	1		
Rhodoplax schinzii										1	1
Stigeoclonium tenue	1	1	1	1	1	1	1	2	1		
Ulothrix zonata	1					2	2	1	2	3	4
Spirogyra spp.	1			1			1	1		1	
Collema flaccidum							1	1			
Verrucaria praetermissa	1							1	1		
Verrucaria other spp.	1	1	1			1	2	4	3	2	3
Acrocladium cuspidatum						1	1	1			1
Brachythecium plumosum							1	1			1
B.rivulare							1	2	1	1	1
B.rutabulum	1	2	2	2	2	2	1	1		1	
Bryum pseudotriquetrum						1	1	1	1		1
Cinclidotus fontinaloides		1					1	2	1	1	
Conocephalum conicum		1					1	2	1		1
Cratoneuron commutatum							1	1			
C.filicinum		1	1				1		1	1	1
Dichodontium pellucidum		1					1	1	1		1
Eurhynchium riparioides	1	1	1	1	1	1	3	2	3	2	4
Drepanocladus uncinatus									1		1
Fontinalis antipyretica	3	3	2	4	2	2	4	2	3	2	2
Funaria hygrometrica									1	1	
Grimmia alpicola		1					1	2	1	2	1
Hygroamblystegium fluviatile	1	1		1	1		2	1	1	2	1
Hygrohypnum luridum									1	2	1
H.ochraceum										1	
Leptodictyum riparium	1	1	1	1	1	2					
Mnium longirostrum	1		1		1		1			1	1
M.punctatum				1			1	1		1	
Pellia endiviifolia							1	1	1		
P.epiphylla		1					1		1		
Philonotis fontana						1	1		1	1	2
Scapania undulata										1	1
Solenostoma triste										1	
Thamnium alopecurum								2			
Tortula mutica							1	1			

species	km up Yarrow Water -7.5	-8.0	-8.5	-9.0	-12.5	-13.0	-13.5	-18.5	-19.0	-20.0	-20.5	-21.0	-21.5
Chamaesiphon spp.(obvious)	2	3	4	5	3	3	3	3	4	2	3	3	2
Nostoc parmelioides	1	1								1			
Nostoc sp.'A'		1			1			1		1			
Phormidium spp.	2	2	4	2	1	2		2	1	2	1	1	1
Tolypothrix penicillata		2		1	2		1	2		2		1	2
Hildenbrandia rivularis	1	2	4		1	1	1	1	1				
Lemanea fluviatilis	1	3	1	2	1	1			1	2	1		1
Diatoma spp.(obvious)	2	3	4	5	3	3	3	3	4	2	3	3	2
Didymosphenia geminata	3	4	2	4	5	4	5	5	5	4	5	5	4
Heribaudiella fluviatilis	2	3	4	3	2	1	1	1	1	2		1	
Chaetophora sp.		2	2	2	2	3	2	2	2		2	1	
Oedogonium spp.	2	3	4	3	2	2	2	1	3	2	1	1	1
Prasiola crispa			1								1		1
Rhodoplax schinzii		3	3	2	4	2	2	2	1	2	3		2
Ulothrix zonata	3	3	4	5	3	3	2	3	4	2	3	3	3
Spirogyra spp.	1	1											
Collema flaccidum	1		1						1				
C.fluviatile	2	2	2	3	2	1			1			1	
Dermatocarpon fluviatile	1					1		1		1			
Verrucaria praetermissa	1	1			1		1		1	2	1	1	1
Verrucaria other spp.	2	2	1	1	2	2	2	1	1	2	1	1	
Acrocladium cuspidatum		1		2			1	1	2	1	1	1	1
Amphidium mougeotii									1				1
Brachythecium plumosum		1		2		1	1	1	2	2		2	
B.rivulare	1	1		2	2	1			1	2	1	2	
B.rutabulum	1		1					1					
Bryum pseudotriquetrum		1					1	1	1		1	1	1
Chiloscyphus polyanthos					1	1	1	1	1	2	1		
Cinclidotus fontinaloides	1	2	1	3	2	1	2	2	2	1	3	3	
Climacium dendroides										1		1	1
Conocephalum conicum	1	1	3	1	1	2	1	1			1		
Cratoneuron filicinum		1	1	1		1				1	1		
Dichodontium pellucidum					1	1		1	1	1		1	1
Eurhynchium riparioides	2	4	3	2	2	3	2	2	2	3	2	1	1
Fissidens adianthiodes		1		1									
Fontinalis antipyretica	1	2	4	2	2	4	4	4	4	5	4	4	3
F.antipyretica var.gracilis	1	2		1			2	2	1		1		1
Funaria hygrometrica					1								
Grimmia alpicola				1		1				1	1	2	
Hygroamblystegium fluviatile	2	2	3	2	1	1	2	2	1	1	1		1
Hygrohypnum luridum	1	2	1	4	2	2	2	2	2	3	1	2	1
H.ochraceum								1				1	
Leskea polycarpa					1		1						
Marchantia polymorpha			1			1					1		
Mnium longirostrum		1		1			1	1				1	1
Mnium punctatum				1							1		1
Pellia epiphylla			1	1			1	1		1			
Philonotis fontana								1		2	2	1	1
Scapania undulata									1	1	1		1
Solenostoma triste		1	2	1	1	2		2	1	1		1	
Thamnium alopecurum	1	1	2	3		1	1		1				
Tortula mutica	1						1	1			1		
Rhacomitrium acicularis									1			1	
R.aquaticum											1	1	
Rhytidiadelphus squarrosus								1		1			

species	km up Yarrow Water												
	7.5	8.0	8.5	9.0	12.5	13.0	13.5	18.5	19.0	20.0	20.5	21.0	21.5
Caltha palustris	1	1	1	1	1		1	1	1		1	1	
Carex nigra		1			1			1	1	1			
C.paniculata		1			1								
C.rostrata	1	1			1	1			1		1		
Cochlearia alpina								1		2		1	2
Eleocharis palustris	1					1		1			1		
Equisetum fluviatile	1	1		1	1		1	1		1	1		
Filipendula ulmaria		1	1	1		1	1	1	2	1	1	2	1
Glyceria fluitans	1			1	1	1	1	1		1		1	1
Iris pseuacorus	1												
Juncus acutiflorus	1	1		1	2	1	1	1	2	1	1	2	2
J.effusus	1					1		1				1	1
Mentha aquatica	1	1		1	1	1	1	1	2	1	2	1	2
Mimulus guttatus	1			1		1		1	2	1	1		1
Myosotis scorpioides	1	1	1	1	1	1	1	2	2	2	1	1	2
Myriophyllum alterniflorum	1	1	1	1	1	2	1	1	2	2	1	2	1
Phalaris arundinacea	2	1	1	1	1	1	1	1	2	1		1	
Ranunculus flammula					1		1	1				2	1
Rorippa nasturtium-aquaticum	1		1	1	1	1	1	1	1		1	1	
Scirpus sylvaticus	1		1	1									
Sparganium erectum	1												
Veronica beccabunga		1				1		1	1		1	1	

species	0.0	0.5	1.0	1.5	4.5	7.0	7.5	8.0	8.5	9.0	9.5	12.0	12.5	13.0
	km up the Ettrick													
Chamaesiphon spp.(obvious)					4	3	5	3	4	2	2	2	3	2
Nostoc parmelioides								1	1	3	1	2	1	1
Nostoc species 'A'					1			2	3	1	1	3	3	2
Phormidium spp.				2	3	1			1	1			2	1
Tolypothrix penicillata										1			2	2
Hildenbrandia rivularis	1	1		1	1	1		1	4	5	1		2	1
Lemanea fluviatilis	1		2	1	1		1	2	2	2	2	3	3	2
Vaucheria sp(p).	2	2	3	2										
Didymosphenia geminata							1			1		1	1	1
Heribaudiella fluviatilis		1	1	1	1	2	3	3	5	3	4	2	3	2
Chaetophora sp.							2	1	4	2	2	2	3	2
Cladophora glomerata	2	2	1	1	1				1	1	1		2	
Haematococcus viride												1	1	
Monostroma bullosum													1	
Oedogonium spp.	2	2	2	1	2	1	2		1	1	1		1	
Prasiola crispa									1	1	1	1	1	1
Rhodoplax schinzii						1	1	1	2	2	3	2	3	2
Stigeoclonium tenue	1	2	2	1										
Ulothrix zonata	3	3	2	2	4	2	2	2			1		1	
Spirogyra spp.						1								
Collema flaccidum							1	2	1			2	1	1
C.fluviatile									1	5	1	2	2	2
Dermatocarponfluviatile										1	1	1	2	1
Verrucaria praetermissa									2	1	2	3	2	2
Verrucaria other spp.	1		1	1	1	1	1	2	4	3	4	1	4	3
Acrocladium cuspidatum						1			1		1		1	1
Brachythecium plumosum					1	1		2						
B.rivulare										2	1		1	
B.rutabulum	1	1							1	1				
Bryum pseudotriquetrum									1	1	1		1	1
Chiloscyphus polyanthos								1		1		1	1	1
Cinclidotus fontinaloides		1	1	1	1		1	1	1	4	1	1	3	1
Conocephalum conicum	1	1	1					1	1		1	1	1	1
Cratoneuron filicinum									1		1		2	1
Dichodontium pellucidum						1								1
Drepanocladus uncinatus											1			1
Eurhynchium riparioides	2	2	4	5	1	1	2	3	1	1	3	2	3	2
Fissidens adianthoides					1	1								
F.rufulus								1	2	4	2		2	1
Fontinalis antipyretica	3	4	3	3	1	3	2	2	2	3	1	2	2	2
F.antipyretica var.gracilis				1	1	1								
Grimmia alpicola				1	1	1	1	2	1		2	1	2	1
Hygrohypnum luridum								1						1
H.ochraceum												1	1	1
Hygroamblystegium fluviatile	2	1	1	1	1		1		1	1	1			1
Leptodictyum riparium	2	2	2											
Mnium longirostrum				1					1		1		1	1
M.punctatum								1						1
Orthotrichum rivulare											1			1
Pellia epiphylla								1	1	1		1	1	1
Philonotis fontana										1	1			1
Solenostoma trista						1		1	1		2		2	1
Thamnium alopecurum		1						2			1		1	

Yarrow foot

species	km up the Ettrick													
	0.0	0.5	1.0	1.5	4.5	7.0	7.5	8.0	8.5	9.0	9.5	12.0	12.5	13.0
Callitriche spp.						2								
Caltha palustris		1	1			1		1	2	1	1	1	1	1
Carex nigra									1	1	1		1	1
C.paniculata											2			
C.rostrata									1				1	1
Eleocharis palustris	1	1					2		2	1	1	1		
Elodea canadensis	1	1	1		1									
Equisetum fluviatile									2		1	1	1	1
Filipendula ulmaria			1	1	1	1	1		1	1		1	2	2
Glyceria fluitans	1	1		1			1							
Iris pseudacorus		1				1								
Juncus acutiflorus	1		1	1	1	1	1	1	2	1		1	2	1
J.effusus							1							
Mentha aquatica	1			1	2	1		1	2	1	1	2	2	2
Mimulus guttatus		1					1	1			1		2	1
Myosotis scorpioides	1	1	1	1	1	1	1	2	2			1	1	1
Myriophyllum alterniflorum	1	1		1	2	1	1	2	2			1	1	1
Phalaris arundinacea	2	2	1	1	1	1	1	1	2	2	2	2	2	2
Potamogeton crispus	1	2	3	1	1									
Ranunculus aquatilis agg.		1	2	1										
R.flammula				1	1	1	1							1
R.penicillatus var.calcareus	2	2	4	3	1									
Rorippa nasturtium-aquaticum		1		1	1	1		1		1				
Sparganium erectum	1									1				
Veronica beccabunga	1								1	1		1		1
sewage fungus (obvious)	2	4	4	4										

Yarrow foot

species	km up the Jed							
	0.0	2.0	2.5	3.0	3.5	4.0	7.0	7.5
Hildenbrandia rivularis	1	2	1	1	1	1	1	
Lemanea fluviatilis					1		2	
Vaucheria sp(p).	1	1			1			
Heribaudiella fluviatilis	1	1	2	1	1			
Cladophora glomerata	5	5	5	4	3	2	2	2
Monostroma bullosum		1						
Tetraspora sp(p).	1	1	1					
Prasiola crispa	1	2	1					
Chara vulgaris								1
Verrucaria other spp.	2	2	1	1	1	1	1	
Brachythecium rivulare		1						
B.rutabulum	1	2	1	2	2			
Cinclidotus fontinaloides	1				1			
Conocephalum conicum	2	2	1	2	1	1	2	
Cratoneuron filicinum							1	
Eurhynchium riparioides	2	3	2	3	4	2	3	1
Fontinalis antipyretica	2	2	2	2	1	1	1	
Funaria hygrometrica	1				1			
Grimmia alpicola	1	2	2	1	1			
Hygroamblystegium fluviatile	2	3	2	2	2	2	3	1
Leptodictyum riparium	2	1	1	1		2		
Marchantia polymorpha	1	1	1	1	1		2	1
Mnium longirostrum	1	1	1	1				
Orthotrichum rivulare	1	1						
Pellia endiviifolia	1	1		1				
Thamnium alopecurum	1				1	1	1	
Thuidium delicatulum							1	
Tortula mutica	1				1			
Caltha palustris	1		2		1	2	1	
Carex sp.		1						
Eleocharis palustris		1						
Filipendula ulmaria	1	1	1	1		1	1	1
Glyceria fluitans	1		1					1
Iris pseudacorus		2						
Juncus acutiflorus	2	2	1	1	1	1	1	1
Mentha aquatica	1	1			2	2	1	
Mimulus guttatus	1	1	1	1	1			
Myosotis scorpioides	2	3	1	1	1	2	2	4
Myriophyllum spicatum	1	1	1	1		4		1
Phalaris arundinacea	3	3	3	2	4	3	2	2
Potamogeton crispus	1	2	2	1		4	1	4
P.natans		1				1		
Rorippa nasturtium-aquaticum	1	1		1				
Scirpus sylvaticus	1	1	1	1				
Sparganium erectum		1						
Veronica beccabunga	1	1		1	2	2	2	2

species	km up Eden Water				
	-0.0	-0.5	-3.0	-3.5	-4.0
Hildenbrandia rivularis	4	3	3	4	2
Lemanea fluviatilis	1	1			
Euglena spp.					1
Botrydium granulatum					1
Vaucheria sp(p).	1	1		1	1
Heribaudiella fluviatilis	1	1	1	1	1
Cladophora glomerata	3	3	3	5	4
Enteromorpha sp(p).	3	4	4	5	3
Gongrosira incrustans	2	1	2	3	2
Oedogonium spp	1		1	1	1
Monostroma bullosum				1	
Prasiola crispa				1	
Tetraspora sp(p).	1	1	1	2	2
Collema flaccidum				1	
Verrucaria other spp.	4	3	2	3	1
Brachythecium rivulare		1			1
B.rutabulum	1	1		1	1
Cinclidotus fontinaloides				2	1
Conocephalum conicum	1	1		1	1
Cratoneuron filicinum	1		1		
Dichodontium pellucidum		1		1	
Eurhynchium riparioides	2	2	1	3	1
Fontinalis antipyretica		1	1	3	3
Grimmia alpicola				1	
Hygroamblystegium fluviatile	1	1	1	1	1
Leptodictyum riparium	2	1			
Leskea polycarpa					1
Marchantia polymorpha	1	1	1	1	1
Mnium longirostrum	1				
Pellia endiviifolia	1				
Tortula mutica	2				
Eleocharis palustris		1	2		
Elodea canadensis	1	1	3	3	2
Equisetum fluviatile		1			1
Filipendula ulmaria		1			1
Glyceria fluitans	1	1	3	2	1
Juncus acutiflorus		1	2		
J.effusus			2	1	
J.inflexus		1	2		
Mentha aquatica		1	1	1	2
Myosotis scorpioides	1	1	2	2	2
Myriophyllum spicatum	1				
Phalaris arundinacea	1	1	1	1	2
Polygonum amphibium	2				
Potamogeton crispus	1	2	3	3	2
P.perfoliatus	1				
Ranunculus fluitans x?	1	2	2	5	3
Rorippa amphibia	2				
R.nasturtium-aquaticum	1	1	1	2	2
Scirpus sylvaticus	1				
Sparganium erectum	2	1	4	1	1
Veronica beccabunga		1	2	2	2
Zannichellia palustris	2	1	3		1

species	km up the Leet 0.0	0.5	1.5	3.0	3.5	5.0	5.5	6.0
Phormidium spp.	5	5	4	4	4	4	2	1
Hildenbrandia rivularis	1		1	1	1	1	2	1
Lemanea fluviatilis							1	1
Botrydium granulatum			1			1	1	
Vaucheria sp(p).	2	3	2	2	3	1	2	3
Heribaudiella fluviatilis			1				1	1
Cladophora glomerata	5	5	3	2	4	4	5	5
Enteromorpha sp(p).	4	3	2	4	5	4	5	4
Gongrosira incrustans		1	1	2	1	1	3	2
Oedogonium spp.			1		1		2	
Stigeoclonium	1	1	1					
Tetraspora sp(p).	1	1	1					
Spirogyra spp.	5	3	2	4	2	2	1	
Collema flaccidum					1	1		
Verrucaria other spp.		1	1	1	1	1	2	1
Brachythecium rutabulum					1		1	1
Cinclidotus fontinaloides					1	1	1	
Conocephalum conicum					1	2	1	1
Cratoneuron filicinum				1	1		1	
Dichodontium pellucidum						1	1	
Eurhynchium riparioides	1	2	1	2	2	2	1	1
Fissidens adianthoides	1		1					
F.crassipes	2	2	3					
Fontinalis antipyretica		1	1	2	1	2	1	
Funaria hygrometrica					1			1
Hygroamblystegium fluviatile	1	1	1	2	1		1	1
Leptodictyum riparium	4	4	3	3	4	4	2	1
Pellia endiviifolia		1			1	2	1	
Tortula mutica					1	1		
Caltha palustris		1	1	1			1	
Carex riparia				1	3	2		4
C.rostrata		1	1	2	1	2	1	
Eleocharis palustris		1	1		1		1	
Elodea canadensis	1							
Equisetum fluviatile		1		3	1		1	
Filipendula ulmaria			1	1	1	1		1
Glyceria fluitans	3	3	2		1		3	1
Iris pseudacorus		1	1	1	1	1	1	
Juncus acutiflorus		1		1	1		1	
J.effusus		1	1					
J.inflexus				1	1	2	2	1
Lemna minor	2	3	1					
Mentha aquatica	2	1	1		1	1	1	
Myosotis scorpioides	2	1	2	2	1	1	2	2
Myriophyllum spicatum	2	2	2	2	2	4	1	
Phalaris arundinacea	2	2	2	2	2	2	3	2
Polygonum amphibium	2	1	1	2	1	2	1	
Potamogeton crispus	2	1		1	1	2	2	
P.pectinatus	1	2	3					
Ranunculus penicillatus var.	2							
Rorippa amphibium (calcareus	1							
R.nasturtium-aquaticum	4		4	4	1	4	3	2
Scirpus lacustris		1	1					
Sparganium erectum	3		2	2	2	2	1	2
Veronica beccabunga	3		2	2	2	4	2	2
Zannichellia palustris	3							
purple photosynthetic bacteria		4	5	2	1			
sewage fungus (obvious)	5							

km up the River Till

species	0.0	1.0	1.5	3.5	4.0	4.5	5.0	5.5	6.0	13.0	13.5	14.0	14.5	15.0	15.5	19.0	19.5
Phormidium spp.		2	1								1	1			1	1	
Hildenbrandia rivularis		3	1	3	3	4	2	1	2	1	2	1	1	1	1	1	
Lemanea fluviatilis		1		1	1	2	1	1			1						
Vaucheria sp(p).	1	2	2	1	1	1	1	2	3	4	2	3	2	2	1	3	4
Heribaudiella fluviatilis			1	2	1	2	1	1	1		2	1	1			1	
Cladophora glomerata		2	1	2	2	3	2	2	2	1	3	2	1	1	1	1	1
Cladophora sp.'A'		1		1	1		1	1		1			1	1			
Enteromorpha sp(p).		1	1	1	2	2	1	2	2	2	3	2	1			1	
Oedogonium spp.							1	1	1	1		1					
Tetraspora sp(p).	1	1	1	1	1	1				1		1					
Stigeoclonium tenue		1									2	1	1				
Collema flaccidum		1															
Verrucaria praetermissa			1	1												1	
Verrucaria other spp.	2	1	2	2	2	2	1	1	2		2	1				1	1
Acrocladium cuspidatum																	
Brachythecium plumosum																	
B.rivulare				1	2	1	1	1	1								
B.rutabulum	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	
Bryum pseudotriquetrum													1	1			
Cinclidotus fontinaloides					1							1					
Conocephalum conicum			1	1	1	1	1	1		1	1	1	1			1	
Cratoneuron filicinum		1						1					1		1	1	1
Dichodontium pellucidum													1				
Eurhynchium riparioides		2	1	2	1	1	1	1	1	2	3	2	2		1		
Fissidens crassipes		1			1	1	1	1	1								
Fontinalis antipyretica	1	1	1	1	1	1	1	1	1	1	1	1			1		
Funaria hygrometrica				1	1								1				
Grimmia alpicola					1												
Hygroamblystegium fluviatile		1		1	1	1	1	1	1			1	2	1	1		
Leptodictyum riparium	1	2		2		1	1	1	1	2	2	2	3	2	3		1
Leskea polycarpa											1	1	2		1		
Marchantia polymorpha	1	1	1	1	1	1	1	1									
Orthotrichum rivulare				1	1												
Pellia endiviifolia				1			1	1									
Philonotis fontana																	
Tortula mutica												1	1				

species	km up tho Rivor Till																
	0.0	1.0	1.5	3.5	4.0	4.5	5.0	5.5	6.0	13.0	13.5	14.0	14.5	15.0	15.5	19.0	19.5
Callitriche spp.			1									1				1	
Caltha palustris		1		1						1			1				
Carex acuta				1		1	1	1	1								
C.paniculata																	
C.riparia								2									
Eleocharis palustris				1	1		1	1	1							1	1
Elodea canadensis	3	1	2	1	2	2	3	1	2	1	2	1	2	3	3	3	2
Equisetum fluviatile					1	1	1										
Filipendula ulmaria				1	1			1	1	1							
Glyceria fluitans	1	2	2			2			1	1	1		2	2	2	2	2
Iris pseudacorus					1		1	2	1								
Juncus acutiflorus		1	1	1	1	1	1	1	1	1					1	2	1
J.effusus				1	1		1	1	1					2	2	2	1
J.inflexus				1		1	1								1		
Mentha aquatica			1	1	1	1	1	1			1	1	1		1		
Mimulus guttatus										1	2	2	2	2	2	2	2
Myosotis scorpioides	2	2	1	1	1	1	2	1	1	1	2	2	2	2	2	2	2
Myriophyllum spicatum	2	2	2	1		1	1		1	2	2	1	3	3	4	3	4
Phalaris arundinacea	1	1	2	1	2	1	2	2	2	1	1	2	1	1		1	1
Phragmites communis											3	2	4				
Polygonum amphibium	3		1		1					1					1		
Potamogeton crispus		1	1	1	1	2	1	1	2	1	1		1	1	3		1
P.lucens	4																
P.pectinatus		2	1				1			2							2
P.perfoliatus				1			1	1									
P.pusillus	1																
P. x suecicus		3	1	1	2	3	5	2	1								
Ranunculus fluitans x ?	2	5	4	3	3	5	2	2	2	5	4	4	3	4	4	2	4
R.penicillatus var calc											1				1		
Rorippa amphibia (areus	1		1							1	2	1	2	1	2	1	1
R.nasturtium-aquaticum				1		1				1		1	2	2	1		
Rumex hydrolapathum																	
Scirpus lacustris																	
S.sylvaticus				1	1	2	1	1	1			1				1	2
Sparganium erectum	4	1	2	2	3	2	2	3	1	1	2	2	2	2	2	3	3
Veronica beccabunga			1	1	2	1	2	1	2	1	3	3		1	3	2	2
Zannichellia palustris		1	2	1		1	1			1	2	2	2	1	1	1	3

species	km up the River Till																			
	20.0	20.5	21.0	28.5	29.0	29.5	30.0	33.0	33.5	34.0	46.0	46.5	47.0	51.0	51.5	52.0	52.5	56.0	56.5	57.0
Phormidium spp.						2	2													
Hildenbrandia rivularis						1			2	2		1	1	1	1	1	1	1	1	
Lemanea fluviatilis												1	1	1	1	1	1	1	1	
Vaucheria sp(p).	3	5	4	1	1	1	2	1	2	2	1	2	1	2	1	2	2	1	2	l
Heribaudiella fluviatilis			1				1		1	2		1		1	1	1			1	
Cladophora glomerata	2	1	1	2	2	2	2	1	2	3	1	2	2	2	1	3	3	2	3	1
Cladophora sp.'A'																				
Enteromorpha sp(p).		1																		
Oedogonium spp.	1			1			1					1					1	1		
Tetraspora sp(p).			1																	
Stigeoclonium tenue	1	1																		
Collema flaccidum		1						1												
Verrucaria praetermissa		2					1					1	1							
Verrucaria other spp.										1	1	1	1	2		1	1	1	1	1
Acrocladium cuspidatum										1							1			
Brachythecium plumosum							1			1			1			1	1	1	1	
B.rivulare						1	1			1	1	1				1	1	1	1	
B.rutabulum			1				1		1	1	1	1	1			1	1	1	1	
Bryum pseudotriquetrum		1				1				1			1	1		1		1		
Cinclidotus fontinaloides							1						1							
Conocephalum conicum						1	1		2	2	1		1	2	2	2	2		2	2
Cratoneuron filicinum	1	1	1				1	1	1	1	1		1	2	2	2	2	1	2	1
Dichodontium pellucidum							1			1			1	1	1	1	2		1	1
Eurhynchium riparioides						1	2	2	3	2	1	2	1	1	1	2	2	2	3	1
Fissidens crassipes																				
Fontinalis antipyretica	2						2	2	3	4	1	3	2	3	3	3	2	2	2	1
Funaria hygrometrica			1					1			1		1	1				1		
Grimmia alpicola							1	1					1			1	1	1		
Hygroamblystegium fluviatile	1	1				1	1	1	1			1	1	1	2	1	1	l	2	
Leptodictyum riparium			1	1		2	1	1	1	1			1			1	1		1	
Leskea polycarpa																				
Marchantia polymorpha		1		1		1	1	1		1		1	1			1				1
Orthotrichum rivulare							1													
Pellia endiviifolia			1			1	1	1	2	1	1	1	1			2	1	1	2	
Philonotis fontana			1			1							1	1				1		
Tortula mutica							2						1	2				1		

species	km up the River Till																			
	20.0	20.5	21.0	28.5	29.0	29.5	30.0	33.0	33.5	34.0	46.0	46.5	47.0	51.0	51.5	52.0	52.5	55.0	56.5	57.0
Callitriche spp.	1	2	1					1	1							1				
Caltha palustris													1							
Carex acuta																				
C.paniculata													1	1		1				
C.riparia																				
Eleocharis palustris	2	2	1								1		1			1	1	1		
Elodea canadensis	2		2	1	1	1	1	1	3	4	3	4	3							
Equisetum fluviatile		1						1	1											
Filipendula ulmaria	1	1							1	1			1			1	1	1	1	1
Glyceria fluitans	2	3	3	2	2	3	1	1	1		2	2	1	1	2	1	1	1	1	
Iris pseudacorus					.1						1									
Juncus acutiflorus	1	1	2	1	2	2	1	2	1		2	2	1	1	2	1	1	1	1	
J.effusus	2	2	4	2	3	1	2	2	1		2	2	2	2	2	2	1	2	2	2
J.inflexus				1	2	2		2	1		1	1	1	2	2	1			1	
Mentha aquatica	1	1	1					2	2		2	1	2	2	2	2	1	2	1	1
Mimulus guttatus	1	1						1	1				1		2	1	1	2	1	1
Myosotis scorpioides	2	2	2	1	2	2	2	2	2		2	2	2	2	2	2	2	2	2	
Myriophyllum spicatum	2	2	2				1				1	2	1							
Phalaris arundinacea	2	2	1	1		1	1	2	1		1	1	1	1	1		1	1		
Phragmites communis																				
Polygonum amphibium		2		1	1			1												
Potamogeton crispus	1	1	1	1	2	3	1					2	1	1	3	2	1			
P.lucens																				
P.pectinatus																				
P.perfoliatus																				
P.pusillus																				
P. x suecicus																				
Ranunculus fluitans x ?	3	1	3	3	4	4	4	3	4	5	3	4	2							
R.penicillatus var calc											1	1	2	2		1	1	1		
Rorippa amphibia (areus	1	1				1														
R.nasturtium-aquaticum	2		1			1		1					1	1		1	1	1		
Rumex hydrolapathum							1	1	2	1			1			1	1		1	
Scirpus lacustris	1		1																	
S.sylvaticus	2		1	2	2	1	1	1	2	1		2	1				1	1		1
Sparganium erectum	2		1	1	1	2		1	3		2		1							
Veronica beccabunga	2	1	1	1	1	2	2	1	2		2	1	1	2	2	1	1	2	2	
Zannichellia palustris	3	2	2	2	2		1	1												

species	17.5	18.0	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	29.0	29.5	30.0	30.5	31.0	34.5	35.0	41.5	42.0	42.5	43.0	43.5
	km up Blackadder Water																					
Phormidium spp.							1					1						1				
Hildenbrandia rivularis	1	3	1	2	2	1	4	2	3	2	3	1	2	3	2	3	4					
Lemanea fluviatilis											1			1								
Botrydium granulatum	1										1	2										
Vaucheria sp(p).	1	1	1																	1		
Heribaudiella fluviatilis	1	2		1	1	1		1	1	1	2	2	2	1	1	1	1	1	1		1	1
Cladophora glomerata	3	2	2	3	3	2	1	4	2	2	1	2	1	1		1	2	3	2	1	1	2
Enteromorpha sp(p).	3	4	5	5	5	4	2	3	1	3	3	2	3	3	2		1	4	5	5	4	3
Gongrosira incrustans				1					1	1	3	4	2	2	2	3	1	1		2		
Monostroma bullosum						1											1					
Prasiola crispa												2	1	1		1	1	1	1			1
Stigeoclonium tenue	1	1			1											1						1
Tetraspora sp(p).	3	1	1	2	1	1	1				3	3	2	4	2	3		2				1
Collema flaccidum	1														1		1					2
Verrucaria paetermissa		1	1	1	1	1	2	2			3				1	2					1	
Verrucaria other spp.	1	2	1	1	1	1	2	2		1	1	1			1	1	2				1	
Brachythecium plumosum																			2	1		
B.rivulare			1							1	2	1				1	1			1	1	1
B.rutabulum	1			1													1				1	1
Cinclidotus fontinaloides	1	1	1									1			1		2			1	2	1
Conocephalum conicum	1	1		1	1		1		1		2	2				1	1		1	1	2	2
Cratoneuron filicinum				1						1		2			1			2	1		2	2
Dichodontium pellucidum				1																	1	1
Eurhynchium riparioides	3	2	2	2	1	1	2	4	4	3	2	3	1	3	3	2	3	5	4	4	5	5
Fontinalis antipyretica	1	1						2	2	1		1		1	1			2	2	3	2	4
Funaria hygrometrica		1	1								1											
Grimmia alpicola		1										1		1	1		1	2	1	2	2	1
Hygroamblystegium fluviat	1	1	1	1			1	1		1	2	3		1	2	1	2			1	2	
Leptodictyum riparium(ile	3	3	1	3		1	3															
Marchantia polymorpha	1	1	1	2	1	1	1					1										
Mnium longirostrum							1					1										
Orthotrichum rivulare											2	1		1	1		1			1		
Pellia endiviifolia			1		1							2						1			1	
Tortula mutica				1								1			1						1	

km up Blackadder Water

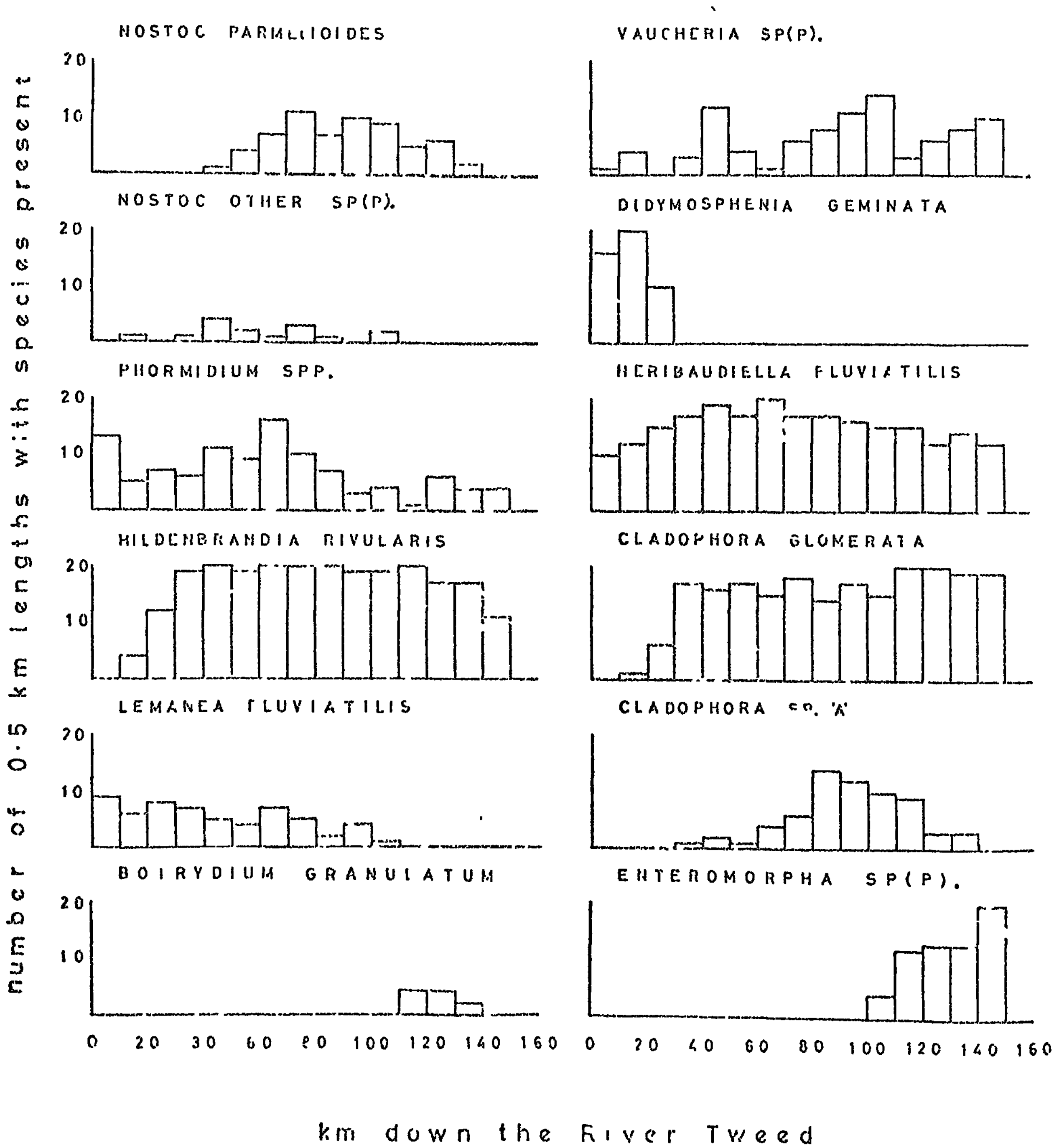
species	17.5	18.0	22.0	22.5	23.0	23.5	24.0	24.5	25.0	25.5	29.0	29.5	30.0	30.5	31.0	34.5	35.0	41.5	42.0	42.5	43.0	43.5
Butomus umbellatus	1	3	3	2	1	1	2		1	3		1	3	2	2	1		1	2	1		2
Callitriche spp.																			1	1		
Caltha palustris	2	1		1			1		1	1		1	1	2	1		1	1		1		1
Carex riparia													2			3					1	2
C.rostrata					1											2				1	1	1
Eleocharis palustris			1								2	2	2	2		1	1	2	2	3	2	2
Elodea canadensis	1	2	5	1	2	1	2	3	2	1	4	5	4	5	3	3	1					
Equisetium fluviatile			1	1														1	1	1		
Filipendula ulmaria										1	1	1		1	1	1			1		1	2
Glyceria fluitans		1	2	1	4	1	1		1		2	2	1	1	1	1		1	2	2	1	1
Iris pseudacorus			2	1		1	2		2	1		3	3	2	2	3	2	1	1			1
Juncus acutiflorus	1	1	1	1	1	1				1		1				3	2	1	1			1
J.effusus			1							1		1				1		1			1	2
J inflexus			1		1	1				2		1		1	1		1	1			1	2
Lemna minor														1								
Mentha aquatica	2	1			1					1			1	1	1	1		2	2	2	3	3
Mimulus guttatus	1	1	1	1	2	1		1				1										
Myosotis scorpioides	3	2	2	2	2	1	2	1	1	2	1	2	1	1	2	1	1	1	1	1	1	1
Myriophyllum alterniflorum													1					3	2	1		
M.spicatum	1	2	4	2	2	2	2	3	4	3	2		5	5	5	2	1	1	2	3		
Phalaris arundinacea	2	1	2	1	1	1	2	2	3	3	3	1	2	2	2	2	1	1	2	2	1	1
Polygonum amphibium		1	1	1					1	1			1		1	1			1	1	1	1
Potamogeton berchtoldii	1	1	4	5	2	2	3	3	3	3	1	1	2	1	2	1	1		1	1	1	1
P. x cooperi							1															
P.crispus	1	3	4	2	2	1	2	3	2	1	3	4	2	1	3	2	1	1	2	2	1	
P.natans												1							1		1	2
P. x olivaceus			2	1			3	2	4	3	2											
P.perfoliatus								2	2	2												
P.pusillus			2	2				1		3			2		3							
Ranunculus circinatus											2	3	1			1		3	3	4	3	1
R.circ. x R.pen.var.calc.							1	1	1	1	2		3	2	1	1	2	1	2	5		
R.flammula																			1		1	
R.fluitans ?	2	4	1	1	3	1	2	3	3	2	5	3	4	5	4	3	3	5	4	1	2	1
R.penicillatus var. calcar								1			2	4			3	1	1	2	1	2	3	2
Rorippa amphibia (eus	1	1																				
R.nasturtium-aquaticum	2	1		2	3				1	2	2	2	2		2	2	1	2	4	5	2	3
Scirpus lacustris						4																
S.sylvaticus							1		1													
Sparganium erectum	2	4	5	1	1	5	1	1	3	3	3	4	4	4	4	3	1	3	3	2	1	2
Veronica beccabunga	2	2	2	1	2		1		2	2	1	2	2	1	2	2	1	1	2	3	2	2
Zannichellia palustris	1	2	3	5	2	3	3	3	2	2												
purple photosynthetic bacteria			3	2	3	2					2											
sewage fungus (obvious)							1															

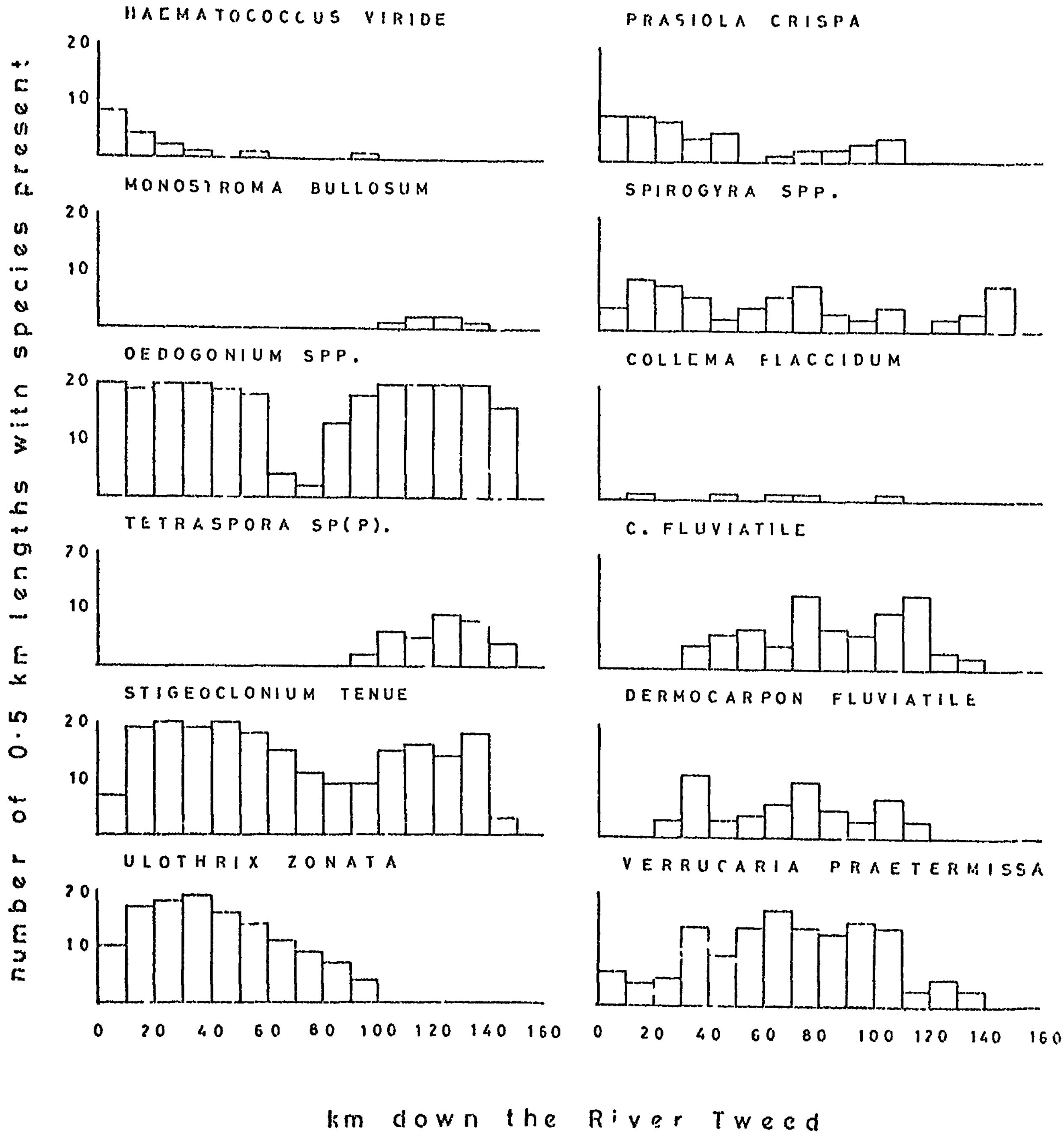
species	km up Whiteadder Water														
	1.0	1.5	2.0	2.5	6.0	6.5	7.0	7.5	14.5	15.0	15.5	17.0	17.5	18.0	18.5
Chamaesiphon spp.(obvious)															
Nostoc sp 'A'															
Phormidium spp.		1		1	1		1	1	3					1	2
Tolypothrix penicillata															
Hildenbrandia rivularis	2	1	1	1	3	3	2	1	1			1		1	2
Lemanea fluviatile															
Vaucheria sp(p).				1	1		1								
Didymosphenia geminata															
Heribaudiella fluviatilis	3	2	1	1	1	2	2	2	1	1	2	1		2	3
Chaetophora sp.															
Cladophora glomerata	2	1	3	1	1	2	2	2	1	2	2	3	2	1	3
Enteromorpha sp(p).	3	4	3	4	3	3	4	5	3	3	5	3	3	4	2
Gongrosira incrustans	2	4	3	2	3	3	2	2	2						
Haematococcus viride															
Monostroma bullosum		1	1												
Oedogonium spp.	1	2	4	3		1	1			1					
Prasiola crispa										1					
Rhodoplax schinzii															
Stigeoclonium tenue	1	2		1											
Tetraspora sp(p).	2	2	2	3	1	1	2	1	1	1	2			2	2
Ulothrix zonata															
Spirogyra spp.	1			1								1	1		
Charaphyta sp.															
Collema flaccidum					1										
Verrucaria praetermissa	1				1				1	1				1	1
Verrucaria other spp.	2	1	2	2		1		2	2	1	3		1	2	3
Brachythecium plumosum															
B.rivulare															
B.rutabulum	1				1		1								
Bryum pseudotriquetrum															
Cinclidotus fontinaloides													1		
Conocephalum conicum	1							1	1		1	1	1	1	1
Cratoneuron filicinum									1		1			1	1
Dichodontium pellucidum															1
Eurhynchium riparioides	1	1	2	1	1	1	2	1	2	1	1	2	3	2	3
Fissidens rufulus															
Fontinalis antipyretica	1		1	1	1								2		2
Funaria hygrometrica															
Grimmia alpicola					1							1			2
Hygroamblystegium fluviatile	1		1	1	1	2	1	1	1		1	1	3	1	3
Hygrohypnum luridum													2		
Leptodictyum riparium				1	2	1	1					2			
Marchantia polymorpha								1		1	1		1		1
Mnium longirostrum															
M.punctatum															
Orthotrichum rivulare					1										
Pellia endiviifolia															
P.epiphylla															1
Philonotis fontana															
Solenostoma triste															
Thuidium delicatulum							1								
Tortula mutica					1										

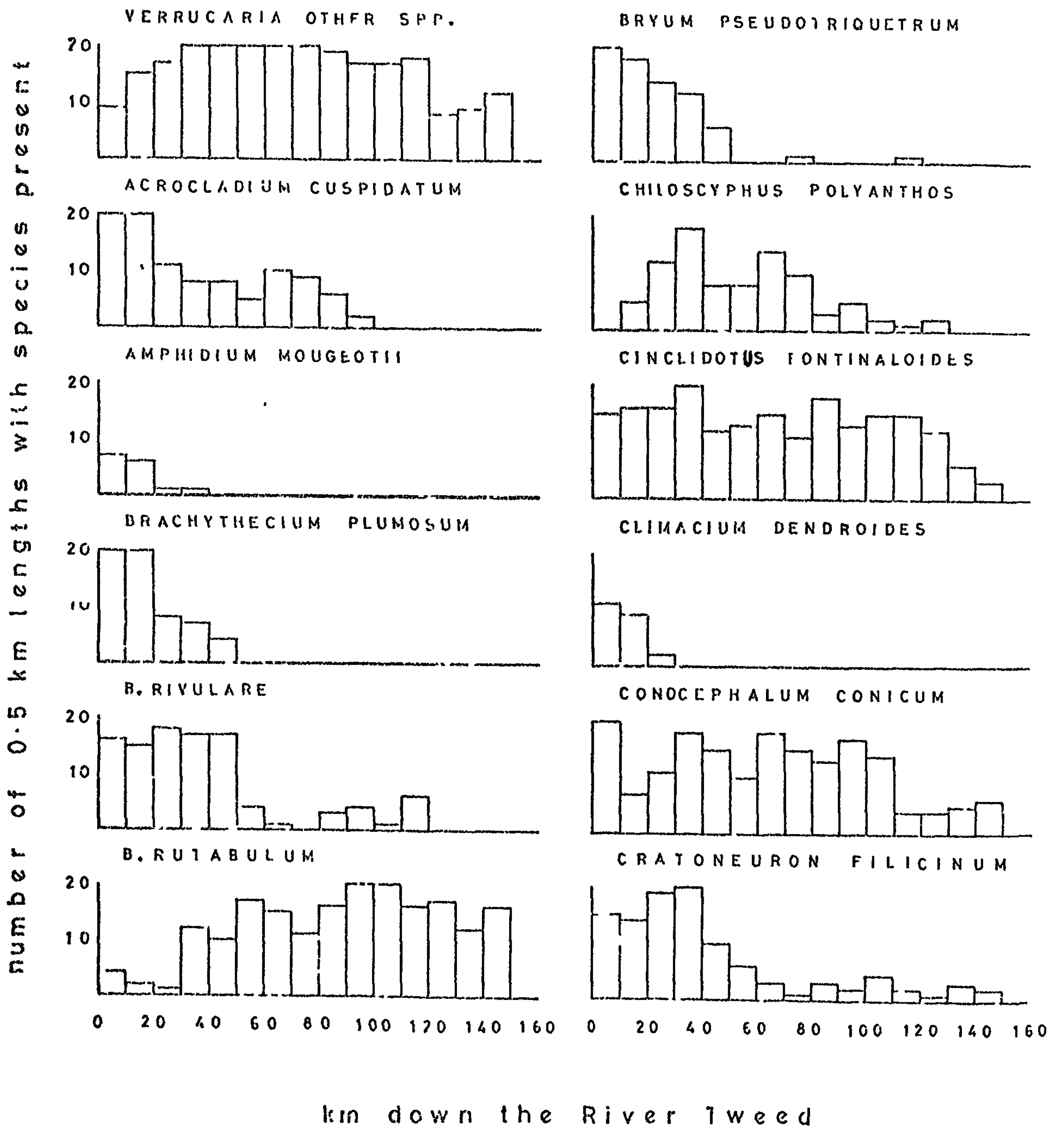
species	km up Whiteadder Water														
	1.0	1.5	2.0	2.5	6.0	6.5	7.0	7.5	14.5	15.0	15.5	17.0	17.5	18.0	18.5
Butomus umbellatus		2		1	3										
Callitriche hermaphroditica															2
Callitriche other spp.	1			1										1	
Caltha palustris	1			1	1	1						1		1	
Carex rostrata															
Eleocharis palustris	1	1		1		2	3	1		1		4		3	1
Elodea canadensis	1	1	1	1	2	1	1	1	2	5	3	1		2	1
Equisetum fluviatile	1				1										
Filipendula ulmaria									1	1				1	1
Glyceria fluitans		1		1	2	1		2			1	1			1
Iris pseudacorus							1			1	1				
Juncus acutiflorus	1	1			1		1					1	1	1	1
J.effusus		1	1									1		1	
J.inflexus	1	1										2			
Mentha aquatica	1	2		1	1	1	1	1						1	
Mimulus guttatus	1	2	1	2	1	1	2	1	2	1	2			1	1
Myosotis scorpioides	1	1	1	2	1	1	2	2	1	2	2	2	2	1	1
Myriophyllum alterniflorum									2	3	3	1	2	2	3
M.spicatum	2	2	1	1	4	4	4	3	2	3	3				
Phalaris arundinacea	2	2	2	2		1	3	3	2	2	2	3	2	2	2
Polygonum amphibium	1	1	2	1	1		1			1	1			2	
Potamogeton berchtoldii	1	1	1	1	2	3		2	2	3	3			3	2
P.crispus	1		1	2	3	3	3	4	2	4	3	1		2	3
P.natans		1	4												
P. x olivaceus		1		1		1	2	1	5	3	3				
P.pectinatus	4	5	4	3											
P.perfoliatus	2	1	2	2	5	3	1	2							
P.pusillus						2		1		4	4				
Ranunculus fluitans x ?	5	5	5	4	5	3	3	4	5	2	4	1	1	1	1
R.penicillatus var.calcareus	1	1	1	1										1	1
Rorippa amphibia	1	1											1		
R.nasturtium-aquaticum	3	1	1	1	1	1	2	2	2	1	2		1	1	1
Scirpus lacustris	1	1		1	2	5		2		1	3				
S.sylvaticus	1	1		1		2	2	2	1	3	2				
Sparganium erectum	2	2	1	2	2	3	2	3	1	4	3	3			
Veronica beccabunga	1	1	1	1	1	2	1	2	1	1	2	2	2	1	1
Zannichellia palustris	4	3	2	2	4	4	3	4	2	4	5			3	3
purple photosynthetic bacteria					1										

species	km up Whiteadder Water												
	21.0	21.5	22.0	23.0	23.5	24.0	24.5	25.0	25.5	26.5	30.0	30.5	31.0
Chamaesiphon spp.(obvious)		2	2	2	1	3	3	2	3	1	4	3	4
Nostoc sp 'A'											2	1	
Phormidium spp.		1		2	2	3	2	3	3	3	3	1	2
Tolypothrix penicillata											2	1	1
Hildenbrandia rivularis	1	1	1	1	1	1				2	1	2	1
Lemanea fluviatile			1							1		2	1
Vaucheria sp(p).												1	
Didymosphenia geminata											3	2	1
Heribaudiella fluviatilis	2	1	2	2	2	1	1	2	1	4	4	5	2
Chaetophora sp.					2	1		1		2	3	2	2
Cladophora glomerata	1	1	2		1		1	1	1	1	1	1	1
Enteromorpha sp(p).	4	3	3	3	3	4	5	1	1				
Gongrosira incrustans													
Haematococcus viride				1					1				1
Monostroma bullosum					1								
Oedogonium spp.	2	1	2	2	2	3	2	2		2	2	2	3
Prasiola crispa											1	1	
Rhodoplax schinzii										1	3	2	2
Stigeoclonium tenue										1			1
Tetraspora sp(p).	3	2	1	2	2	3	4	4	4				
Ulothrix zonata						1				1	2	1	1
Spirogyra spp.		2	2	2		2						1	
Charaphyta sp.					2				1				
Collema flaccidum													
Verrucaria praetermissa	1	2	1					1		1	3	2	1
Verrucaria other spp.	2	2	2	3	2	3	2	2	2	5	4	4	3
Brachythecium plumosum											1	1	
B.rivulare		1				1			1			1	
B.rutabulum													
Bryum pseudotriquetrum									1	1	1	1	1
Cinclidotus fontinaloides										2			
Conocephalum conicum	1	2			1	1				2	3	2	1
Cratoneuron filicinum	1	1			1				1	1	1	1	1
Dichodontium pellucidum		1				1						1	
Eurhynchium riparioides	2	2	1	1	2	1	1	2	2	3	4	4	3
Fissidens rufulus											2		1
Fontinalis antipyretica	1				1			1		2	1	1	2
Funaria hygrometrica											1		
Grimmia alpicola	1	1								1	1		1
Hygroamblystegium fluviatile	2	2	1	1	1				1	2	2	2	1
Hygrohypnum luridum											2	1	
Leptodictyum riparium													
Marchantia polymorpha		1	1		1				1			1	
Mnium longirostrum	1		1										1
M.punctatum											1		1
Orthotrichum rivulare		1		1						1			
Pellia endiviifolia		1										1	
P.epiphylla	1	1								1			
Philonotis fontana												1	
Solenostoma triste	1											1	
Thuidium delicatulum												1	
Tortula mutica										1			

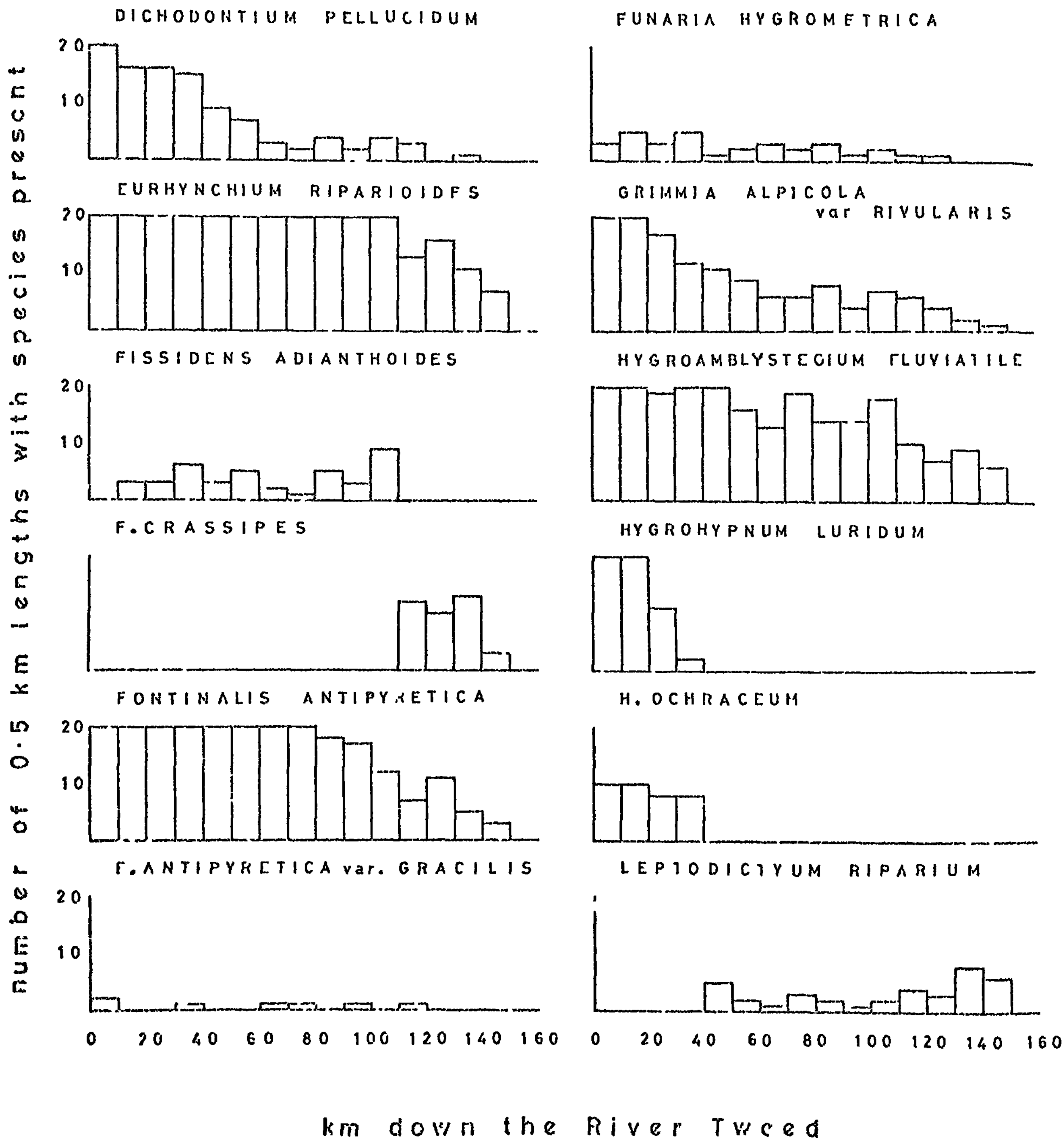
species	km up Whiteadder Water												
	21.0	21.5	22.0	23.0	23.5	24.0	24.5	25.0	25.5	29 5	30.0	30.5	31.0
Butomus umbellatus													
Callitriche hermaphroditica													
Callitriche other spp.						1							
Caltha palustris		1	1	1	1	1	1	1		1	1	1	1
Carex rostrata	1											1	
Eleocharis palustris	1	2	2	2	1			1	1			1	1
Elodea canadensis	2	4	2	1	4	1						1	
Equisetum fluviatile		1				1		1	1		1		
Filipendula ulmaria		1		1				1	1		1		
Glyceria fluitans	1					1	1	1	1		1	1	2
Iris pseudacorus													
Juncus acutiflorus		1	1	1	2	1	1		1	2	2	2	2
J.effusus			1	1	1			1					
J.inflexus				1	1	1		1					
Mentha aquatica	1	1	2	1	1	1	1	2	2	1	1	2	2
Mimulus guttatus	1	2	1	2	2	3	1	1	2	2	2	2	2
Myosotis scorpioides	1	2	1	1	1	2	1	2	2	2	2	2	3
Myriophyllum alterniflorum	2	1	3	5	4	3	3	1	3	4	3	4	4
M.spicatum													
Phalaris arundinacea	2	1	2	2	2	1	2	2	2	2	2	2	2
Polygonum amphibium			1	1	2								
Potamogeton berchtoldii	1	3	2	3	3	2	1	2	3	1	2	1	3
P.crispus	2	5	5	5	5	2	4	4	3	3	4	2	4
P.natans													
P. x olivaceus													
P.pectinatus													
P.perfoliatus													
P.pusillus													
Ranunculus fluitans x ?	1	2	1	3	3	2	2	2	2	3	3	3	2
R.penicillatus var.calcareus	1	2	1	3	3	2	3	3	2	1	1	2	2
Rorippa amphibia													
R.nasturtium-aquaticum	1	1	1	2	2	2	2	2	2	1	2	3	3
Scirpus lacustris													
S.sylvaticus													
Sparganium erectum		1	1										1
Veronica beccabunga	1	2	2	2	1	1	1	2	2	1	1	2	2
Zannichellia palustris	2	4	4	4	4	2	4	4	3				
purple photosynthetic bacteria													

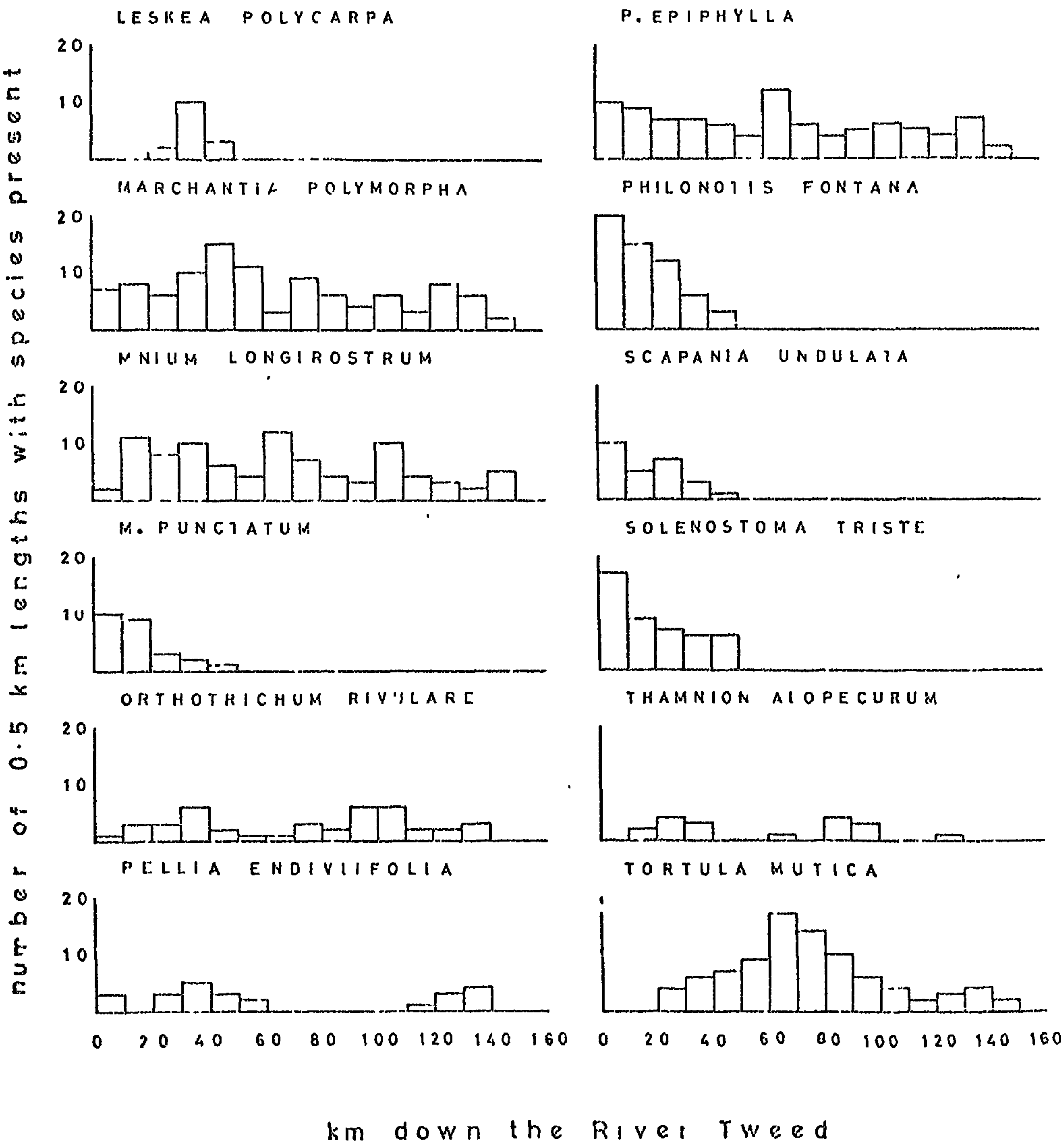

NOSTOC PARMELIOIDES
VAUCHERIA SP(P).
NOSTOC OTHER SP(P).
DIDYMOSPHENIA GEMINATA
PHORMIDIUM SPP.
HERIBAUDIELLA FLUVIATILIS
HILDENBRANDIA RIVULARIS
CLADOPHORA GLOMERATA
LEMANEA FLUVIATILIS
CLADOPHORA SP. 'A'
BOTRYDIUM GRANULATUM
ENTEROMORPHA SP(P).
number of 0·5 km lengths with species present
km down the River Tweed


HAEMATOCOCCUS VIRIDE
PRASIOLA CRISPA
MONOSTROMA BULLOSUM
SPIROGYRA SPP.
OEDOGONIUM SPP.
COLLEMA FLACCIDUM
TETRASPORA SP(P).
C. FLUVIATILE
STIGEOCLONIUM TENUE
DERMOCARPON FLUVIATILE
ULOTHRIX ZONATA
VERRUCARIA PRAETERMISSA
number of 0·5 km lengths with species present
20
10
0 20 40 60 80 100 120 140 160
km down the River Tweed

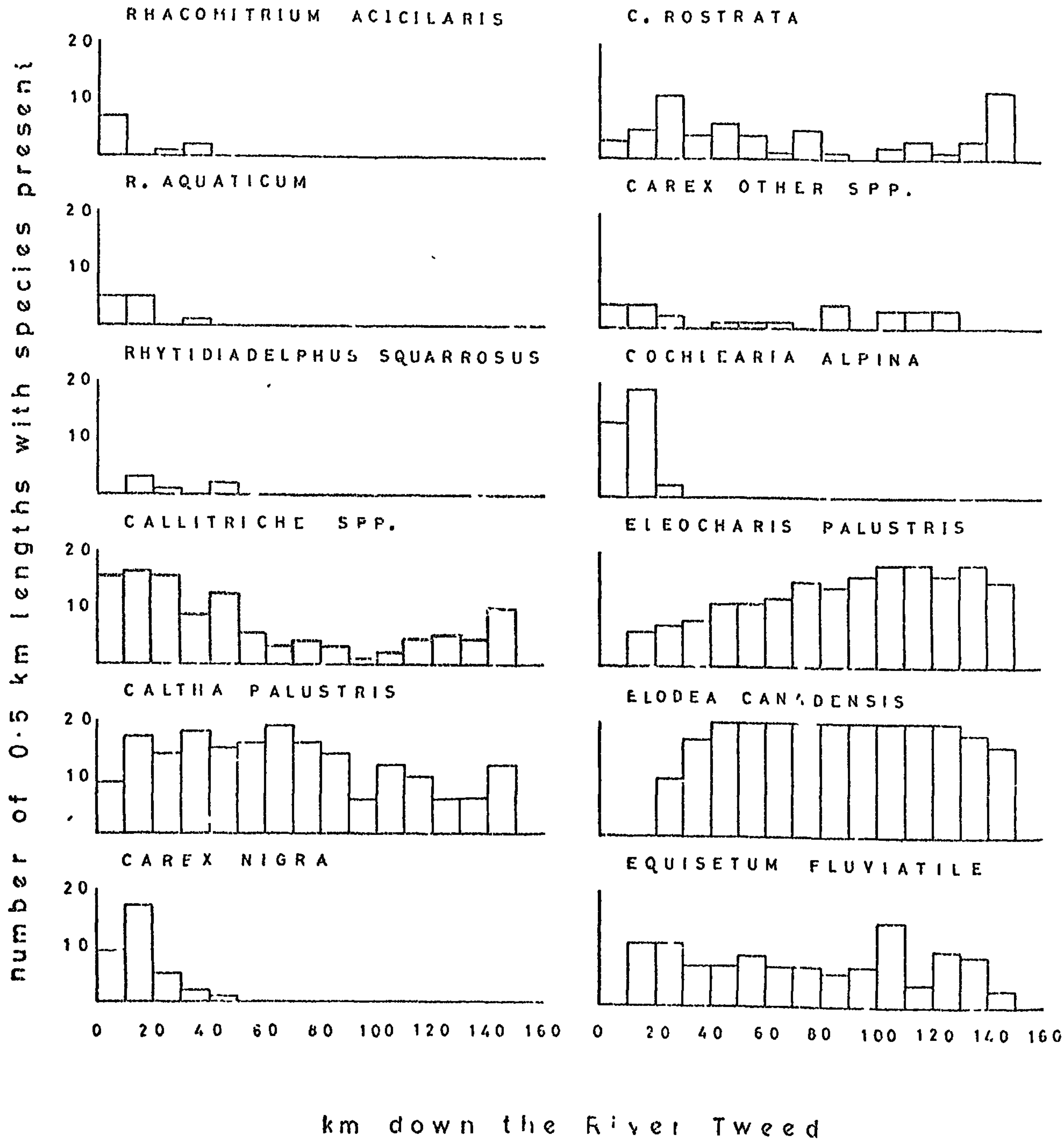


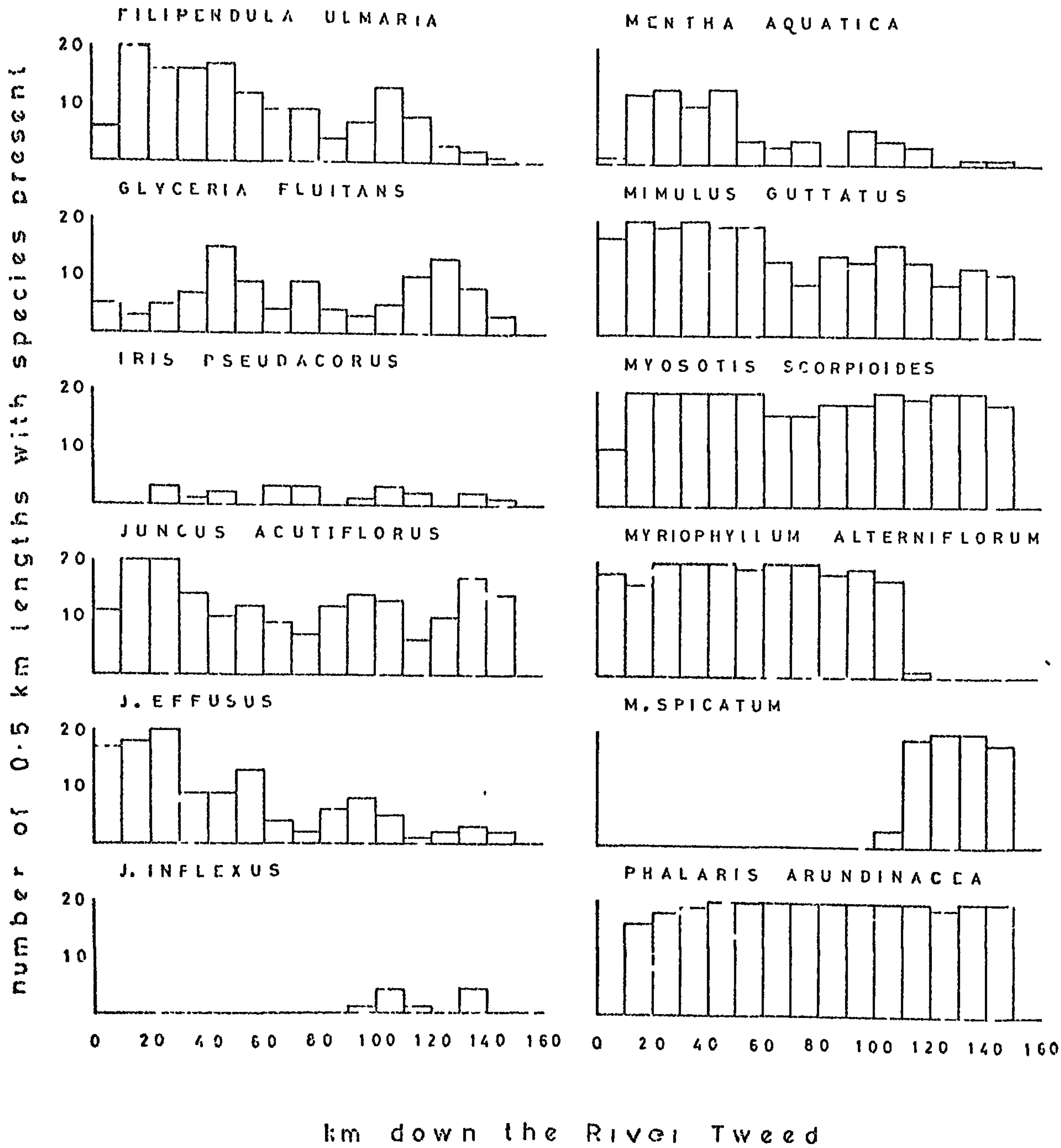
VERRUCARIA OTHER SPP.
BRYUM PSEUDOTRIQUETRUM
ACROCLADIUM CUSPIDATUM
CHILOSCYPHUS POLYANTHOS
AMPHIDIUM MOUGEOTII
CINCLIDOTUS FONTINALOIDES
BRACHYTHECIUM PLUMOSUM
CLIMACIUM DENDROIDES
B. RIVULARE
CONOCEPHALUM CONICUM
B. RUTABULUM
CRATONEURON FILICINUM
number of 0·5 km lengths with species present
20
10
0 20 40 60 80 100 120 140 160
km down the River Tweed

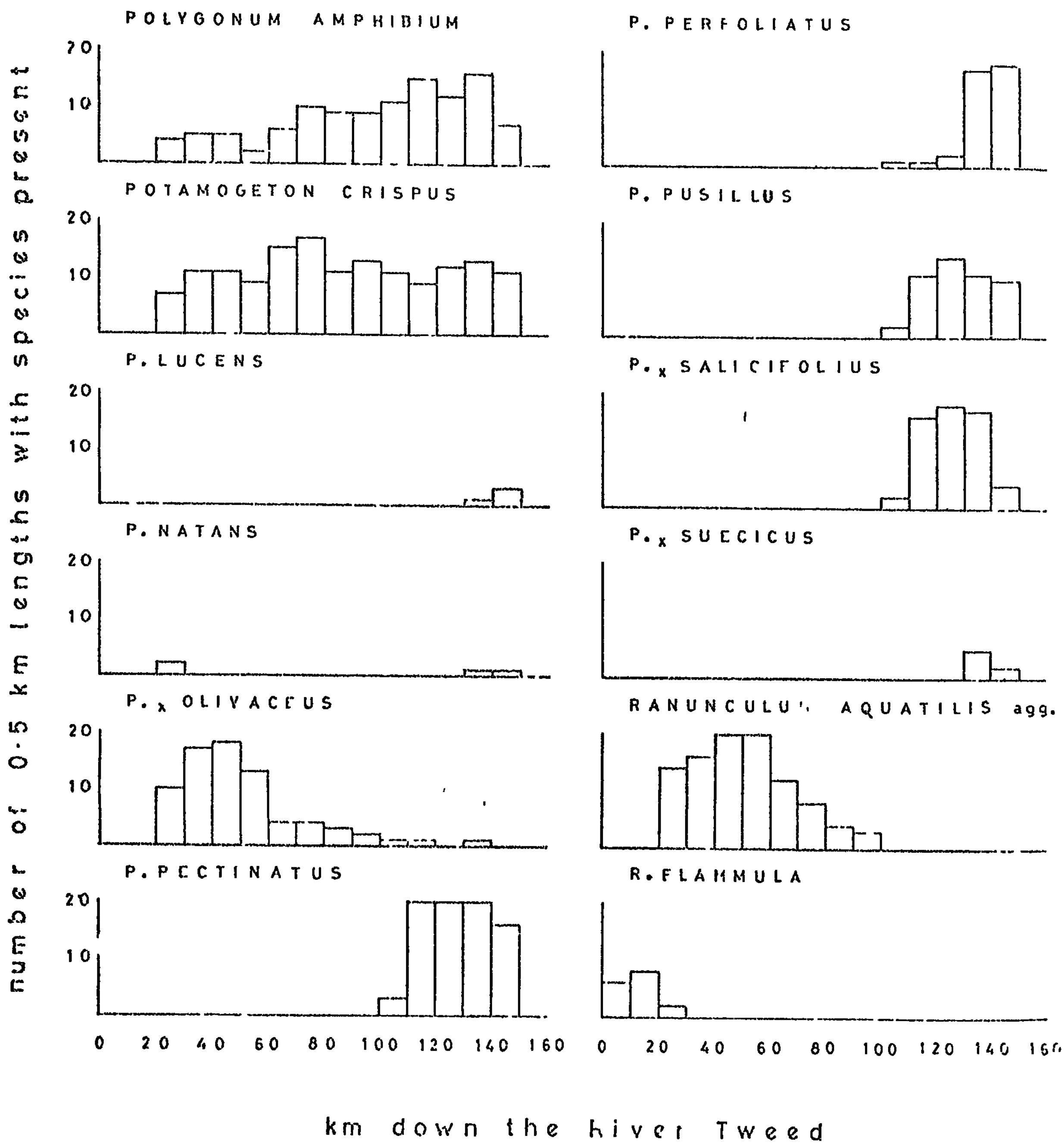

DICHODONTIUM PELLUCIDUM
FUNARIA HYGROMETRICA
EURHYNCHIUM RIPARIOIDES
GRIMMIA ALPICOLA var RIVULARIS
FISSIDENS ADIANTHOIDES
HYGROAMBLYSTEGIUM FLUVIATILE
F. CRASSIPES
HYGROHYPNUM LURIDUM
FONTINALIS ANTIPYRETICA
H. OCHRACEUM
F. ANTIPYRETICA var. GRACILIS
LEPTODICTYUM RIPARIUM
20
10
0 20 40 60 80 100 120 140 160
number of 0·5 km lengths with species present
km down the River Tweed

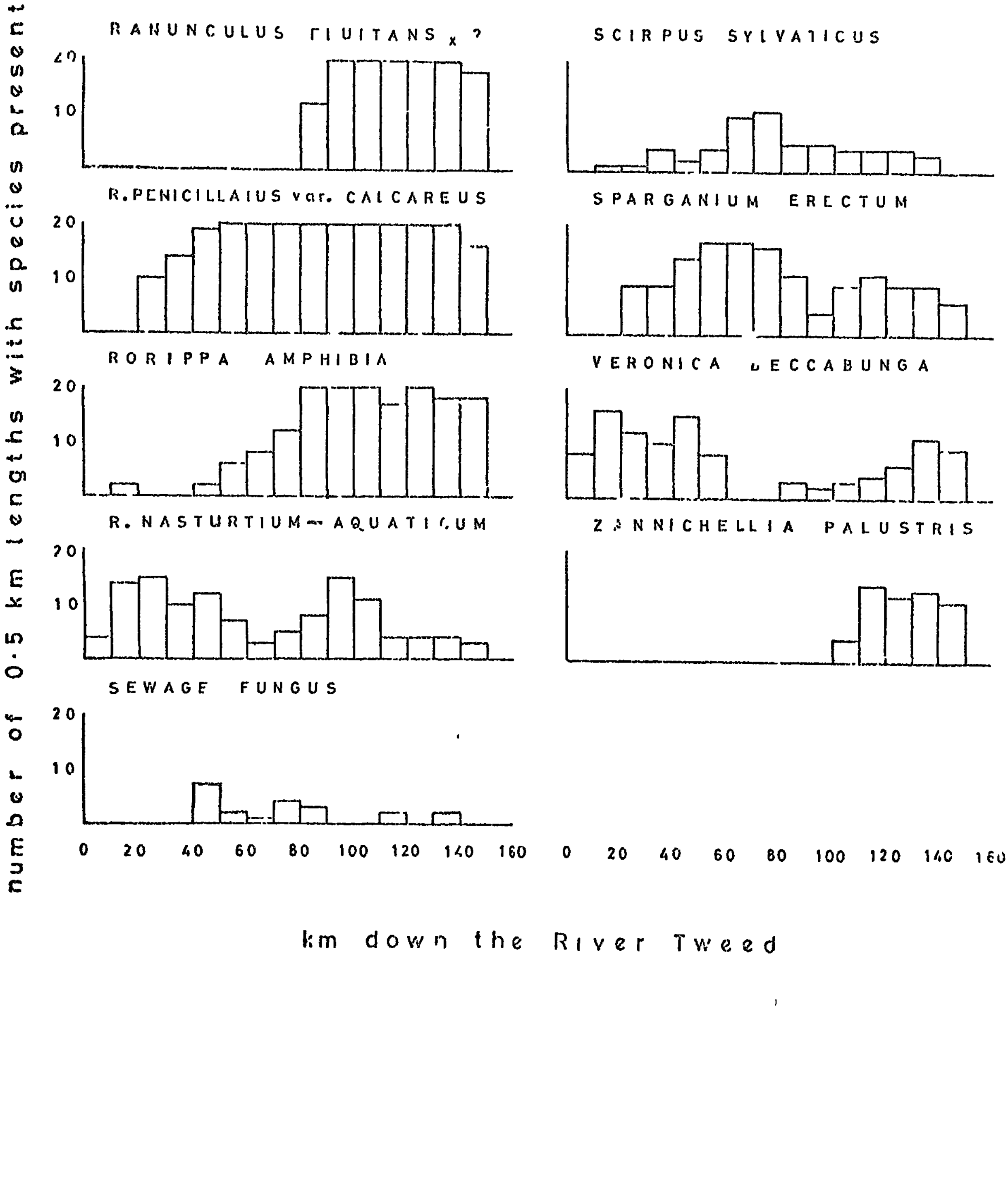


LESKEA POLYCARPA
P. EPIPHYLLA
MARCHANTIA POLYMORPHA
PHILONOTIS FONTANA
MNIUM LONGIROSTRUM
SCAPANIA UNDULATA
M. PUNCTATUM
SOLENOSTOMA TRISTE
ORTHOTRICHUM RIVULARE
THAMNION ALOPECURUM
PELLIA ENDIVIIFOLIA
TORTULA MUTICA
20
10
0 20 40 60 80 100 120 140 160
number of 0.5 km lengths with species present
km down the River Tweed

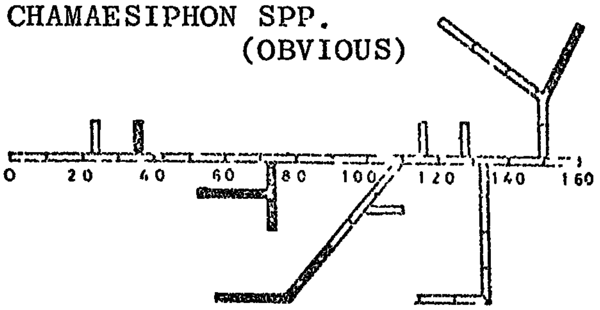

RHACOMITRIUM ACICILARIS
R. AQUATICUM
RHYTIDIADELPHUS SQUARROSUS
CALLITRICHE SPP.
CALTHA PALUSTRIS
CAREX NIGRA
C. ROSTRATA
CAREX OTHER SPP.
COCHLEARIA ALPINA
ELEOCHARIS PALUSTRIS
ELODEA CANADENSIS
EQUISETUM FLUVIATILE
number of 0.5 km lengths with species present
0 20 40 60 80 100 120 140 160
km down the River Tweed


FILIPENDULA ULMARIA
GLYCERIA FLUITANS
IRIS PSEUDACORUS
JUNCUS ACUTIFLORUS
J. EFFUSUS
J. INFLEXUS
MENTHA AQUATICA
MIMULUS GUTTATUS
MYOSOTIS SCORPIOIDES
MYRIOPHYLLUM ALTERNIFLORUM
M. SPICATUM
PHALARIS ARUNDINACEA
number of 0·5 km lengths with species present
20
10
0 20 40 60 80 100 120 140 160
km down the River Tweed

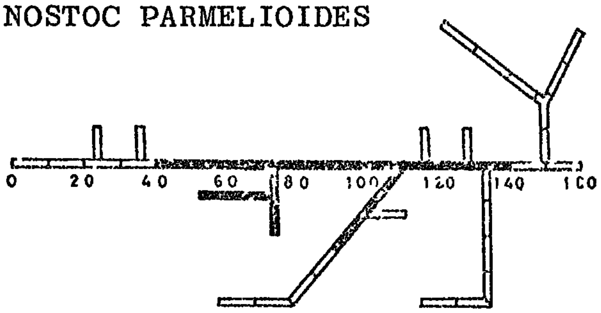

POLYGONUM AMPHIBIUM
P. PERFOLIATUS
POTAMOGETON CRISPUS
P. PUSILLUS
P. LUCENS
P.x SALICIFOLIUS
P. NATANS
P.x SUECICUS
P.x OLIVACEUS
RANUNCULUS AQUATILIS agg.
P. PECTINATUS
R. FLAMMULA
20
10
0 20 40 60 80 100 120 140 160
number of 0.5 km lengths with species present
km down the River Tweed


RANUNCULUS FLUITANS x ?
SCIRPUS SYLVATICUS
R. PENICILLATUS var. CALCAREUS
SPARGANIUM ERECTUM
RORIPPA AMPHIBIA
VERONICA BECCABUNGA
R. NASTURTIUM-AQUATICUM
ZANNICHELLIA PALUSTRIS
SEWAGE FUNGUS
number of 0·5 km lengths with species present
km down the River Tweed
0 20 40 60 80 100 120 140 160
10
20

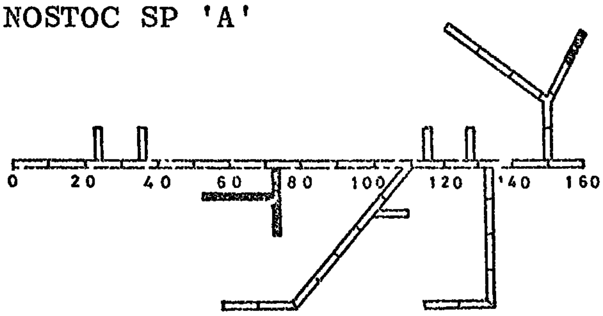
CHAMAESIPHON SPP. (OBVIOUS)



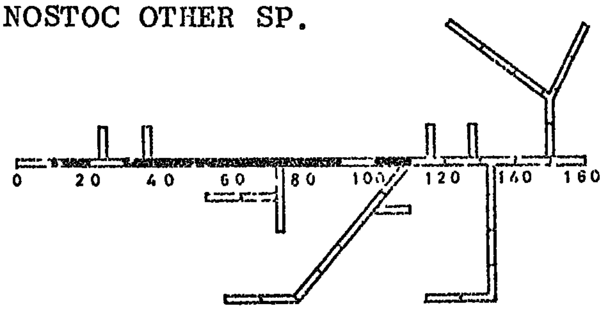
NOSTOC PARMELIOIDES



NOSTOC SP 'A'



NOSTOC OTHER SP.



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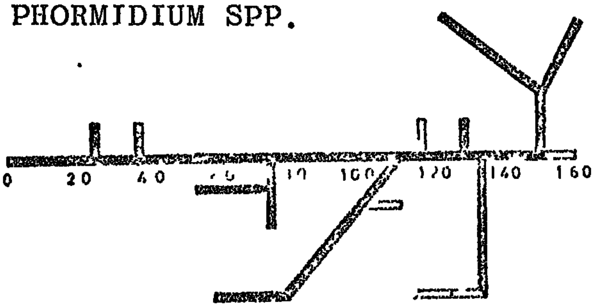

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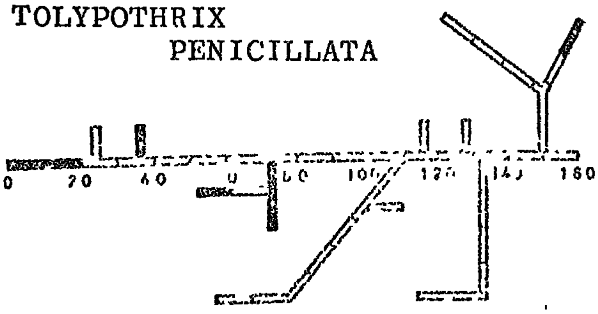

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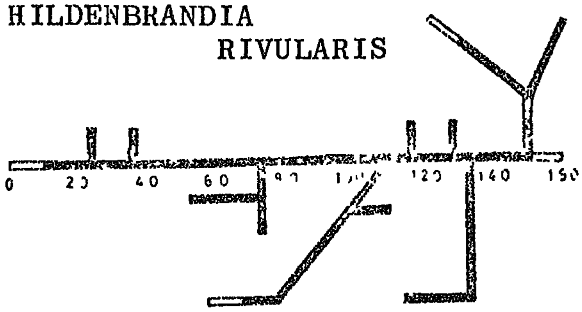

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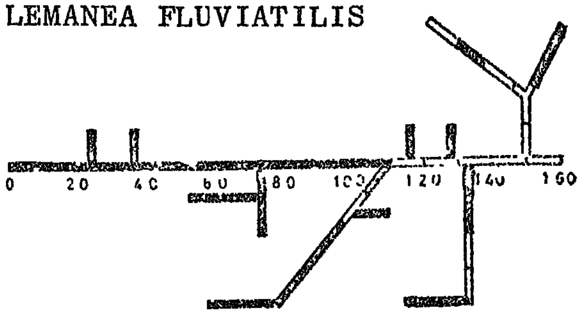

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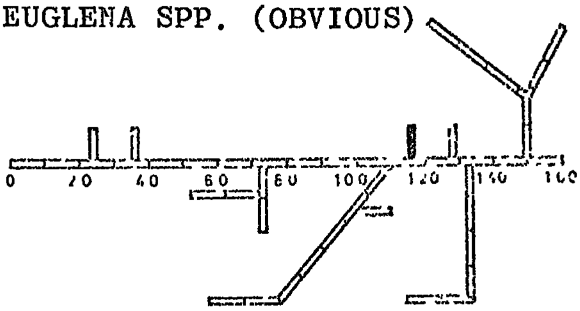

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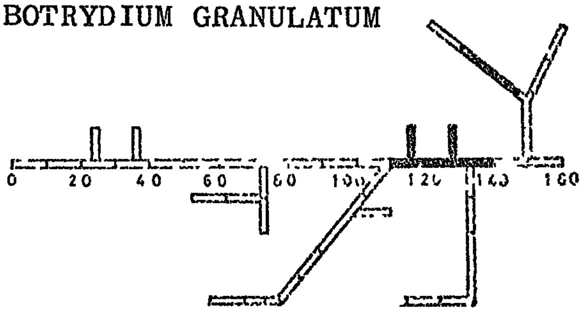

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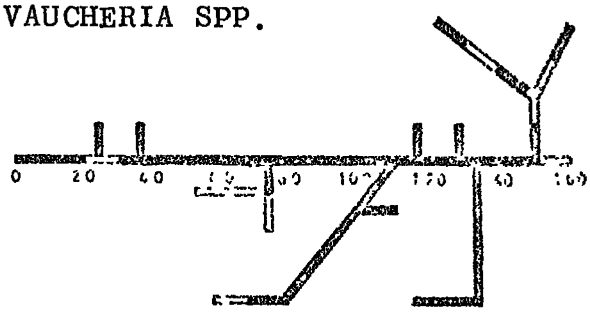

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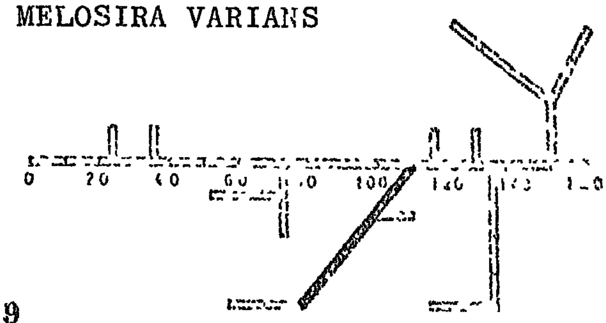

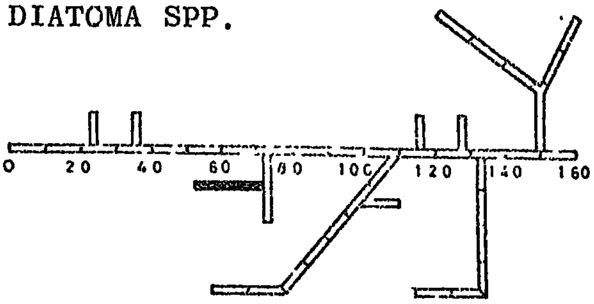

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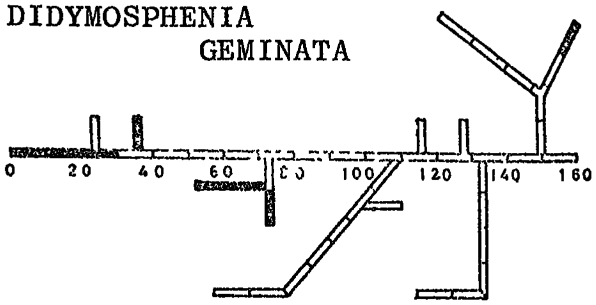

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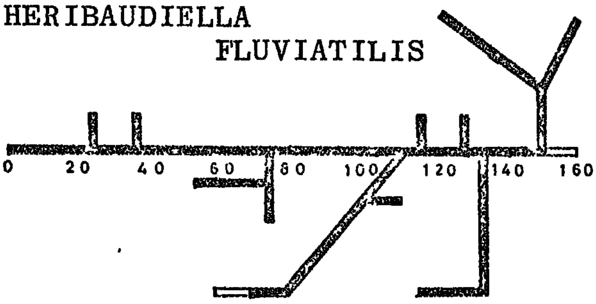

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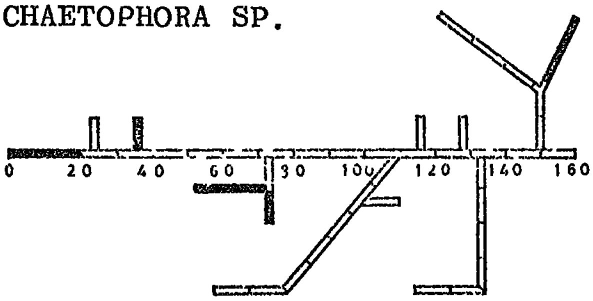

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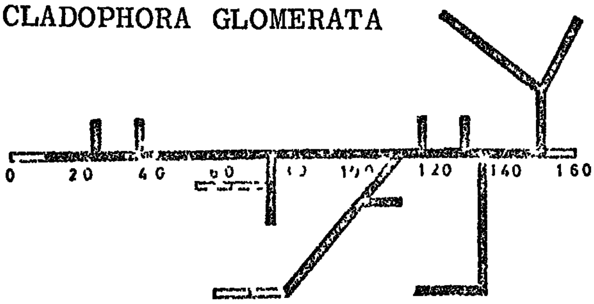

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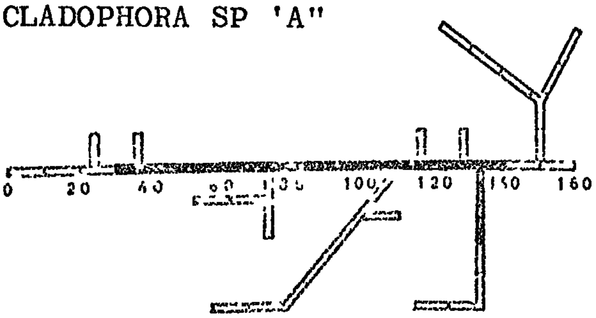

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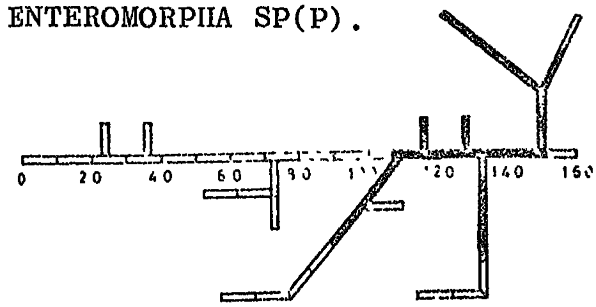

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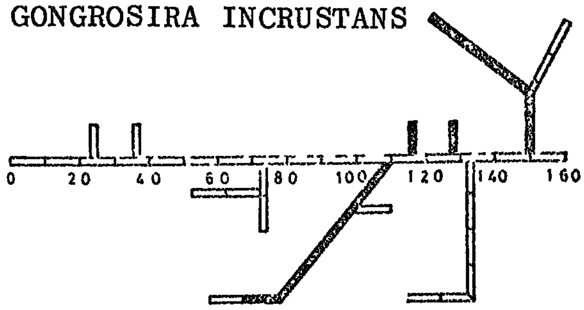

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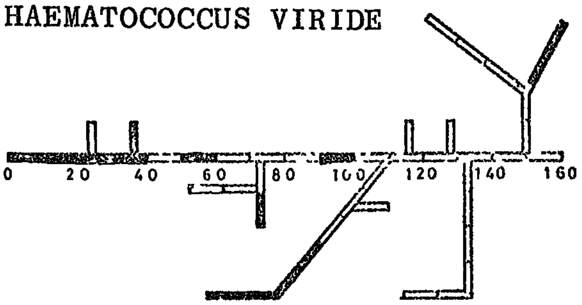

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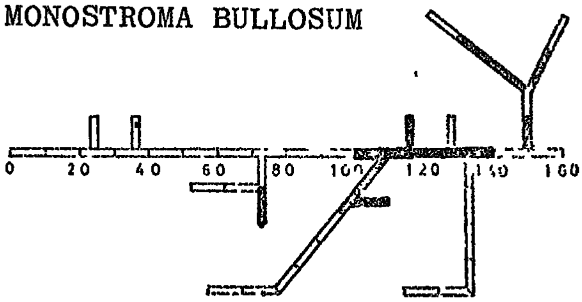

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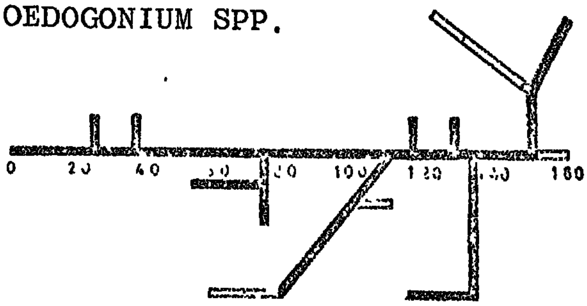

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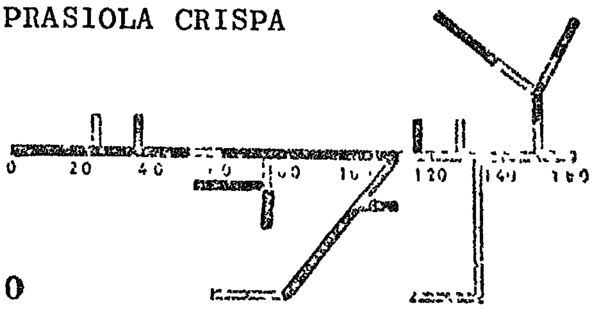

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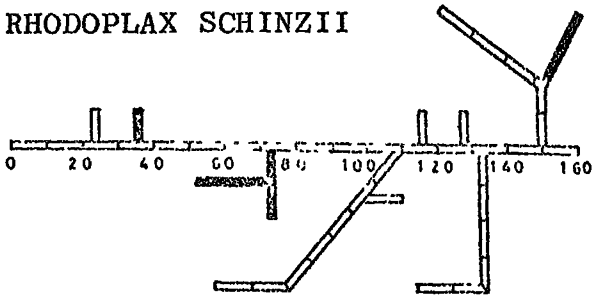

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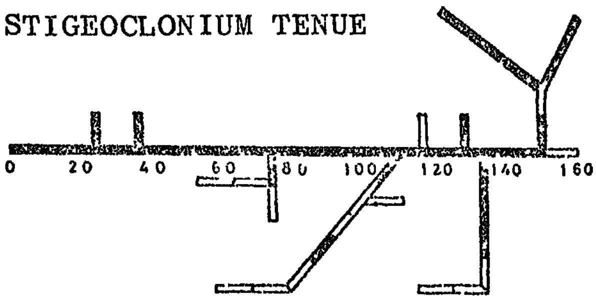

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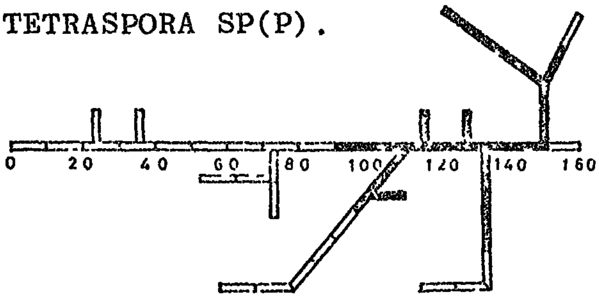

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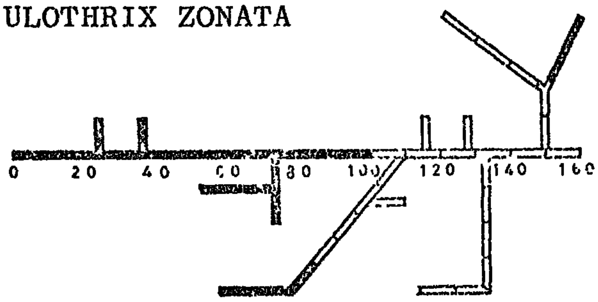

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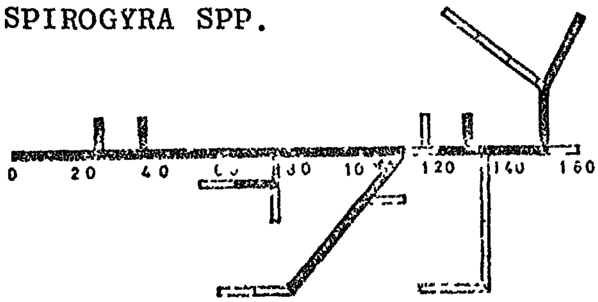

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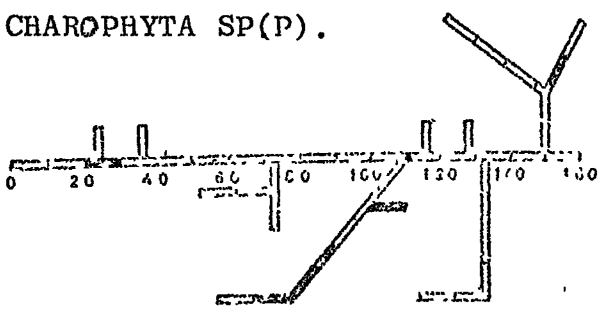

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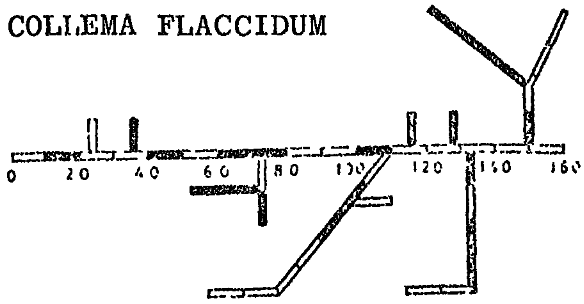

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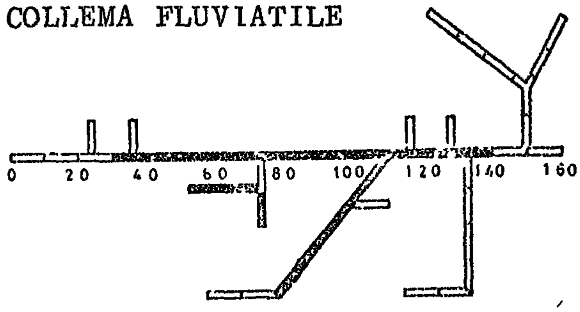

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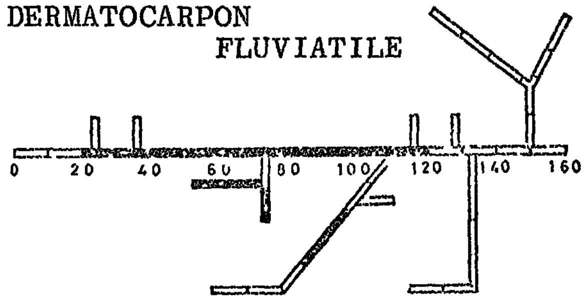

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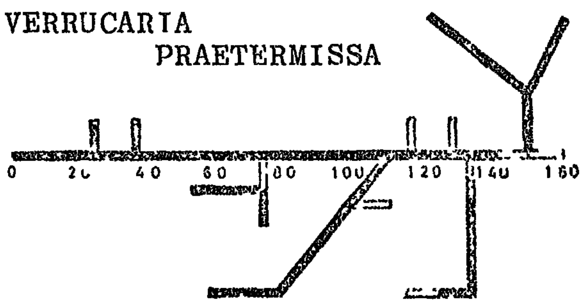

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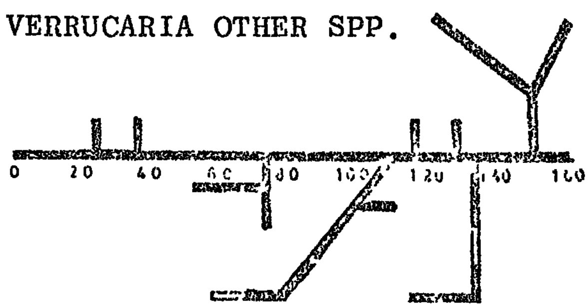

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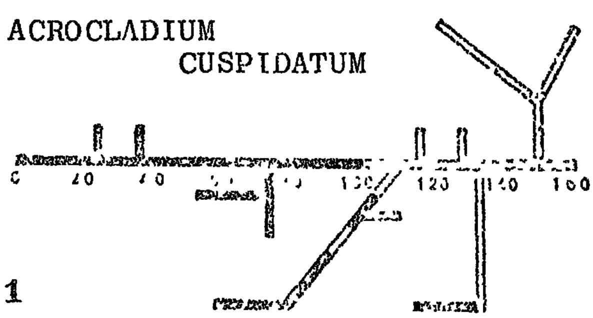

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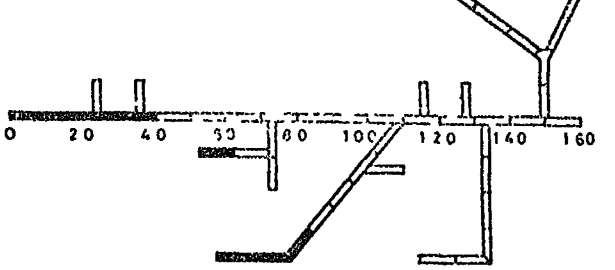

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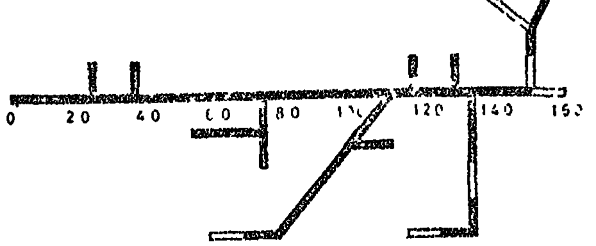

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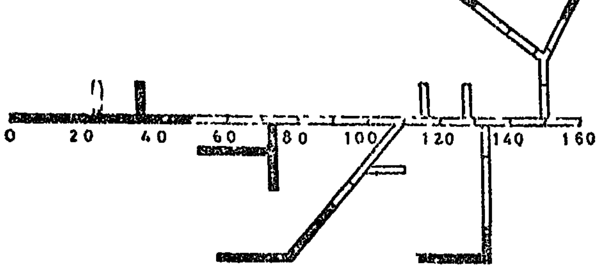

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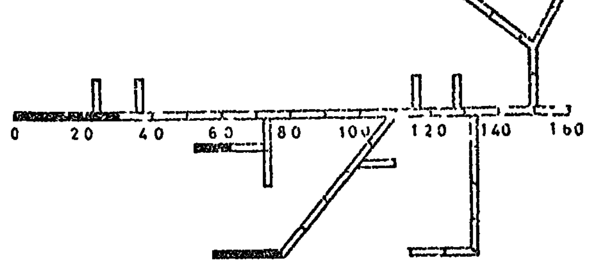

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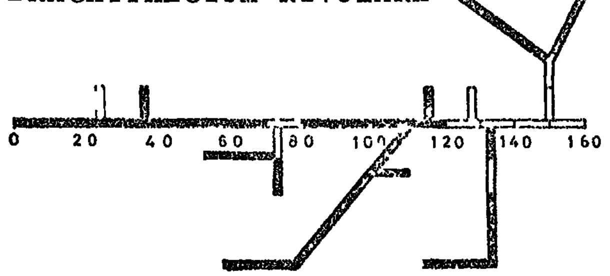

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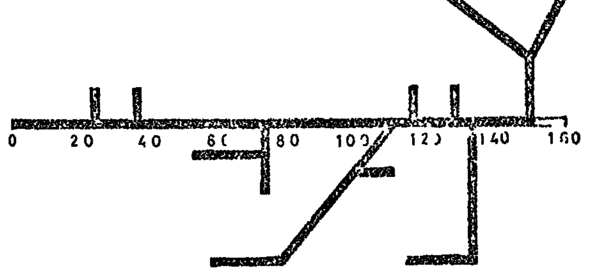

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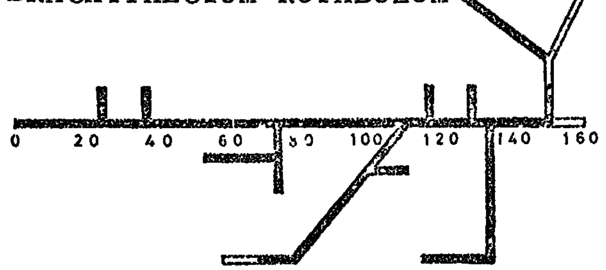

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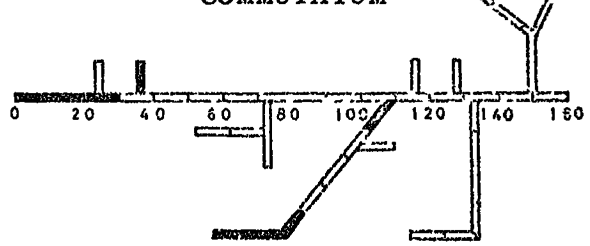

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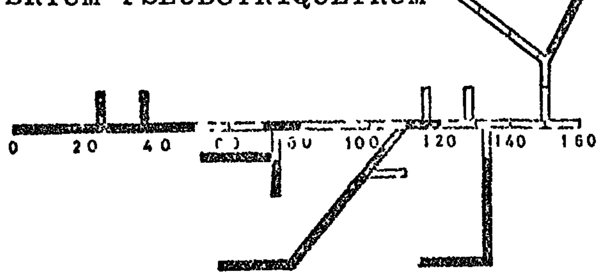

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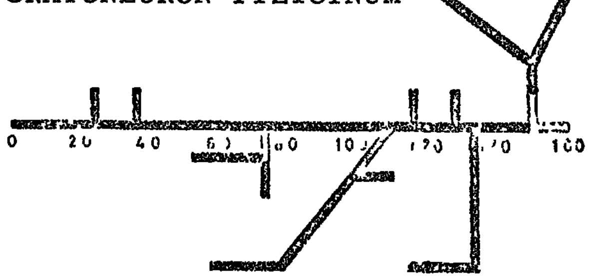

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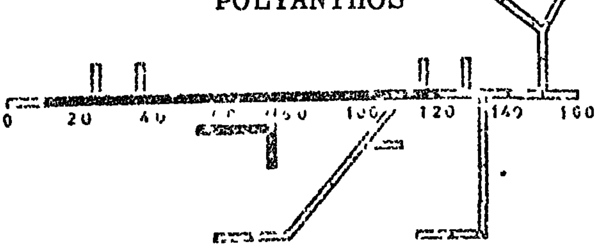

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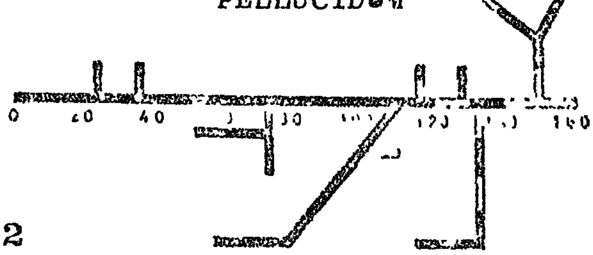

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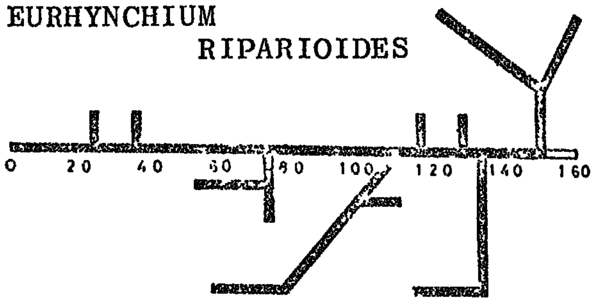

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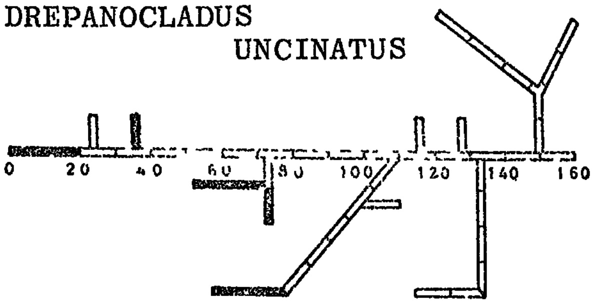

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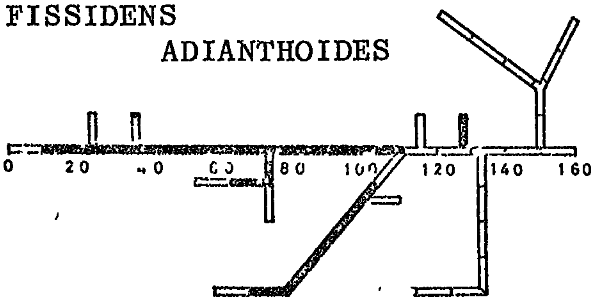

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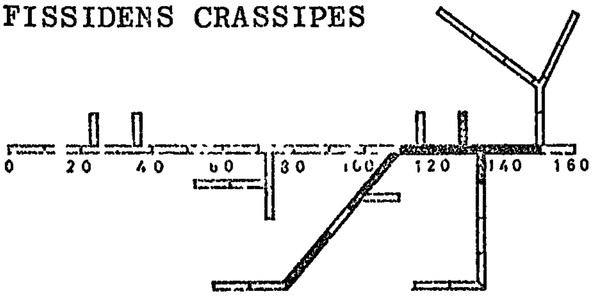

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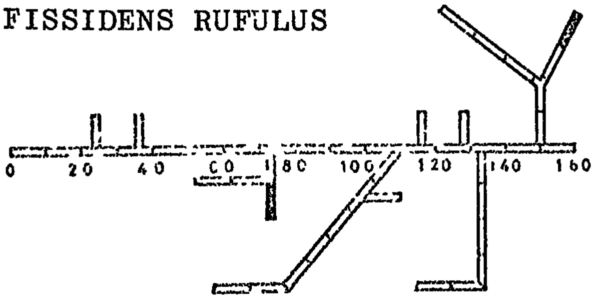

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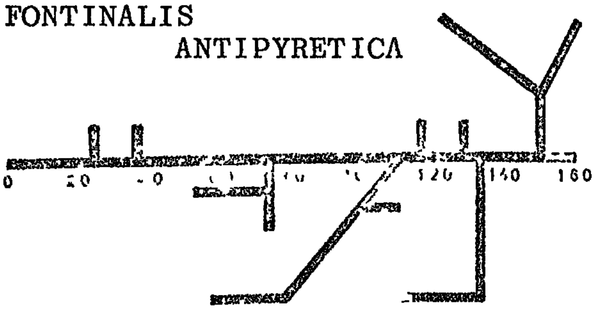

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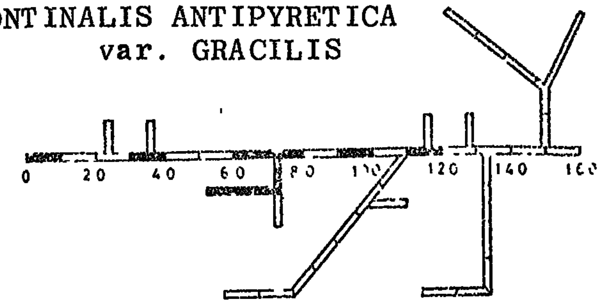

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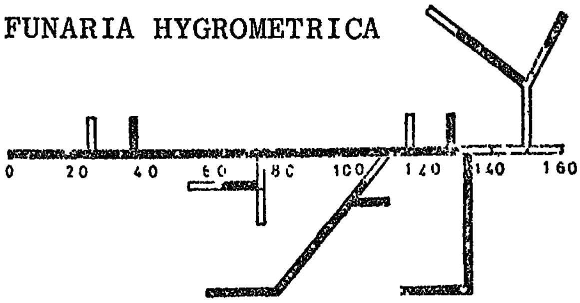

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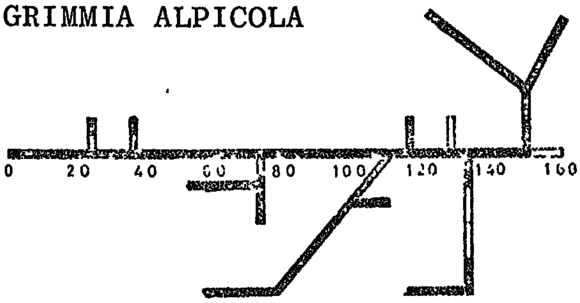

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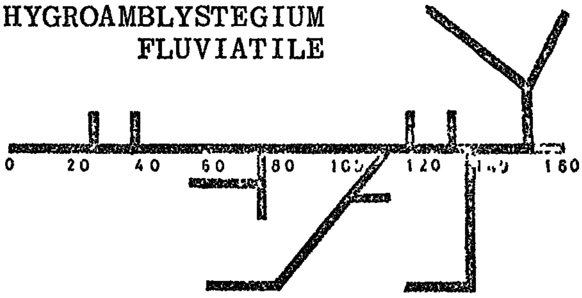

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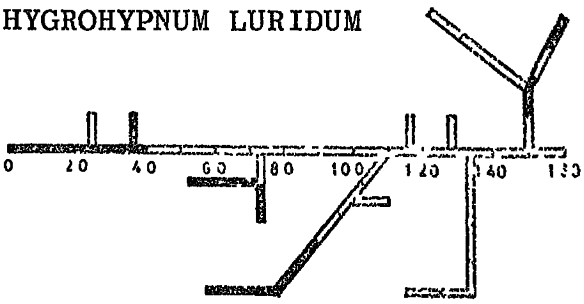

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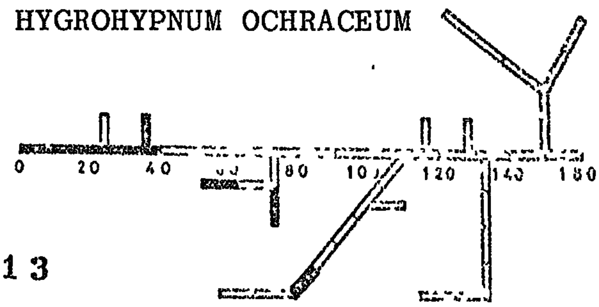

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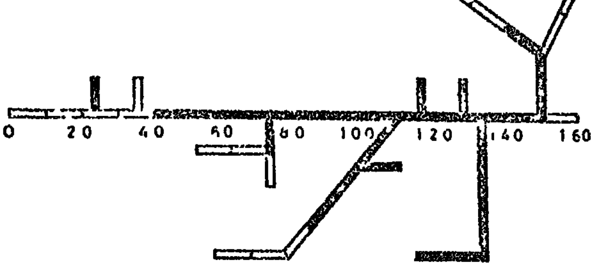

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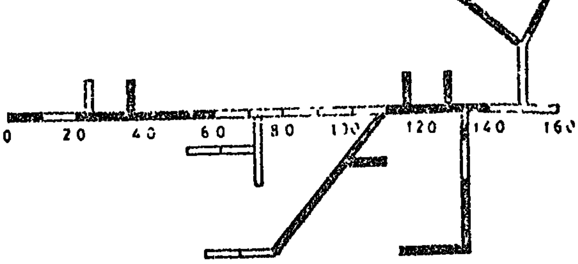

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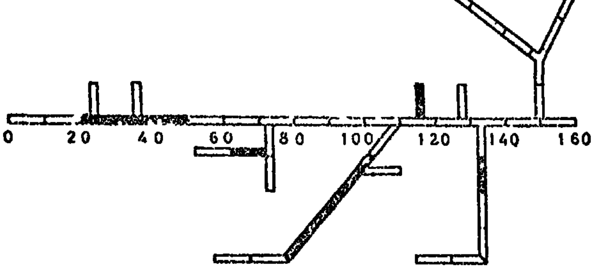

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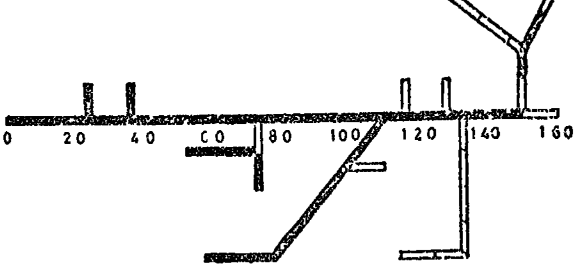

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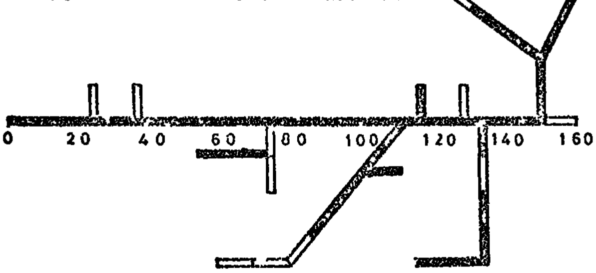

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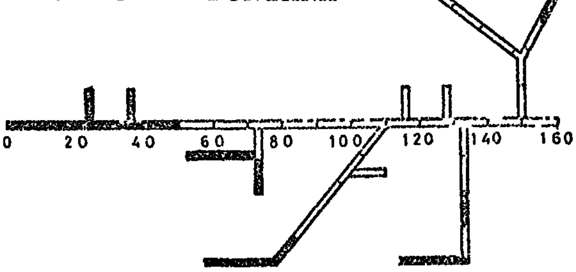

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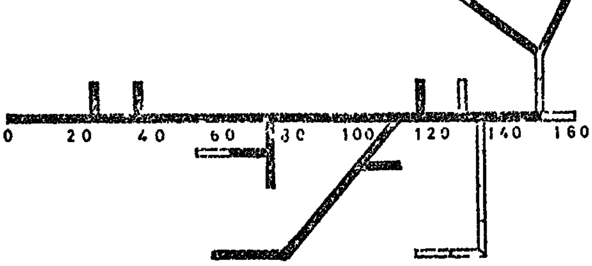

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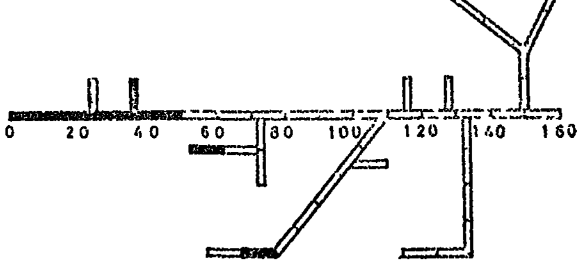

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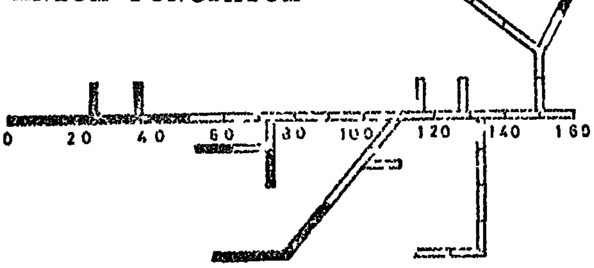

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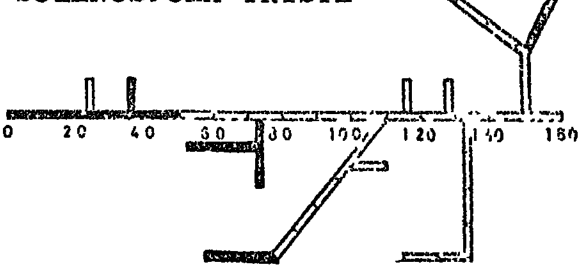

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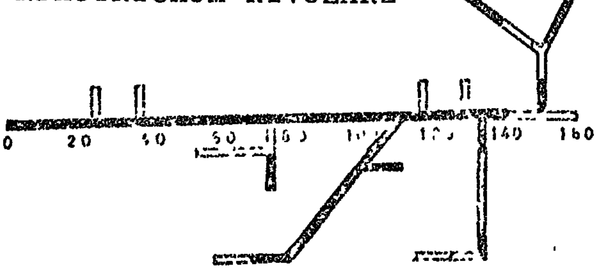

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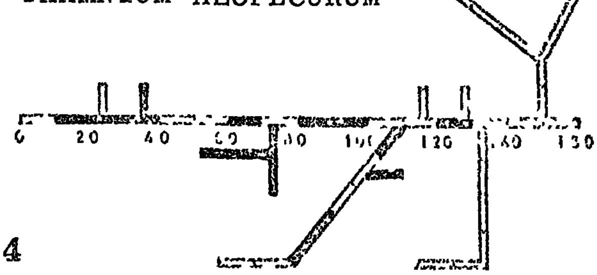

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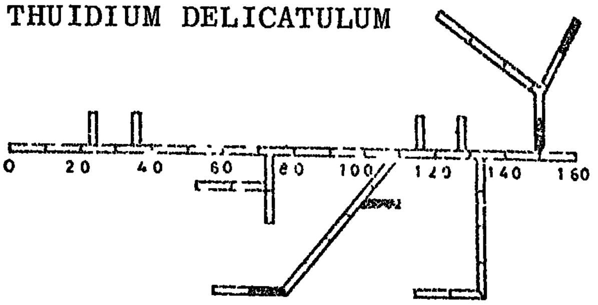
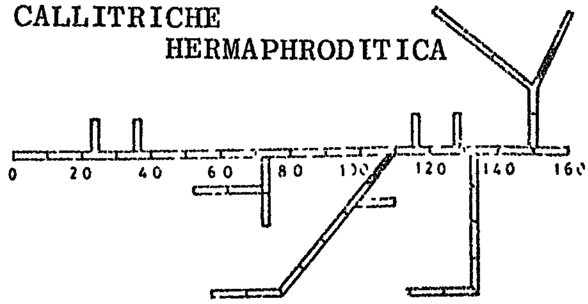


CALLITRICHE HERMAPHRODITICA



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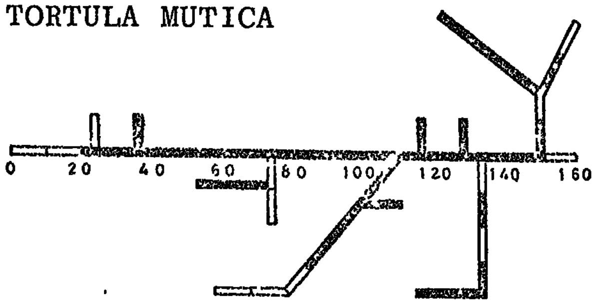

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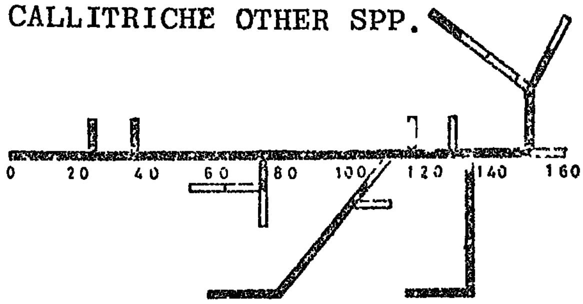

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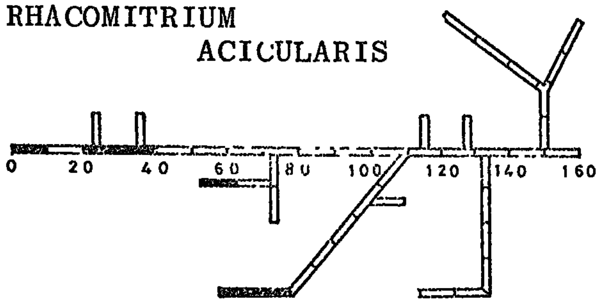

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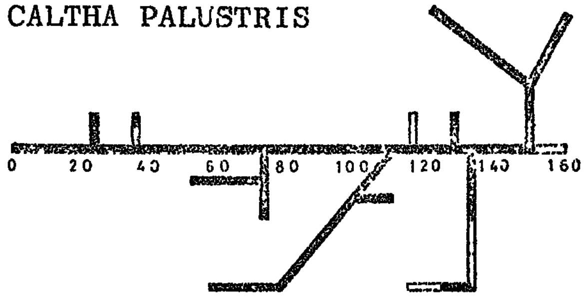

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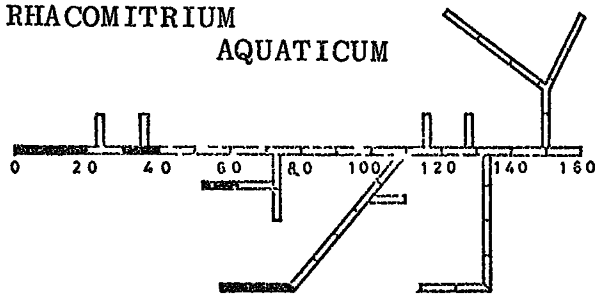

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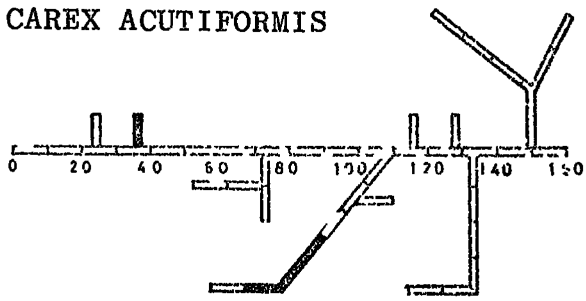

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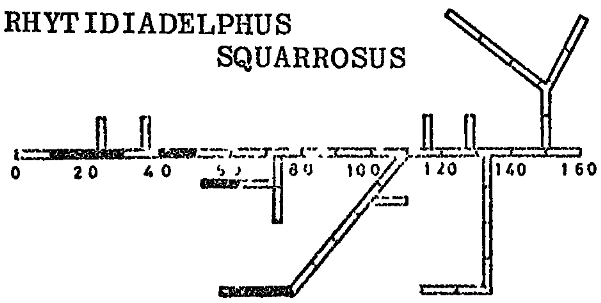

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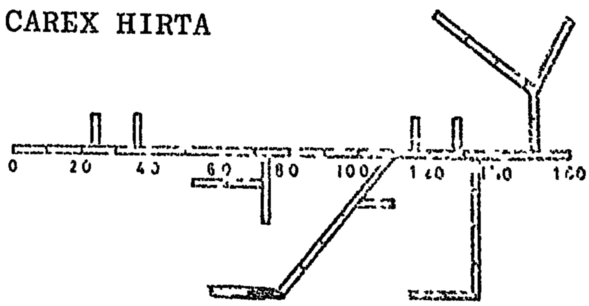

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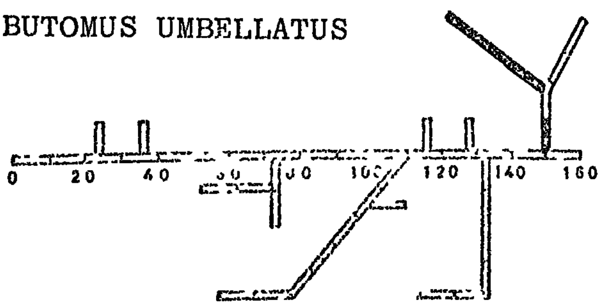

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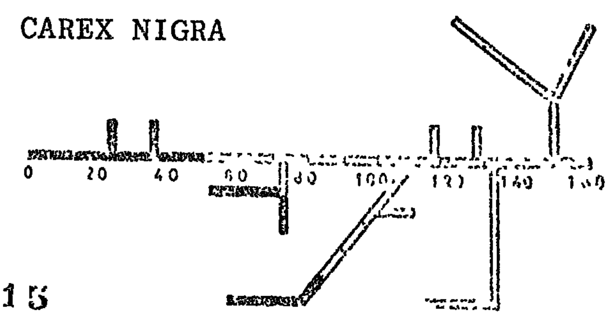

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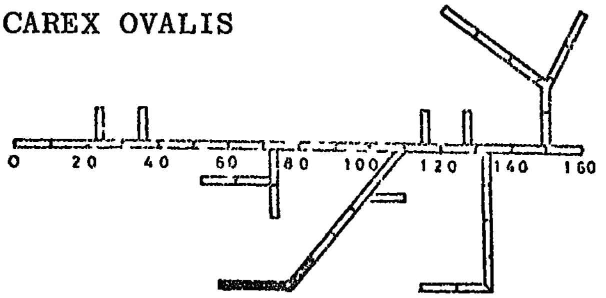

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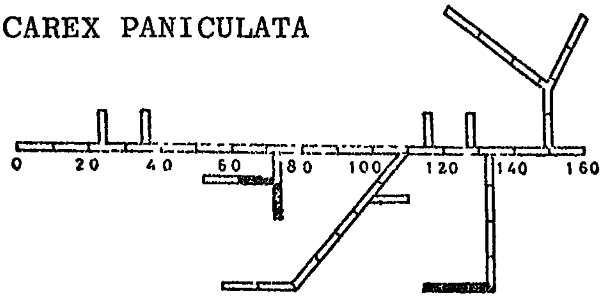

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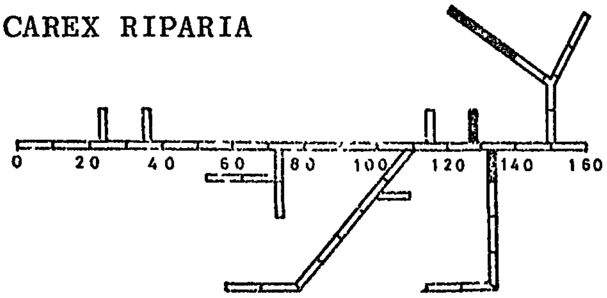
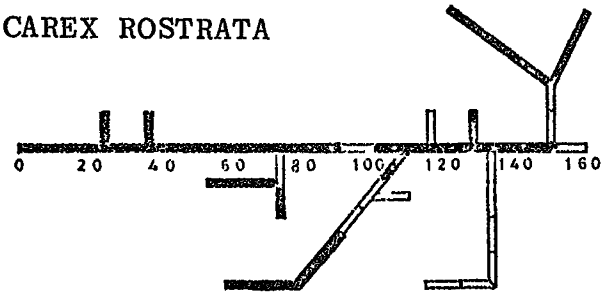


CAREX ROSTRATA



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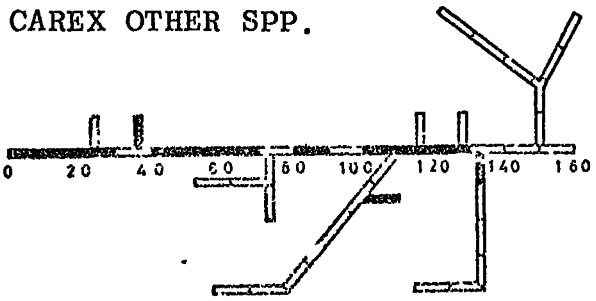
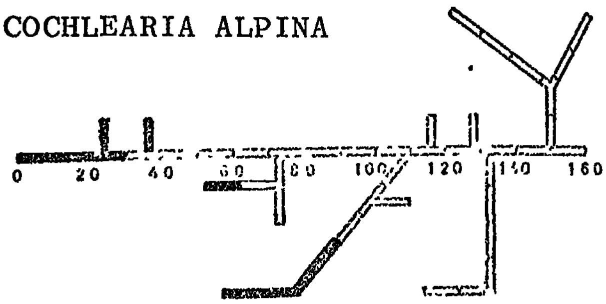


COCHLEARIA ALPINA



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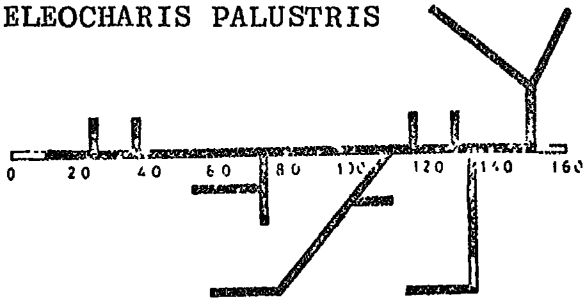

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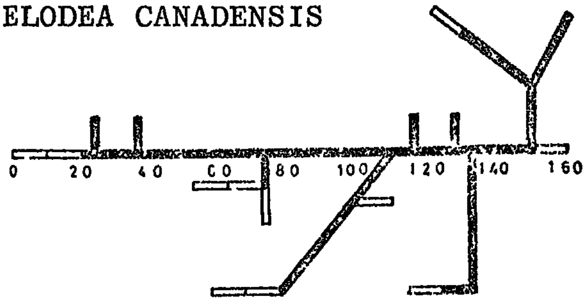
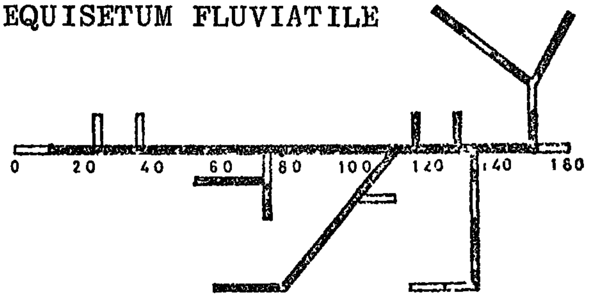
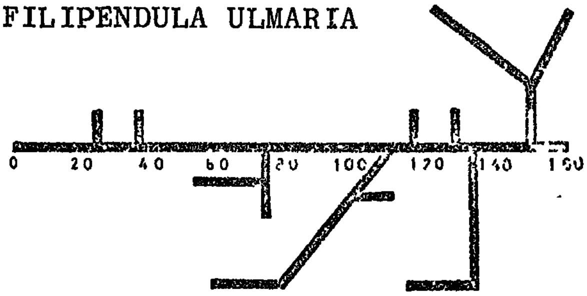


EQUISETUM FLUVIATILE



FILIPENDULA ULMARIA



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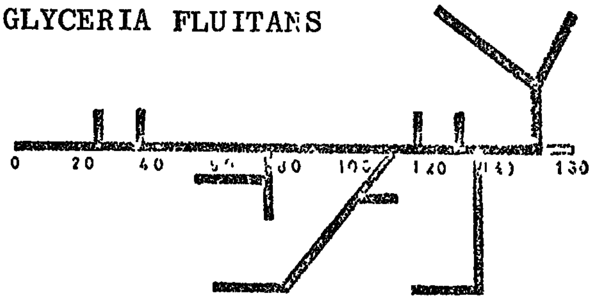
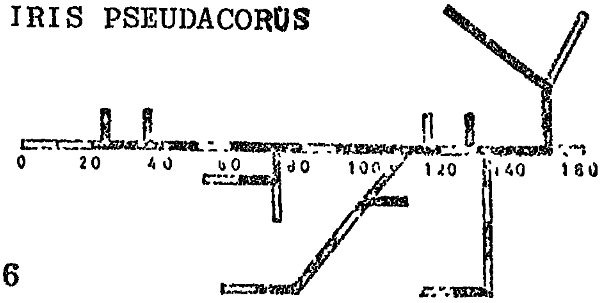
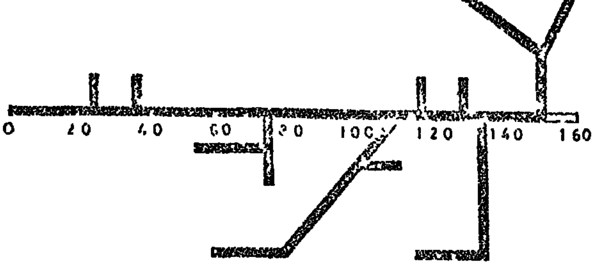


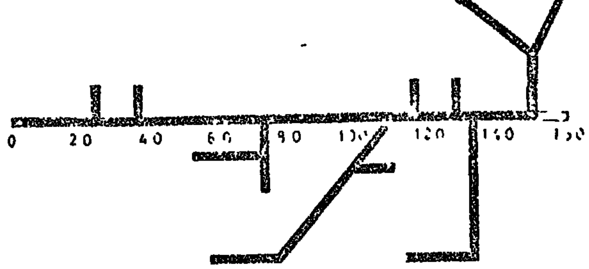
IRIS PSEUDACORUS



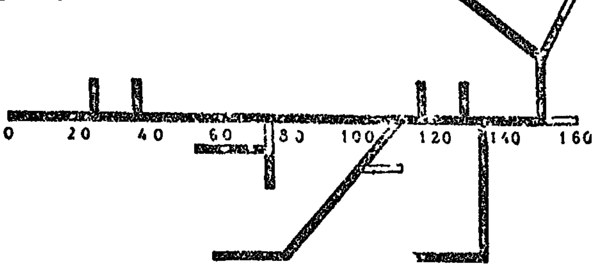
JUNCUS ACUTIFLORUS



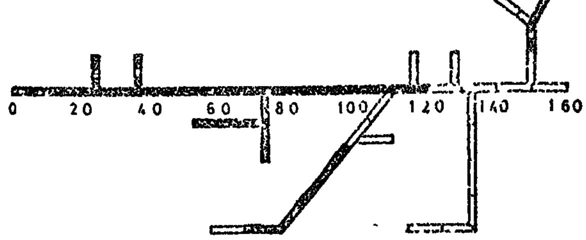
MYOSOTIS SCORPIOIDES



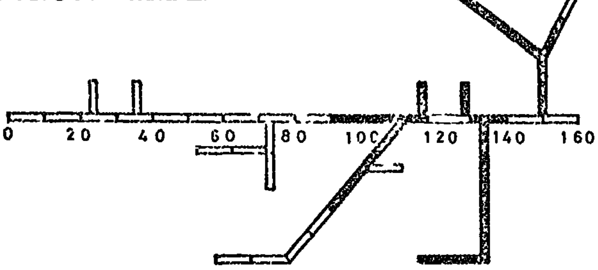
JUNCUS EFFUSUS



MYRIOPHYLLUM ALTERNIFLORUM



JUNCUS INFLEXUS



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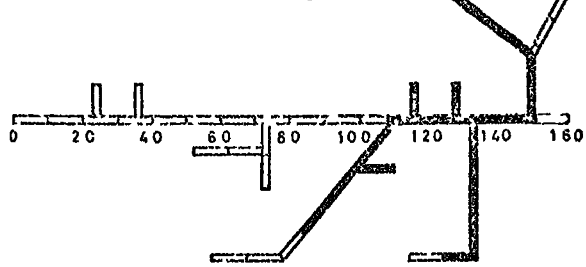
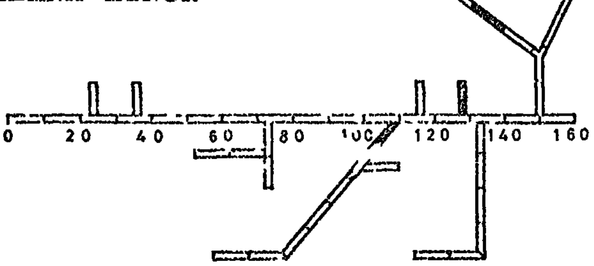
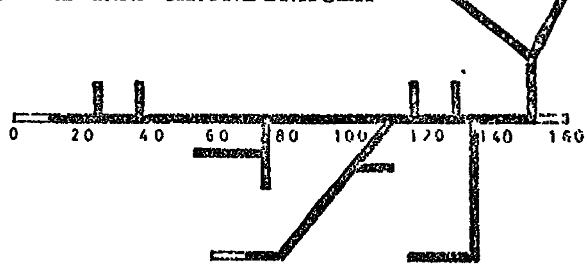


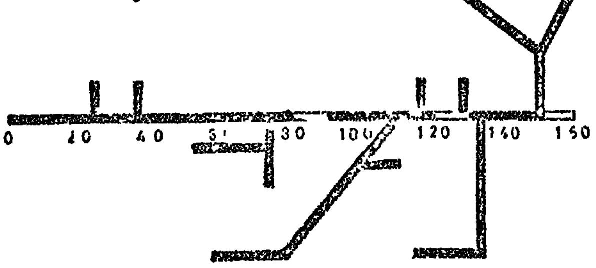
LEMNA MINOR



PHALARIS ARUNDINACEA



MENTHA AQUATICA



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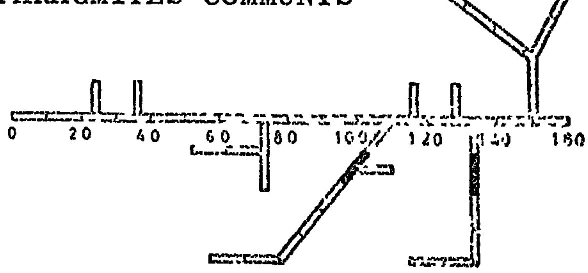

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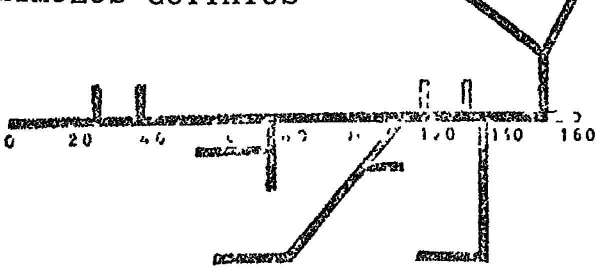

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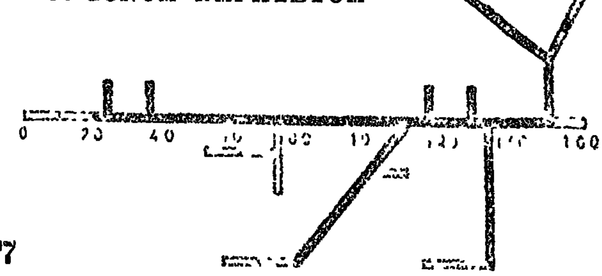

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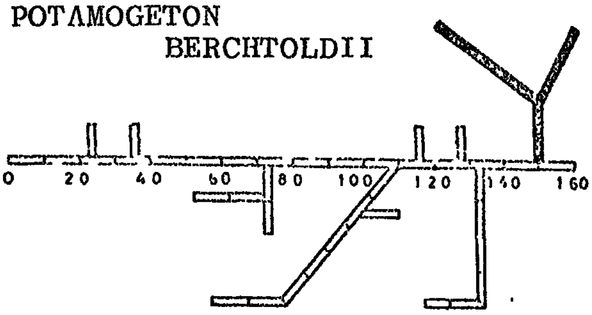

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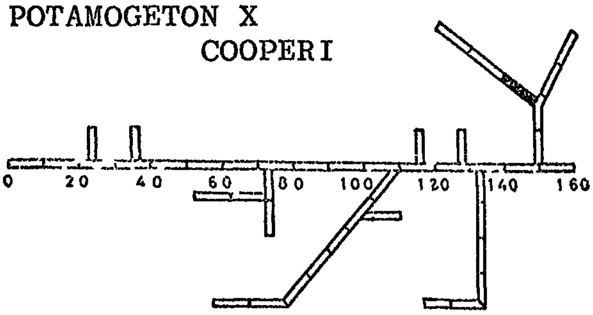

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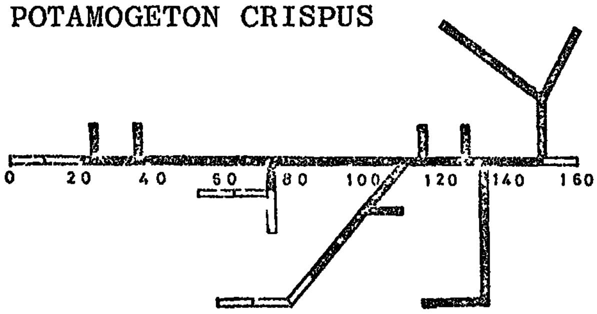

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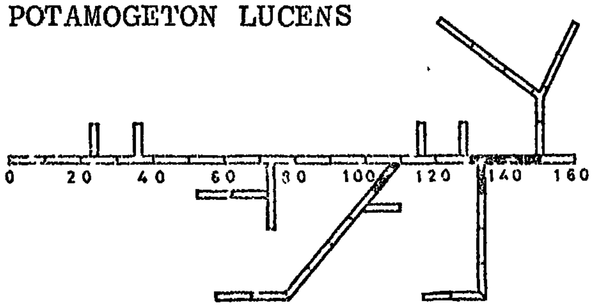
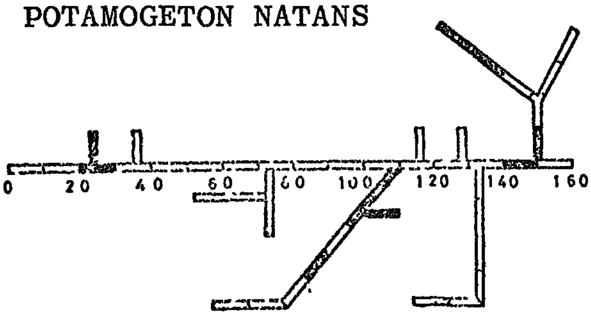


POTAMOGETON NATANS



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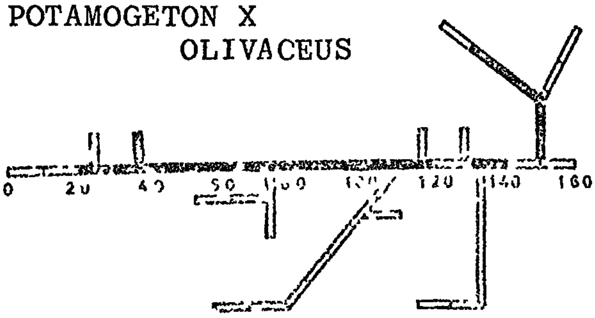

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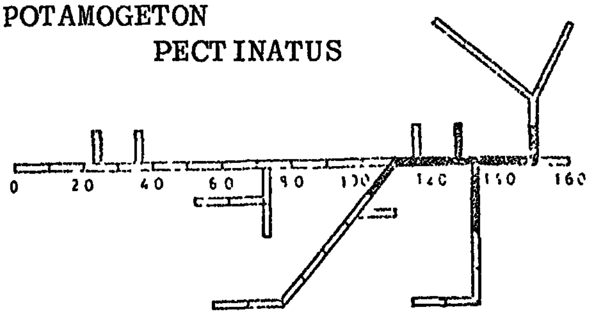

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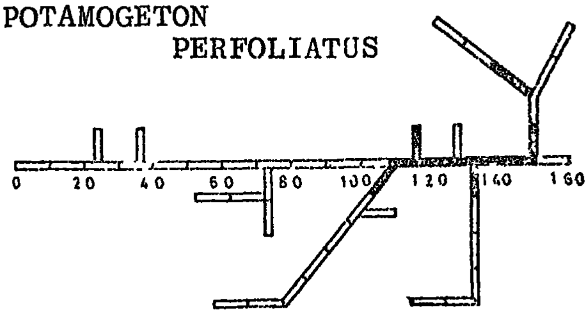

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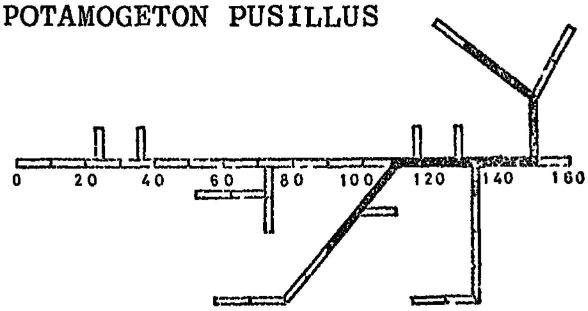

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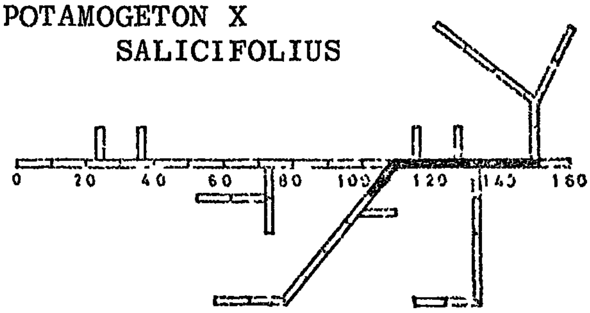

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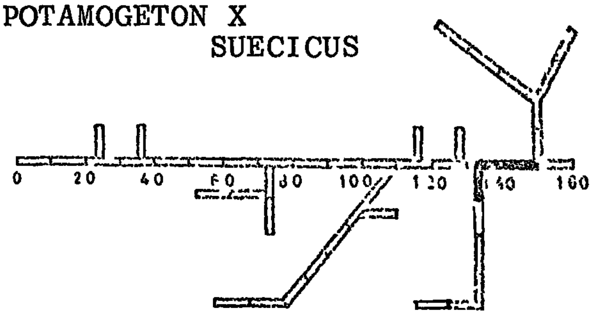

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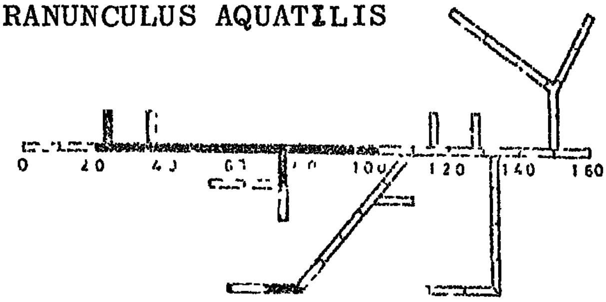

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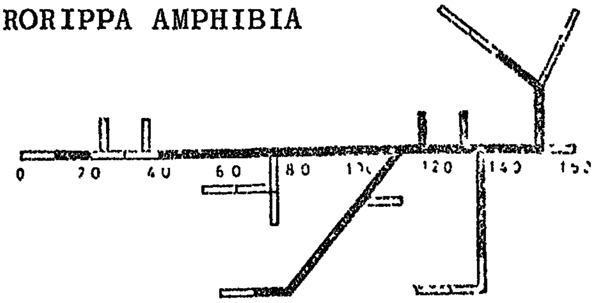

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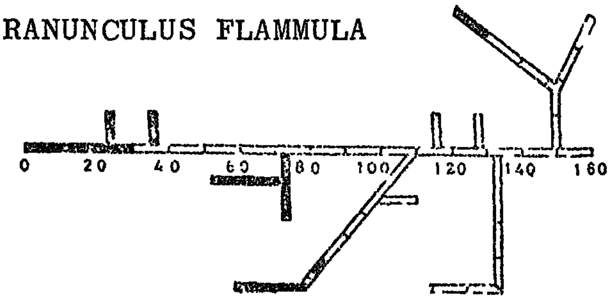

RORIPPA
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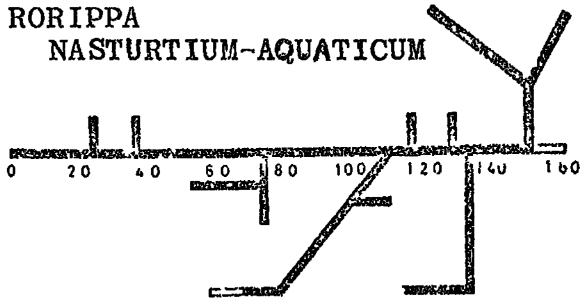
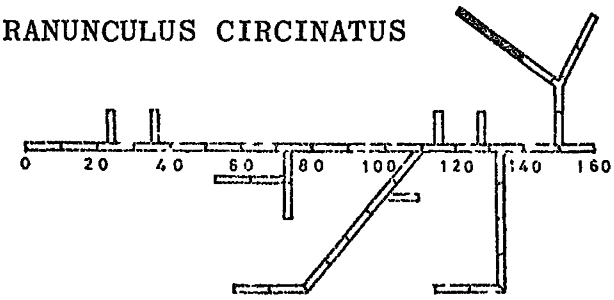


RANUNCULUS CIRCINATUS



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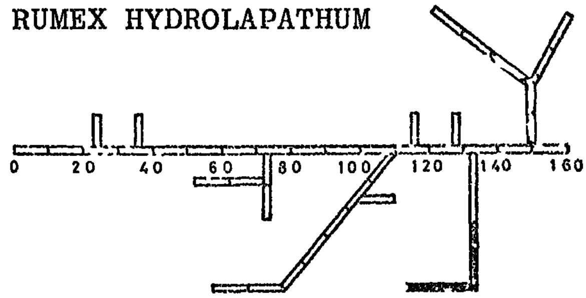
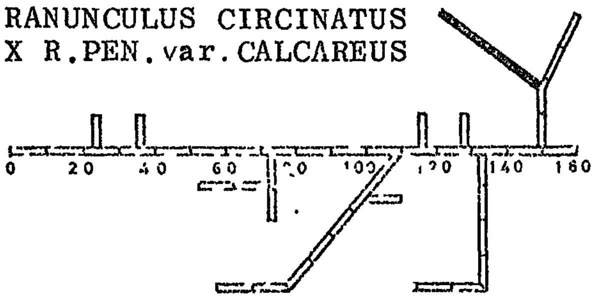
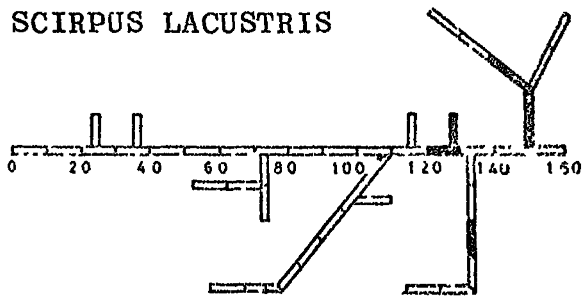


RANUNCULUS CIRCINATUS
X R.PEN.var.CALCAREUS



SCIRPUS LACUSTRIS



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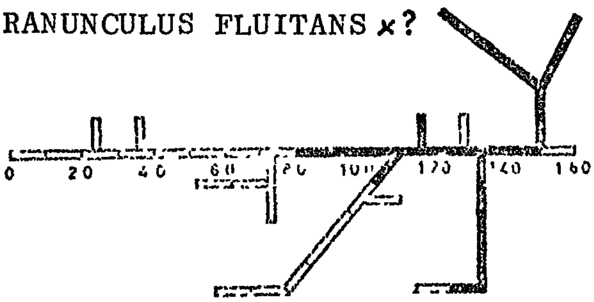
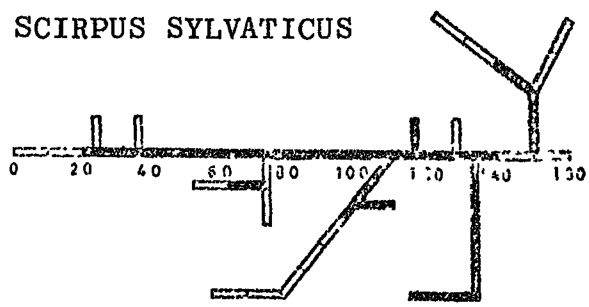
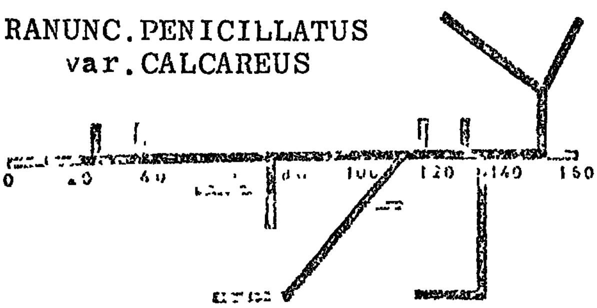


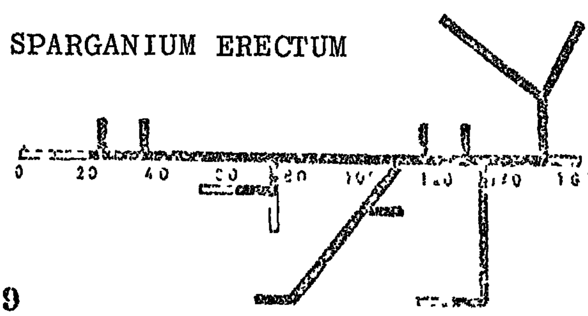
SCIRPUS SYLVATICUS



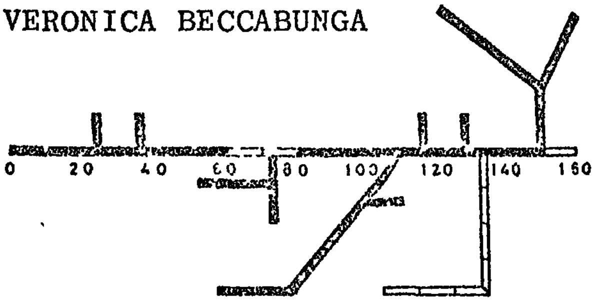
RANUNC.PENICILLATUS
var.CALCAREUS



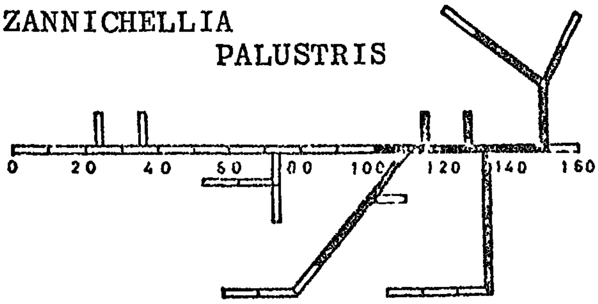
SPARGANIUM ERECTUM



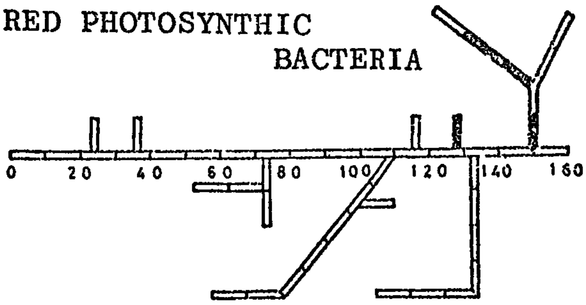
VERONICA BECCABUNGA



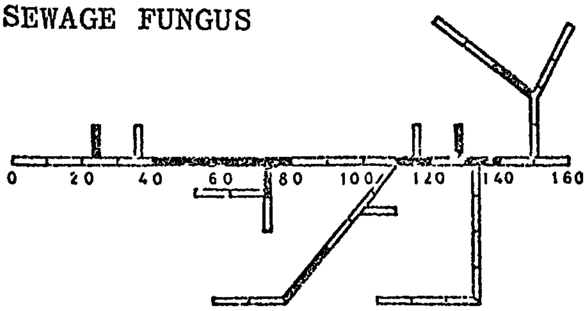
ZANNICHELLIA
PALUSTRIS



RED PHOTOSYNTHIC
BACTERIA



SEWAGE FUNGUS



6.5 Relationship of abundance values to presence or absence technique

The importance of not only recording the presence of a species, but also its abundance (see 2.2), is illustrated in Table 6.5a. On the left are listed the 20 most recorded species from the three hundred 0.5 km lengths surveyed in the Tweed; on the right are listed the 20 most abundant species in the river based on the aggregate of the subjective abundances for each 0.5 km length in which they were present. Table 6.5b summarizes similar data from the Teviot. Both serve to show that the number of times a species is recorded is not always proportional to its overall abundance in the river.

The Tables show that permanently submerged bryophytes and angiosperms (SB and SA), are placed higher in the abundance column than in the presence column (apart from Eurhynchium riparioides which was top of both columns for the Teviot). This is particularly obvious in the case of Ranunculus penicillatus var. calcareus in both the Tweed and Teviot, R. fluitans x ? in the Tweed, and Myriophyllum spicatum, Zannichellia palustris and Hygrohypnum luridum in the Teviot. Conversely, bank species tended to be present in more 0.5 km lengths, but in less abundance. This is best illustrated in both rivers by Myosotis scorpioides.

Reference to partially surveyed tributaries also shows the additional information gained by including a subjective judgement of the abundance of a species in each particular 0.5 km length. For example, in the Biggar (p. 182), both Eurhynchium riparioides and Fontinalis antipyretica were recorded in all six 0.5 km lengths, however, the former species was rare in all lengths, whereas the latter was much more common. The comparative abundance totals of six and 16 respectively are an indication of the latter species abundance and the former species rareness. In the same river, Potamogeton natans was recorded in only five 0.5 km lengths, but

(a)		(b)	
Myosotis scorpioides	275	Ranunculus penicillatus var. calcareus (SA)	637
Phalaris arundinacea	272	Eurhynchium riparioides (SB)	582
Eurhynchium riparioides (SB)	267	Elodea canadensis (SA)	554
Oedogonium spp.	249	Phalaris arundinacea	495
Elodea canadensis (SA)	241	Fontinalis antipyretica (SB)	481
submerged Verrucaria spp.	240	Oedogonium spp.	474
Ranunculus penicillatus var. calcareus (SA)	237	submerged Verrucaria spp.	415
Hildenbrandia rivularis	237	Hygroamblystegium fluviatile (SB)	415
Fontinalis antipyretica (SB)	233	Myriophyllum alterniflorum (SA)	402
Heribaudiella fluviatilis	228	Hildenbrandia rivularis	392
Hygroamblystegium fluviatile (SB)	225	Cinclidotus fontinaloides	347
Mimulus guttatus	224	Myosotis scorpioides	344
Cladophora glomerata	214	Ranunculus fluitans x ? (SA)	334
Stigeoclonium tenue	213	Cladophora glomerata	317
Myriophyllum alterniflorum (SA)	208	Heribaudiella fluviatilis	299
Cinclidotus fontinaloides	201	Stigeoclonium tenue	286
Caltha palustris	190	Mimulus guttatus	274
Juncus acutiflorus	189	Eleocharis palustris	262
Brachythecium rutabulum	189	Brachythecium rutabulum	224
Eleocharis palustris	185	Conocephalum conicum	224

(SB) = submerged bryophyte (SA) = submerged angiosperm

Table 6.5a R. Tweed - comparative tables of species importance based upon two techniques. (a) presence alone (b) subjective abundance.

(a)		(b)	
Eurhynchium riparioides (SB)	124	Eurhynchium riparioides (SB)	380
Fontinalis antipyretica (SB)	118	Ranunculus penicillatus var. calcareus (SA	242
Mimulus guttatus	108	Fontinalis antipyretica (SB)	228
Gongrosira incrustans	103	Myriophyllum spicatum (SA)	202
Myosotis scorpioides	97	Gongrosira incrustans	189
Phalaris arundinacea	93	Cladophora glomerata	180
Hygroamblystegium fluviatile (SB)	88	Zannichellia palustris (SA)	165
Dichodontium pellucidum	85	Elodea canadensis (SA)	154
Heribaudiella fluviatilis	83	Hildenbrandia rivularis	154
Cladophora glomerata	80	Mimulus guttatus	142
Hildenbrandia rivularis	80	Potamogeton crispus (SA)	131
Conocephalum conicum	78	Cinclidotus fontinaloides	129
submerged Verrucaria spp.	77	Hygroamblystegium fluviatile (SB)	125
Filipendula ulmaria	77	Hygrohypnum luridum (SB)	125
Myriophyllum spicatum (SA)	72	Phalaris arundinacea	124
Oedogonium spp.	72	Grimmia alpicola	119
Elodea canadensis (SA)	72	submerged Verrucaria spp.	116
Potamogeton crispus (SA)	70	Myosotis scorpioides	116
Glyceria fluitans	69	Oedogonium spp.	112
Juncus acutiflorus	68	Heribaudiella fluviatilis	108

(SB) = submerged bryophyte (SA) = submerged angiosperm

Table 6.5b R. Teviot - comparative tables of species importance based upon two techniques. (a) presence alone (b) subjective abundance.

its abundance total was 20. In the Jed (p. 187), both *Cladophora glomerata* and *Juncus acutiflorus* were recorded in all lengths surveyed. The former was, however, very abundant, as indicated by the abundance total of 28, while the latter was rare, with a total abundance of only 10. As a final example, in the Eden (p. 188) both encrusting algae, *Hildenbrandia rivularis* and *Heribaudiella fluviatilis* were recorded in all lengths surveyed. The abundance totals, however, were 16 : 5.

Tables 6.5a and b are useful to show that a recording system based on presence alone can furnish results that differ widely from one that takes into consideration abundance values. In the examples given for tributaries, if records were based solely on presence or absence, no difference in the comparative abundances of the pairs of species given above could have been detected. Although the subjective judgement of the abundance of a species in each particular length surveyed is open to greater error, the additional information provides valuable knowledge about individual species, and also the general flora of each river.

In 6.41 and 6.42 (pp 200-222) the distribution of species according to presence or absence has been plotted, abundance values being ignored. Further descriptions consider both the presence or absence, as well as the abundance values of each macrophyte. In 8.62 and 8.63a (pp 399-404) the number of submerged algal, lichen, bryophyte and angiosperm species recorded in 10 km stretches of river, and their relative abundance values are compared

7. SUMMARY OF THE DISTRIBUTION OF INDIVIDUAL MACROPHYTES

7.1 Introduction

The distribution of every macrophyte found in the Tweed or in any of its tribitaries are summarized here. In the previous chapter, the primary data were tabulated or plotted in taxonomic order, and the linear order of 0.5 km lengths surveyed in the rivers. This chapter summarizes the distribution of each species in relation to its ecology. Special reference is made to physical characteristics and other features of each river described in Chapter 3, and water chemistry given in Chapter 5. Altitude, flow rate, geology, historical influences, substrate, water chemistry, water depth, as well as the influence of tributaries and their inocula are the main influencing factors discussed. Growth habit and any morphological seasonal differences of species found in the same community are often related to one another. Occasional mention is made of species sited in tributaries within the catchment area that have not been systematically surveyed. Such observations were usually made while collecting water samples for chemical analysis.

Since so many macrophyte species were recorded, for convenience, reference to the literature specifically concerning individual species has been included here, instead of leaving until the final discussion. Reference is also made to all old records and herbarium specimens that give some idea of the distribution of each species in the river basin during the past 200 years. This has been done so that all data concerning a single species are included together. For a few representative species, a summary and more critical comparison with the literature is given in the final discussion (Chapter 9).

Each species is described in the order given in Chapter 4 using the following format:

(i) Vice-county distribution, given in numerical order.

(ii) Problems in field recognition of species, and taxonomic problems and morphological variation within designated categories.

(iii) Distribution in the Tweed. The distribution is initially summarized by giving the total number of times a species was recorded in each 10 km stretch of the river. The abundance totals for each stretch are also given, and the total for the whole of the river given in parentheses at the end. Values from left to right are for 10 km stretches from km 0.0 downstream to km 149.5.

(iv) Distribution in the Teviot, in the same format as above, except figures from left to right read from km -0.0 upstream to km -61.5.

(v) Distribution in the tributaries only partially surveyed, and where relevant, a discussion of the overall distribution in the Tweed River System. References to literature in this section are confined to works that specifically describe plant distribution in the Tweed Basin, e.g. Johnston (1853).

(vi) Comparison with data from other rivers, particularly those in the North East of England (N-E.), and published works which have either conflicting or complimentary findings.

Where relevant to the discussion, occasional reference is made to the the mean altitude at which some species occurred in the Tweed, and also the means of some water chemistry paramters. Data are tabulated for all the species recorded from the Tweed in 9.7a (p. 464).

7.2 Descriptive accounts

7.21 Algae

Chamaesiphon spp. (obvious) (S)

(i) 78,79,80,81.

(ii) With experience, certain brown flecks on rock surfaces could, with confidence, be referable to Chamaesiphon. Subsequent microscopic examination usually showed that such flecks if in permanently submerged positions were C. fuscus, while ones which could occur above the water level during very low flow were C. polonicus.

(iii) No macroscopically obvious Chamaesiphon flecks were present at time of survey.

(iv) *,*,*,3/3,12/20,14/19,4/5.(33/47)

Macroscopically obvious growths were confined to the river above Hawick, where on rounded stones at the edge of the river, C. polonicus was recorded frequently, although never common. The tips of these stones which have their upper parts exposed during very low flows only, were most colonized.

(v) Common and often very abundant in Lyne, Yarrow, Ettrick and upper Whiteadder, but absent in other tributaries. C. fuscus was most obvious in fast flowing stretches and rapids, where it colonized rock sheets, boulders and flat stones. It was abundant in the Yarrow (where it was associated with Rhodoplax schinzii) and in the Whiteadder. C. polonicus on the other hand reached its maximum abundance in the slower stretches of the Ettrick where most frequently round stones were colonized. At times of average flow, many stones in the middle of the river indicated by their two tone colour, the level to which the river may drop to during periods of low flow. The permanently submerged parts of such stones were dark green due to Chaetophora sp., while the upper, only occasionally exposed part a contrasting brown, due to C. polonicus.

Nostoc parmelioides (S) (see Fig. 7.3a)

(i) 78,79,80.

(ii) Identified in the field by the smooth surfaced, discoid shape of the thalli, which in the Tweed never exceeded 15 mm, but Geitler (1932) reported them to grow as large as 30 mm in diameter. Like material described from Coloradoby Todd(1971)the average diameter of the thalliwere 10 mm. N. parmelioides macroscopically resembles N. verrucosum, however the latter is usually larger (up to 100 mm) and with a rougher surface. Short barrel shaped cells are the characteristic features of both species, heterocyst and spores are also similar in shape and size. The trichomes of N. parmelioides are however usually slightly larger than in N. verrucosum, the former 4-4.5 μm and the latter 3-3.5 μm in diameter.

Johannsen (1937) was the first to report that their was a mutualistic relationship between N. parmelioides and a midge larvae - Cricotopus. Brock (1960) describes in detail the morphology and life history of the species. Todd (1971) confirmed the findings of Brock, that the emergence of the Cricotopus larvae in early summer causes the disintergration of the thallus.

(iii) *,*,*,*,1/2,4/4,10/12,11/16,7/7,10/17,9/17,5/8,6/7,2/2,*.(62/81)

N. parmelioides was present in only one 0.5 km length in the upper one third of the river, frequently recorded in mid-river, but became increasingly less common below Teviot Foot. In the more upstream localities where Silurian rocks were the substratum,the species was found only in very fast flowing stretches upon large sheet like boulders. However, on the sandstone and Cement-stone substrata lower downstream it occurred in much slower stretches, either on rock surfaces resembling pavements, or upon smaller stones. This species was most commonly associated with Cladophora aegagropila, both species frequently occurring on the same rock surfaces.

(iv) 1/2,1/1,1/1,*,*,*,*.(3/4)

Rare, present in only three localities in the lower half of the river upon similar sandstone habitats as described for the Tweed.

(v) Confined to the softest waters surveyed, the Yarrow and Ettrick. On the silurian rocks of the Ettrick Water above the Yarrow, N. parmelioides was recorded in seven out of eight 0.5 km lengths surveyed, associated with Collema fluviatile.

Thalli in the Tweed were macroscopically obvious throughout the year, being most conspicuous in summer, but less so in winter. The destruction of thallus shape by emergence of the Cricotopus larvae was not observed, and throughout the year larvae were present within the thalli.

(vi) Not reported from any other sites in the British Isles. In mainland Europe, N. parmelioides has been recorded several times from mountain streams, the first record being from the Thuringian Forest, Germany by Kützing in 1843 (Todd 1971). In the United States, the species has been recorded from many States, the first report being from California by Drouet (1943). Since that date it has been reported from the Firehole River (Jones, 1967), nine mountain streams in Colorado, and the Upper Rio Grande River (Todd, 1971).

Nostoc sp. 'A' (S) (see Fig. 7.3a)

(i) 79,81.

(ii) This macrophyte was usually very inconspicuous. It formed very flat, almost circular yellow-brown colonies that blended in with the colour of the rock surfaces they colonized. Individual thalli were small and never exceeded 2.5 mm in diameter. Trichome width of 4.0 µm, heterocyst width of 5.0 to 6.0 µm, and gross morphology, agreed with the description of N. rivulare given by Geitler (1932).

(iii) Absent.

(iv) Absent.

(v) Confined to the Yarrow, Ettrick and upper Whiteadder. Only in the Ettrick above its confluence with the Yarrow was the species common. Here it was the ninth most abundant macrophyte. N. rivulare was confined to smooth rock surfaces in slow to moderate currents. It was often present in the same reaches as Nostoc parmelioides and Collema fluviatile, but they were rarely in close association since the latter two species preferred rough surfaces in fast flowing water. It most commonly occurred overlying growths of Chamaesiphon polonicus.

Nostoc, other sp. (S)

(i) 78,79,80.

(ii) All specimens had the characters of young N. commune, but few showed features pertaining to mature plants of that species. Thalli were gelatinous, globose and less firm that those of N. parmelioides. Trichome widths were always within the N. commune range of 4.5 - 6 µm. No flattened thalli were found. Perhaps plants remained in spherical, characteristically juvenile state because they were in flowing water.

(iii) *,1/1,*,1/1,4/5,2/2,1/1,3/3,1/1,*,2/2,*,*,*,*.(15/16)

This Nostoc was usually found loosely attached to rock surfaces of all sizes in moderately flowing water. At three sites however enlarged less firm, and flattened specimens were found floating in calm water alcoves at the side of the river away from the main current. Such specimens had obviously been washed down from more upstream sites and served to indicate that attachment to substrates was only very tennuous. In 1972 and 1973 it was noticed that colonies were present only during periods of low flow either in spring, summer or autumn. After a flood no macroscopic trace was left of them.

(iv) Absent.

(v) Absent.

(vi) Geitler (1932) and Desikachary (1959) describe N. commune as most common on moist soil and rocks in standing waters.

Phormidium spp. (obvious) (S)

(i) 68,77,78,79,80,81.

(ii) Any obvious gelatinous or leathery blue-green-algal films that could be easily scraped from their substratum were included under this category. Many such films when examined microscopically showed P. autumnale and P. subfuscum to be the dominant species.

(iii) 13/13,5/5,7/8,6/7,11/12,9/14,16/23,10/14,7/8,3/4,3/3,1/1,6/6, 4/4, 4/4.(105/127)

Present down the whole length of the river, but more common in the upper half. Obvious Phormidium mats were restricted almost exclusively to rock surfaces, being most common on the round smooth protruding lip of rocks subject to the most rapid currents in fast flowing stretches. However on sheet like surfaces in rapids in the upper stretches it was absent. Rarely, Phormidium mats were found upon mud and fine sand at the rivers edge, or floating upon the surface of the water in calm stretches.

(iv) 3/4,1/1,6/10,3/4,15/25,20/32,2/3.(50/79)

More common in the upper Teviot than the Tweed, the loose rounded stones being more favourable for transient growths of Phormidium rather than the more permanent colonization by mosses. The great reduction in obvious Phormidium growths further downstream was probably due to lack of favourable habitats.

(v) Present in all tributaries except the Jed and Eden. In the Biggar, the lower Ettrick below Selkirk Sewage Works, the Leet and parts of the

Whiteadder, macroscopic growths of Phormidium were found not only on rocks, but also smothering submerged higher plants in particularly slow stretches.

(vi) Phormidium spp. were also recorded as abundant in the N. Tyne and Tyne by Holmes et al., who reported that only in slow flowing stretches did it smother higher plants. In the Tyne, P. autumnale was the most abundant species, as it was in the Tweed. Fritsch (1929) also reported that that species, and P. retzii (Ag.) Gom. were the most frequent species in streams in N. Devon.

Rivularia biasolettiana (S)

(i) 80,81.

(ii) Colony size was almost always between 2.0 and 4.0 mm, and macroscopic features similar to that described by Geitler (1932).

(iii) Absent.

(iv) Present only in km -8.5. It was present above the general level of the river on a vertical wall that was colonized by species characteristic of calcareous flushes, e.g. Cratoneuron commutatum var. commutatum and Ctenidium molluscum.

(v) Present at a single sight on the Whiteadder (km -30.5). Here it grew on limestone rocks submerged by the main stream of the river.

Tolypothrix penicillata (S)

(i) 68,78,79.

(ii) Identified in the field by the conspicuous brown colouration that likens the growths to Rhodochorton and other red algal chantransia.

Microscopic examination clearly showed the characteristic false branching of Tolypothrix species. Separation of T. distorta and T. pencillata is difficult, the latter however more commonly forms brown coloured macrophytic growths (Kann, 1973, personal communication).

(iii) At time of survey, macroscopically obvious only in three 0.5 km lengths; km 8.5, 13.0 and 16.0. Subsequent observations showed that the species became obvious every year in a few localities, but only during periods of low flow in June, July and August.

(iv) Absent.

(v) Present in Lyne, Yarrow, upper Ettrick and upper Whiteadder. Again only rock sheets and large boulders in fast stretches were colonized. Obvious growths were confined to upland, clear and relatively soft non-polluted waters.

Hildenbrandia rivularis (S) (see Fig. 7.3a)

(i) 68,78,79,80,81.

(iii) *,4/4,12/15,19/29,20/34,19/39,20/36,20/27,20/36,19/35,19/34, 20/39,17/22,11/16.(237/393)

Common, but absent in the most upstream stretches and rarer in the most downstream localities. The obvious dark red crusts were present on either rock sheets, boulders or small stones and most common in fast flowing stretches. During exceptionally low flows in the two years preceeding the survey several deep and excessively swift stretches were looked at. Many had flat stones that were completely covered by Hildenbrandia rendering several square metres a bright red colour. Other species were completely absent, including the very common Verrucaria spp. and Eurhynchium riparioides. Those stretches which were impossible to wade except during minimal flows, were the habitats where Hildenbrandia thrived most.

This species showed tolerance, and even preference, for intense shading. It was often found at the edge of the river under the willow or alder canopy, and even found on the undersides of very large boulders. Many smaller stones that are intermittently turned over by the current, were colonized on both sides.

The reduced abundance of *Hildenbrandia* in the lower stretches is correlated with fewer rock surfaces and the increase in deep, slower reaches, with muddy substrata. Its absence in the more upstream localities could be an interaction of several factors, including lack of nutrients, intolerance of desiccation during summer droughts, or even the possibility that intense light passing through very shallow water is inhibitory to its growth.

(iv) 18/50,17/32,16/26,20/35,7/9,2/2,*.(80/154)

Present in similar habitats as described for the Tweed. In the lowest 10 km, *Hildenbrandia* was frequently completely smothered by *Eurhynchium riparioides*.

(v) Present and usually common in all tributaries, except the Biggar and middle reaches of the Till. Both tributaries flow over alluvium, where stones are rare.

(vi) *Hildenbrandia* also occurs in rivers in close proximity to the Tweed. It was reported from the N. Tyne and Tyne by Holmes *et al*. (1972) where it was less abundant than in the Tweed. The present author has also found *Hildenbrandia* in the Wear and Tees, however, in the former river it was not reported to be present by Whitton and Buckmaster (1970). The probable recent invasion of this species into the river indicates its ability to grow quite rapidly in suitable habitats. In all rivers in the N-E. where it was present, *Hildenbrandia* was most frequent in well shaded localities which had rapid currents.

The reported abundance in, or even preference for shaded areas of the Tweed and other rivers in N-E. England supports the findings of Fritsch (1929) in England, and Lingelsheim and Schroder (1918), Skuja (1926), Zimmermann (1927) and Oberdorfer (1928) in mainland Europe.

They all reported the abundance of Hildenbrandia in localities with low light intensity, the latter two authors reporting the presence of the species at depths of up to 30 m in Lake Bodensee. Fritsch (1929) reported that Hildenbrandia was absent from stretches with rapid flows, but Allorge (1925), reported that the species was confined to siliceous torrents in the French Alps. The findings of the latter author were confirmed in the Tweed.

Lemanea fluviatilis (S)

(i) 68,78,79,80,81.

(ii) A very variable species which is difficult to separate from L. mamillosa. Israelsson (1942) described it as usually very sparsely branched, the length of branches being anything from 0.05 to 0.3 m in length.

(iii) 9/9,6/7,8/10,7/8,5/5,4/4,7/7,5/6,2/2,4/4,1/2,*,*,*,*.(58/63)

As the season of survey was the one when this alga is least evident, data of its abundance were a marked underestimate, although the distribution pattern is probably representative. Lemanea was by no means confined to the upper stretches, but grew in any fast flowing stretches which had boulders. The rock surfaces most commonly colonized were those that projected above the general level of the substratum and were thus subjected to fierce currents. Often large areas of the rock surfaces were colonized with filaments as long as 0.3 m. During periods of very low flow several boulders with Lemanea on their surfaces were exposed, resulting in the death of the alga.

(iv) 6/7,*,1/2,6/7,9/14,2/2,1/1.(25/33)

A disjointed pattern of distribution was caused by lack of favourable habitats in many reaches. The species was rarest in the upper stretches, probably due to the unstable nature of the river bed.

(v) Present in all tributaries. Lemanea was always rare in the slower muddier rivers, i.e. Biggar, mid-Till and Blackadder and most common in those tributaries which are characteristically rocky and fast flowing, i.e. Lyne, Yarrow and Ettrick. The species was tolerant of a very wide range of chemistries; of particular interest was its presence in the hard, and nutrient rich Leet. In April and May Lemanea was common on rock surfaces in not particularly swift flowing water and frequently smothered by epiphytic growths of Gongrosira incrustans. Later in the season the same stretches become dominated by Cladophora glomerata and Enteromorpha flexuosa.

(vi) Occasional in the N. Tyne and Tyne, but described by Whitton and Buckmaster (1970) as the most abundant macrophyte in the upper stretches of the Wear. Sirjola (1969), reported L. fluviatilis to be the species with the greatest tolerance, and preference for the fiercest currents in the Teuronjoki, Finland. This agrees with its behaviour in the Tweed Basin.

Botrydium granulatum (B)

(i) 68,80,81.

(iii) *,*,*,*,*,*,*,*,*,*,*,4/4,4/4,2/2,*.(10/10)

Present only on the banks of the river below Teviot Foot. This dark, dull green, balloon-like alga grew on mud exposed during low flows only. When the river rose, the tiny (less than 2.0 mm in diameter) vesicles were damaged and collapsed. As the river level recedes and the mud begins to dry out, new plants develop from the underground rhizoides and resting spores. In the tidal area no mud was colonized since diurnal changes in water level occur with no long periods of low water.

(iv) Absent.

(v) Present in similar localities as described above on the banks of the Eden, Leet and Blackadder. Botrydium as a bankside species was confined to lowland areas with an altitude mean of only 20 m in the Tweed. This species was rarely evident during winter.

(vi) Not commonly recorded from rivers, although frequently present on muddy banks in their lowest reaches, as in the Tyne, Wear and Tees. Szemes (1967) reported its presence in the lower reaches of the Danube, including the Delta region, where it was common.

Vaucheria spp. (S)

(i) 68,77,78,79,80,81.

(ii) Submerged material taken from the Tweed, Leet and Till showed considerable variation in growth form and filament width, and no plants were found in fruit. However, when material was left in the laboratory on damp soil in petri dishes, fruits frequently developed. Filament width and fruiting bodies suggested that most material was V. sessilis.

(iii) 1/1,4/4,*,3/3,12/13,4/4,1/1,6/7,8/9,11/12,14/19,3/3,6/6,8/8,10/14. (91/104)

Although present throughout the river, this species became more abundant in the lower stretches. The two years following the main survey showed that this alga was least evident in mid and late summer, the peak of its development always occurring in April and May. After this period, large mats could be observed tenuously attached to boulders or floating away downstream. The presence/abundance ratio indicates that in late summer, wherever Vaucheria was present in the Tweed, it was invariably rather rare. Of all macrophytes recorded, Vaucheria probably had the widest range of habitats. Plants were found on rocks, sand or mud in fast or slow flowing water and either above the water level or permanently submerged. Only the fiercest rapids were not colonized.

(iv) 2/2,1/1,10/16,6/9,1/1,2/2,*.(22/31)

Less common than in the Tweed, although in spring the species was also much more common than in summer or autumn.

(v) Absent in the Yarrow, upper Ettrick and Jed, and rare in the Blackadder and Whiteadder. In the Biggar, Ettrick below Selkirk sewage works, Leet and the lower half of the Till, Vaucheria often carpeted the river from one bank to the other, growing on unstable soft sand or mud.

(vi) Occasional in N. Tyne and Tyne, and common in the lower two-thirds of the Wear. Both Whitton and Buckmaster (1970) for the Wear, and Backhaus (1967) for the Danube reported autumnal, rather than the spring maxima found in the Tweed Basin.

Melosira varians (obvious) (S)

(i) 80.

(iii) Absent.

(iv) 11/25,11/24,5/10,4/6,8/12,*,*.(39/77)

Only in the Teviot during July, August and early September did Melosira grow in such quantities that it was macroscopically identifiable. In the year of survey (1972), and the following year, the species was often locally very abundant, although absent in the upper 15 km. Most commonly in slow stretches, Melosira shrouded higher plants in a light brown veil that often trailed a little way downstream. In near stagnant water at the edge of the river, free floating material was common. Water with significant amounts of Melosira gave off a most characteristic, musky odour.

(vi) The micro-algae survey showed Melosira to be present in the Tweed, and most of its other tributaries. This was also true for the Tyne, Wear and Tees. However in none of these rivers did it grow as a macroscopic growth. Melosira was described by Szemes (1967) as widespread in all areas of the Danube.

Diatoma spp. (obvious)

(i) 79.

(ii) The species were usually D. hiemale, or D. vulgare, but more commonly both.

(iii) Although commonly recorded in samples collected for microscopic examination, Diatoma was never macroscopically abundant.

(iv) As above.

(v) Only in the Yarrow did Diatoma grow in sufficiently large quantities to be macroscopically very obvious. At the time of survey, most Ulothrix zonata mats in medium paced stretches showed no sign of green colouratio- but were dark brown. Microscopic examination showed the Ulothrix to still be perfectly healthy and green, but completely smothered by Diatoma. This phenomena was common in all 0.5 km lengths surveyed in the Yarrow, but never so obvious in any other tributaries.

Didymosphenia geminata (S) (see Fig. 7.3a)

(i) 78,79,81.

(iii) 16/24,20/46,10/21,*,*,*,*,*,*,*,*,*,*,*,*,*,*.(46/101)

This large diatom was only macroscopically visible in the upper 25 km. Individual cells were almost certainly present in nearly all downstream 0.5 km lengths due to washout, but this species was only macroscopically visible when very abundant. Mats of Didymosphenia resembling light brown sheeps wool, were confined to fast flowing stretches where whole stones were frequently completely carpeted.

(iv) Absent.

(v) Present in the Lyne and Yarrow, and also the upper stretches of the Ettrick and Whiteadder. In the Yarrow the species was particularly common, and usually recorded in all 0.5 km lengths as abundant. In the

Tweed and other tributaries, Didymosphenia was most common in spring and autumn being in little evidence during mid summer. However in the Yarrow the species remained common throughout the year. Growths of Didymosphenia carpet the edge of St. Mary's Loch throughout the year. Since this loch is at the head of the Yarrow it must impart to the river a constant inoculum.

Didymosphenia was confined to rock surfaces in fast flowing high altitude soft waters, which are particularly poor in PO_4-P. In fast flowing stretches in more downstream localities the species was absent. The Tweed means for most elements are the lowest recorded for any species and where the species occurs, most anions are below the detection limit. These facts perhaps illustrate that Didymosphenia shows an inability to thrive in anything but the most nutrient poor waters.

(vi) Although not reported in the literature, Didymosphenia is frequent in the upper reaches of other rivers in N-E. England.

Heribaudiella fluviatilis (S) (see Fig. 7.3a)

(i) 68,78,79,80,81.

(ii) This is an encrusting species that is often inconspicuous. The small, irregular, and yellow-brown thalli often blend in with the colour of the stones and are overlooked or mistaken for the thalli of submerged Verrucaria species.

(iii) 10/10,12/12,15/15,17/20,19/25,17/19,20/26,17/21,17/20,16/20,14/17, 15/22,13/19,14/25,12/28. (228/299)

Distributed down the whole length of the river, being least common in the more upstream stretches. This alga was confined to rock surfaces permanently submerged in fast, medium or slow flowing water. Like Hildenbrandia rivularis, Heribaudiella showed great tolerance of heavy shading, often being recorded from the undersides of stones, and in more downstream localities on rock surfaces that carry a thick layer of mud throughout the year. On pebbles in the shallower, fast flowing stretches of the freshwater tidal area, Heribaudiella was particularly common.

(vi) 13/21,14/16,19/21,20/32,13/14,4/4,*.(83/108)

Less common in the upper stretches, but as common in mid and lower Teviot as in the Tweed.

(v) Present in all tributaries, usually more common than Hildenbrandia in upstream localities, but less common in downstream areas.

(vi) Fritsch (1929), described this species from fast flowing streams in Devonshire. At this date, it was under the name of Lithoderma, and his record was the first for a freshwater Phaeophyta in Britain. Since that date, no additional Heribaudiella records have been made, although it is common in the northern English rivers, Coquet, Aln, Eden and Tees. The author has also recorded the species from the Thames at Marlow, and Lakes Coniston and Windermere.

Chaetophora sp. (S)

(i) 78,79,81.

(ii) Hemispherical, quite tough thalli with microscopic features most akin to C. pisiformis, as described by Printz (1964).

(iii) At the time of the main survey no macrophytic growths were obvious. However in the two following summers, minute amounts did occur in several localities in the upper 20 km only.

(iv) Absent.

(v) Common and locally very abundant in the Yarrow, and upper stretches of the Ettrick and Whiteadder. In the Lyne, obvious Chaetophora growths were confined to within a 5.0 m radius of where two streams enter the river. *Chaetophora* was confined to the same tributaries as *Didymosphaenia geminata*.

(vi) West and Fritsch (1927) described *C. pisiformis* as the most abundant British species, and also added that "it favours flowing water".

Cladophora glomerata (S)

(i) 68,77,78,79,80,81.

(ii) Specimens showed the full range of variations described by van den Hoek. (1963).

(iii) *,1/1,6/7,17/22,16/20,17/23,15/16,18/23,14/17,17/23,15/27,20/34, 20/36,19/22,19/46.(214/317)

In the upper 25 km *Cladophora* was present at only one site - Tweedsmuir water falls (km 10.5). This was 15 km above any other records. At km 25.0 the Biggar enters the Tweed causing an increase in the levels of nitrate and phosphate (see p. 121). From this point downstream, *Cladophora* colonized more than 75% of the 0.5 km lengths of the river. In rapids and fast flowing water, plants were generally of a bushy very branched nature. In more downstream stretches thick wiry filaments often exceeding 5.0 m in length and with few branches were the more dominant form. *C. glomerata* extended well into the brackish tidal water where many filaments were characteristically a silver colour.

(iv) 19/20,19/43,20/52,16/42,6/13,*,*.(80/180)

Again absent in the upper stretches, but more common in the lower stretches than in the Tweed.

(v) Common, the only tributary where the species was not present was the Yarrow. In the lowland tributaries *Cladophora* was recorded in all but four of the 0.5 km lengths surveyed, being exceptionally common in the most nutrient rich waters of the Jed and Leet. In the middle reaches of the Till which flow over alluvium and peat, Cladophora was still present. In many stretches peat mounds that mimicked boulders were devoid of encrusting algae such as Hildenbrandia rivularis and Heribaudiella fluviatilis, but Cladophora was common.

(vi) C. glomerata is the most frequent Cladophora species in Britain (see van den Hoek, 1964); and Blüm(1956) suggests that it is the most abundant alga in streams throughout the world. It frequently causes serious problems in rivers throughout Britain - Pitcairn and Hawkes (1973) Whitton (1971, 1974) and Bolas and Lund (1974). In the Wear, Whitton and Buckmaster (1970) described it as the most common macrophyte. The near absence in the upper reaches of the river, was attributed by the authors to be due to low nitrate and phosphate levels. Butcher et al.(1937) also closely related the growth of Cladophora with sewage effluents,

Cladophora sp. 'A' (S)

(i) 68,78,79,80,81.

(ii) Cladophora sp. 'A' = C. aegagropila. The dense branched thalli never exceed ed 30 mm in length. The extensive branching of the filaments, and the thick walls of the cells give plants a tight knit stiff texture. (In lakes only, characteristic balls are often formed). Material was checked by van den Hoek,1974.

(iii) *,*,*,1/1,2/2,1/1,4/4,5/5,14/16,12/17,10/14,9/14,3/4,3/4.*.(64/82)

Like Nostoc parmelioides, (a species in frequent association) C. aegagropila was most common in mid-river and absent in the upper stretches. In the more upstream sites where the species occurred, it was confined to cracks in silurian rocks and boulders in fast flowing water. Smooth unmarked surfaces were never colonized. On the Old Red Sandstone, which has a much rougher surface however, plants were present on rock faces that were not scratched or cracked. Unlike *C. glomerata*, *C. aegagropila* remained obvious throughout the year, the size and shape in winter being almost the same as during the summer months.

(iv) Absent.

(v) Present only in a few localities in the lower Till. With such a wide distribution on a variety of substrata in the Tweed, the species might have been expected to occur in more tributaries.

(vi) *C. aegagropila* has previously been recorded (data from van den Hoek, 1963) only in a few lake localities from Britain, the Tweed being the first river in which it has been found. The species has however been recorded in France from the R. Seine at Paris, and also the R. Moine. In Switzerland, Finland and France, it has also been recorded from small rivers and rivulets. It is possible that *C. aegagropila* has often been overlooked in other rivers in Britain, and it is suggested that it will more than likely be recorded from some of these in the future.

Enteromorpha spp. (S)

(i) 68,80,81.

(ii) In the Tweed, Teviot, Jed, Eden, Leet and Whiteadder all freshwater material was clearly *E. flexuosa*. In the Blackadder however, not only *E. flexosa* was present, but also another unknown form. It had the characters of *E. prolifera* and *E. flexuosa*, but cells had more than five pyrenoids, a character leading to *E. crinita*, but the tubes were not branched. No branching material was found subsequently, resulting in the original specimen remaining unnamed. In the brackish reaches of the Tweed E. intestinalis, E. prolifera and E. torta were also present.

(iii) *,*,*,*,*,*,*,*,*,*,4/10,12/22,13/27,13/27,20/50.(62/136)

Enteromorpha was absent in the Tweed above Teviot Foot. At this point and for about 200 m downstream, the left bank was clear, but Enteromorpha was so common as to cause a continuous green belt approximately 10 m wide on the right bank. Below, a deep pool followed by a weir, results in complete mixing of the two waters and the consequent presence of Enteromorpha on both banks of the river. In the Tweed, Enteromorpha was most commonly found floating in slow stretches held by Potamogeton spp. Only rarely were attached forms found, and these were in soft mud. This would suggest that most material was washed down from the Teviot, and very little if any in situ development occurs (see Fig. 7.3b).

In the tidal, brackish section of the river, E. intestinalis formed massive tubes that were predominately attached to rocky substrates. These were obviously formed in situ.

(iv) 20/47,19/43,2/4,*,*,*,*.(41/94)

Much more common than in the Tweed. Smaller tubes attached to stones and mud were common, indicative of in situ production of new young material.

(v) Absent in all upland tributaries, but present in great abundance in the Eden, Leet, Blackadder and Whiteadder. In the lower Till, Enteromorpha was present but never common. Its absence in the Jed at the time of survey was surprising, for in may, 1974 it was frequent. In all tributaries where present, attached, thin young tubes were common. This, however, was not so for the Tweed. The extent to which the distribution of Enteromorpha in the main river is influenced by tributaries is difficult to evaluate. It does not occur in the river above

Teviot Foot, and the earliest growths in the Tweed normally develop shortly after those in the Teviot. It is therefore difficult to asses whether the species would occur in the river in the absence of inocula from tributaries.

(vi) In freshwater, Enteromorpha sp(p). were absent from the N. Tyne and Tyne, but present in the Wear. As with the Tweed, freshwater material was E. flexuosa and tidal plants predominately E. intestinalis. Whitton and Dalpra (1968) reported a probable recent invasion of Enteromorpha into the Tees. Rich (1925) reported the presence of E. intestinalis in canals in Leicestershire, but the accuracy of his taxonomy is not known.

Gongrosira incrustans (S)

(i) 80,81.

(iii) Absent.

(iv) 19/36,17/33,20/35,19/33,15/33,13/19,*.(103/189)

Present in all but the upper reaches on rock surfaces, and in late summer epiphytic on Eurhynchium riparioides, Myriophyllum spicatum, Potamogeton pectinatus and P. x salicifolius. The small, hard, light green colonies also often grew directly upon flatter encrusting alga such as Hildenbrandia rivularis. During April to October when most macroscopic growth was obvious, if stones were put into the river they were frequently covered by this alga within three weeks.

(v) Present only in the Eden, Leet and Blackadder, and the Whiteadder below Blackadder Foot. In the Leet, even filamentous algae were colonized, including ageing Lemanea fluviatilis and young Enteromorpha.

(vi) G. incrustans was restricted to hard or very hard water tributaries of the Tweed. On non-calcareous surfaces most colonies were still hard, usually distinct, and characteristically a spherical shape . In the highly calcareous chalk streams of southern England where the species is very abundant, the spherical colony shape is usually lost, being deeply incorporated into the chalk substratum (A. Marker, personal communication).

Haematococcus lacustris (B)

(i) 78,79,80,81.

(iii) 8/8,4/4,2/2,1/1,*,1/1,*,*,*,1/1,*,*,*,*,*.(17/17)

This species was commonly recorded in the upper 10 km, but gradually decreased in abundance, with only two sites colonized in the bottom two thirds of the river. The only microhabitats where Haematococcus occurred was in rock surfaces that retained either rain water or flood water. These were usually tainted red when damp, but when dried out, the combination of the algae pigment and the thin film of mud often produced a very dull pink colour.

(iv) *,*,*,1/1,1/1,4/5,3/3.(9/10)

Like the Tweed, restricted to the upper reaches.

(v) Present in a total of only six 0.5 km lengths scattered in the Lyne, upper Ettrick and upper Whiteadder. As would be predicted, Haematococcus was absent in lowland tributaries which have no large boulders at their edges.

Monostroma bullosum

(i) 68,79,80,81.

(ii) Material was as described by Printz (1964) and Bliding (1968). The species main macrophytic characteristics are its sac like structure anchored to its substratum by a single holdfast.

(iii) *,*,*,*,*,*,*,*,*,*,1/1,2/2,2/2,1/1,*.(6/6)

Very rare, and present only in the lower one third of the river. In the six localities where recorded, Monostroma was found exclusively upon rock surfaces that are subject to splash and periodic submergence.

(iv) 7/9,2/2,*,*,*,*,*.(9/11)

Restricted to the lower stretches of the river where more or less permanently damp rock surfaces were colonized, although plants were rarely permanently submerged. Prasiola crispa was also quite common in the same stretches, but usually separate boulders were colonized. When occurring together, Monostroma was much more common near the water, and Prasiola more common on the drier surfaces.

(v) Present in a total of only eight 0.5 km lengths in the Ettrick, Jed, Eden, Blackadder and Whiteadder. This species was generally present in similar habitats as previously described, but in the Whiteadder, thalli were found on Sparganium stalks and permanently submerged fibrous tree roots. In this latter habitat the balloon nature of the thalli were most obvious.

Oedogonium spp. (S)

(i) 68,78,79,80,81.

(ii) Many different species, often occurring together were responsible for the macroscopically obvious growths. However by far the most frequent species was one with almost square cells approximately 55 μm long. Cell width or length never exceeded 75 μm.

(iii) 20/43,19/24,20/26,20/20,19/28,18/34,4/6,2/2,13/28,18/37,20/50, 20/71,20/55,20/44,16/38.(249/474)

Oedogonium had a most unusual distribution pattern, being very common at both ends of the river, but rare in the middle. This resulted from almost all Oedogonium records in the upper half of the river being attached filaments and almost all the lower half records being for unattached, free-floating filaments. In the middle of the river, few filaments were attached, and because there are few slow stretches there, there were few free-floating ones also.

After periods of high flow during the summer months, tough entangled mats of Oedogonium filaments could be observed either washed up at the edge of the river, or floating downstream. It was these washed down filaments that settled and became entangled among pondweeds in slow deep stretches further downstream. In many such stretches below Teviot Foot, Oedogonium was most abundant, and although washed down, it was quite healthy and capable of growth in its new free floating existence.

(iv) 12/14,16/28,15/23,17/26,12/19,*,*.(72/112)

Less common than in the Tweed and absent in the upper stretches at the time of survey, although present earlier in the year.

(v) Present in all tributaries except the Jed and Blackadder. In the Yarrow and the upper Ettrick and Whiteadder, attached forms were frequent. In the lower stretches of the Whiteadder washed down filaments were held by angiosperms.

(vi) Both attached and free-floating Oedogonium are also frequent in other rivers in the neighbourhood of the Tweed e.g. in the Tyne (Holmes et al.,1972).

Prasiola crispa (B)

(i) 78,79,80,81.

(iii) 8/8,8/8,7/7,4/4,5/5,*,1/1,2/2,2/2,3/3,4/4,*,*,*,*.(44/44)

Relatively common in the upper one third of the river, becoming less common on passing downstream,and totally absent below Teviot Foot. Only rocks and boulders that are submerged infrequently were colonized. These dry surfaces often carry a thin layer of flakey mud, the thalli were always attached to this, rather than directly upon the rock surface. The distributuon pattern, like that of Grimmia alpicola was more or less directly related to the frequency of suitable rock surfaces down the length of the river. Prasiola only very rarely colonized boulders at the edge of the river, and since few if any boulders exist actually in the river below Teviot Foot, the species was absent there. The reasons why boulders in the middle of the river are colonized and not those at the edge is unknown. A possible explanation is that birds common in rivers most frequently take refuge on boulders in mid-stream rather than at the edge, where their droppings produce a very nutrient rich surface. Verrucaria praetermissa on the other hand almost exclusively colonized rock surfaces at the side of the river, and was absent from rock surfaces in mid river (see Fig. 7.3b).

(iv) 10/15,3/3,4/4,5/6,2/2,*,*.(24/30)

The distribution pattern of Prasiola in the Teviot was the converse of its distribution in the Tweed. Only in the lower stretches of the Teviot are to be found large boulders that protrude from the surface of the water. In these reaches, Prasiola was more common than in any other region of the Tweed Basin.

(v) Present in Lyne, Yarrow, Ettrick, Jed, Eden, Blackadder and Whiteadder, but rarely common.

(vi) Common on protruding boulders in other rivers in N-E. England, but not reported in the literature except by Holmes et al.(1972). Szemes (1967) commented on its aerial existence in the upper reaches of the Danube.

Rhodoplax schinzii (S)

(i) 78,79,81.

(ii) This species is described by Jaag (1938) and Bourrelly (1966). Its main features are the crimson macroscopic colouration it gives to the rock surfaces it colonizes, and the red tinted, 10-18 μm diameter elliptical cells.

(iii) Macroscopically absent, although microscopic examination of scrapings from stones taken from the upper stretches of the river occasionally showed the species to be present.

(iv) Absent.

(v) Present only in torrents and very fast stretches of the Lyne, Yarrow, Ettrick and upper Whiteadder. In these stretches, many large stones were blood red colour, entirely due to the presence of this alga. In the Megget Water, a tributary above St. Mary's Loch, Rhodoplax was very abundant, whole rock surfaces in many waterfalls frequently being covered by this alga.

(vi) Rhodoplax is not frequently recorded. In Europe, the most quoted site is that from the Rhine Falls at Schaffhausen, reported by Jaag (1938). There are no other previous records for this alga in Britain.

Stigeoclonium tenue (S)

(i) 68,77,78,79,80,81.

(ii) Stigeoclonium is a very difficult taxonomic group, but all material was close to that described by Cox and Bold (1966). Those authors referred to S. tenue as "the most common, and most polymorphic species of the genus".

(iii) 7/9,19/26,20/24,19/19,20/25,18/19,15/15,11/11,9/10,9/9,15/18,16/37, 14/27,18/34,3/3.(213/286)

Common throughout the whole length of the river. In the upper half, the main substrata colonized were those flat stones that offered least resistance to the flow. This seems surprising since the species only occurred in relatively fast flowing stretches. In the lower half of the river, Stigeoclonium was most commonly found growing epiphytically on the leaves of submerged Ranunculus spp., and rarely upon rock surfaces.

(iv) 1/2,*,*,4/7,*,*,4/6.(9/15)

Rare, and not found epiphytically on Ranunculus spp.

(v) Absent in Yarrow, Jed and Eden, and present, but never common in other tributaries, with the possible exception of the Biggar.

Spirogyra spp. (S)

(i) 68,78,79,80,81.

(ii) Several species.

(iii) 4/4,9/12,8/8,6/6,2/2,4/5,6/6,8/8,3/4,2/2,4/5,*,3/6,8/12.(69/82)

Present throughout the river, but rarely common. In the upper stretches filamentous flocs were often found attached to rock surface in moderately flowing water. In other parts of the Tweed *Spirogyra* was usually found unattached and suspended in the water. Shallow water at the river's edge that is slightly cut off from the main current was the preferred habitat of free floating *Spirogyra*. Such water bodies usually became very warm during sunny summer days. Deep muddy stretches were rarely colonized.

(iv) 8/10,13/23,9/13,11/16,*,*.(50/72)

Attached flocs occurred further downstream than in the Tweed, and free floating filaments were also common in warm water at the edge of the river . In the Teviot, *Spirogyra* was more common than in the Tweed.

(v) Absent in Jed, Eden, Till and Blackadder. The Leet was the only locality in the whole of the Tweed System where *Spirogyra* was common. Attached and free floating filaments were frequent, often completely intertangled with *Cladophora glomerata* and *Enteromorpha flexuosa*.

Tetraspora sp(p).

(i) 68,80,81.

(ii) Almost certainly all *T. gelatinosa*. Most surveys were carried out in late summer when the earlier, more distinct shape had broken up to give way to variable, amorphous green gelatinous masses.

(iii) *,*,*,*,*,*,*,*,*,2/2,6/9,5/5,9/9,8/11,4/4.(34/40)

Present only in the lower stretches where it occurred attached to rocks and more commonly suspended from larger plants. Colonies began to develop on stones in April and May, and by July many had grown so large as to be released and float downstream where they become held by higher plants.

(iv) 16/26,4/4,*,*,*,*,*,*.(20/30)

Only present in the lower stretches where it was more common than in any equivalent length of the Tweed.

(v) Absent in the upland tributaries, but present in all the lowland ones from Jed Water downstream. In certain stretches of the Blackadder and Whiteadder Tetraspora was particularly common.

A Tweed altitude mean of only 20 m, the presence of the species in all tributaries below the Teviot, but its absence in all tributaries above, showed Tetraspora to be restricted to hard water sites of high nitrate and phosphate levels.

(vi) Tetraspora occurred in other rivers in N-E. England, and as in the Tweed Basin, was most frequent in the lower stretches of each river.

Ulothrix zonata (S)

(i) 77,78,79,80,81.

(iii) 10/17,17/27,18/32,19/25,16/23,14/19,11/11,9/9,7/7,4/4,*,*,*,*,*.
(125/174)

Most common in the upper third of the river, and absent in the lower third. Only smooth rock surfaces were colonized, the most healthy looking green filaments usually being present in the faster flowing stretches.

(iv) *,*,*,*,9/18,20/38,*.(29/56)

Confined to the upper stretches of the river where it was more common than in the Tweed.

(v) Present in all the tributaries discharging into the Tweed above Teviot Foot, and absent in all those below, with the exception of the upper Whiteadder. In the Lyne, Yarrow and Ettrick, U. zonata was common at the time of surveying in late summer. In the Tweed and Teviot, Ulothrix was always most common in late spring and early summer, and consequently, surveys in August and September underestimate the species importance at other times of the year.

(vi) Ulothrix also occurs in other rivers in N-E. England, but as in the Tweed, it is only frequent in the upper strtches which are rocky and fast flowing.

Charophyta sp(p). (S)

(i) 78,80,81.

(ii) All material except the single record in the Jed had characteristics of Nitella flexilis as described by Wood and Imahori (1964). The Jed plants were more heavily incrusted and also had solitary spine cells, and were identified as Chara vulgaris.

(iii) A single plant at Tweed Ford (km 21.0) was found on soft sand in the shelter of anoverhanging bank. For three years the plant was observed regularly, but it did not spread or even show much seasonal change.

(iv) *,*,*,2/4,1/1,1/1,*.(4/6)

Present in a few localities above Hawick, where shaded muddy stretches were colonized.

(v) Present in one site in the Jed above Jedburgh and two sites in the Whiteadder above Blackadder Foot.

(vi) Procter (1971) found N. flexilis in the Wheel of the Tees, and Butcher (1933) found C. vulgaris in the Wharfe. Iverson (1929) only found N. flexilis in neutral or alkaline waters, and Ackenheil (1944) and Sirjola (1969) observed that it was capable of growing in either slow or moderate currents. The above indicates that the two members of Charophyta reported from the Tweed Basin also occur in other rivers.

7.22 Lichens

Collema flaccidum (B)

(i) 68,78,79,80,81.

(ii) Easily identified in the field since C. flaccidum characteristically forms perfectly round, soft colonies. The size of colonies varies from 30 mm to 200 mm.

(iii) *,1/1,*,*,1/1,*,1/1,1/1,*,*,1/1,*,*,*,*.(5/5)

Rare, recorded only in five 0.5 km lengths, but spanning 100 km of river. C. flaccidum was confined to vertical surfaces just above the water level and thus exposed during periods of low flow. In the most upstream locality a single plant was found on the mud covered support of Kingledors bridge. In the four other sites boulders were colonized.

(iv) *,2/2,1/1,*,*,*,*.(3/3)

Rare, with only three isolated records in similar habitats.

(v) Present in most tributaries, being absent only in the Biggar and Jed Waters. In all but the Ettrick Water the species was rare. In the more upstream section of the Ettrick, C. flaccidum was present in six out of the eight 0.5 km lengths surveyed. Only here were C. flaccidum and C. fluviatile found growing in close proximity, the former predominately above the water level, the latter permanently below it.

(vi) C. flaccidum also occurs in the N. Tyne (Holmes et al., 1972) in similar habitats. Degelius (1954) reported that this species is widely distributed in the N. Hemisphere, and is the most common non-calcicolous species of the genus.

Collema fluviatile (S) (see Fig. 7.3a)

(i) 68,78,79,80,81.

(ii) Specimens agreed with the description of the only permanently submerged *Collema* spp. in Europe (Degelius, 1954). The thalli are small, rarely exceeding 35 mm, very variable in thickness, and either foliose or rounded. Hyphae and *Nostoc* cells are very densly packed, and the small apothecia and very large pycnidia are characteristic.

(iii) *,*,*,4/10,6/8,7/7,4/9,13/16,7/7,6/8,10/26,13/21,3/4,2/2,*.(75/118)

Similar distribution pattern as *Nostoc parmelioides*, *C. fluviatile* however being slightly more common. The species was restricted to fast flowing stretches where only large immovable rock surfaces were colonized, (cf. *N. parmelioides*, which also colonized smaller stones). Wherever *C. fluviatile* and *N. parmelioides* occurred together, the former was dominant on the surface most exposed to the current, while the latter was common on the more sheltered surfaces. Both species frequently grew over crusts of *Hildenbrandia rivularis* and submerged *Verrucaria* spp.

(iv) 2/3,3/4,1/2,3/4,2/2,*,*.(11/15)

Much rarer than in the Tweed, but present in similar localities.

(v) Present in the Yarrow and upper Ettrick only. In both tributaries *C. fluviatile* was locally very abundant in fast stretches which had raised jaggered rocks in mid stream.

(vi) Absent from rivers in N-E. England. According to Degelius (1954) "*C. fluviatile* is evidently a very rare species". Previous records from the British Isles include the R. Isla in Scotland.

Dermatocarpon fluviatile

(i) 78,79,80,81.

(ii) *,*,3/4,11/11,3/3,4/4,6/7,10/12,5/5,3/3,7/10,3/3,*,*,*.(55/62)

Absent from upper and lower stretches of the river, with a variable abundance in mid-river. *Dermatocarpon* most commonly colonized boulders at the river's edge that carried upon their surfaces a thin film of drying mud. Such mud films are formed during periods of flood. The species thus showed great tolerance to desiccation, but occasionally grew closer to the low water mark.

(iv) *,*,3/3,1/1,*,*,*.(4/4)

Rare, although recorded in similar habitats.

(v) Present in the Yarrow and Ettrick Waters only, where in the latter river it was commonly associated with Collema flaccidum.

(vi) Not recorded from other rivers in N-E. England, but probably present.

Verrucaria praetermissa (B)

(i) 68,78,79,80,81.

(ii) "The very pale thallus distinguishes this species from all other Verrucaria species" (Swincow, 1968).

(iii) 6/6,4/5,5/6,14/14,9/9,14/17,17/18,14/14,13/16,15/18,14/21,3/3, 5/5,3/3,*.(136/155)

V. praetermissa was most common in mid-river, occasional in the upper stretches and rare below Teviot Foot. Plants grew semi-encrusted on rocks and boulders at the water's edge, usually just above the low flow water mark. This lichen would never be permanently submerged, although underwater whenever the river flow was normal or above.

(iv) 4/5,3/3,4/4,8/8,5/22,14/19,3/4.(51/65)

More common in the upper reaches of the Teviot than the Tweed, but becoming less common on passing downstream. As with the Tweed, the reduced abundance in lower Teviot was corrolated with the fewer rocks and boulders found at the edge of the river.

(v) Present in all tributaries except the Jed, Eden and Leet. Although the Blackadder had few stones and boulders protruding out of the water, V. praetermissa was still quite common. Virtually all suitable rocks in this tributary were colonized.

(vi) Swincow (1968) described this species as widespread, but not common. He also added that it has not been reported from limestones. The abundance of this species in the Blackadder would appear to contradict this.

Verrucaria other spp. (S)

(i) 68,77,78,79,80,81.

(ii) The following species were present within the Tweed Basin : *V. aethobiola*, *V. aquatilis*, *V. elaeomelaena*, *V. hydrela* and *V. margacea*. The characteristic and determining features of each are described by Swincow (1968). The distribution of each species has not been mapped.

(iii) 8/8,15/22,17/22,20/29,20/53,20/43,20/54,20/35,19/25,17/36,17/21, 18/32,8/8,9/13,12/14.(240/415)

Submerged *Verrucaria* spp. were most abundant in the middle reaches of the river, where many rock surfaces become completely covered. In the upper stretches obvious colonies were absent in very fast flowing stretches, but rounded stones in slower paced water were lightly colonized. Since *Verrucaria* spp. were present only on rock surfaces, there was an inevitable reduction in abundance in the lower reaches correlated with an increase in continuous muddy stretches.

(iv) 18/30,18/28,19/26,16/26,3/3,3/3,*.(77/116)

Permanently submerged *Verrucaria* spp. were observed not to colonize stones that showed signs of being moved. In the upper stretches of the Teviot most stones showed more signs of being constantly rolled or turned over than in the equivalent stretch of the Tweed. Such stones were not colonized accounting for a comparatively rare occurrence in the upper 25 km.

(v) Submerged *Verrucaria* spp. were most abundant in those tributaries which had rocky substrata, i.e. the Lyne, Yarrow, Ettrick, Eden and upper Whiteadder; only in the Till where it flows over alluvium and peat was it absent.

(vi) The abundance of this genus in the Tweed Basin confirms Swincow (1968), who described the aquatic species as mostly widespread in England and the continent on rocky substrata in rivers, particularly at high altitudes.

7.23 Bryophytes

Acrocladium cuspidatum (B)

(i) 68,77,78,79,80.

(iii) 20/33,20/35,11/13,8/10,8/9,5/5,10/10,9/9,6/6,2/2,*,*,*,*,*.(99/123)

Most common on loose sandy banks, especially those subject to only periodic submergence. Plants nearest the waters edge were generally more luxuriant than others. Acrocladium was common in the upper stretches, but gradually became less abundant downstream until it disappeared above Teviot Foot. A species often in association was Bryum pseudotriquetrum.

(iv) *,1/1,*,3/3,19*26,20/48,4/11.(47/89)

In the Teviot Acrocladium was more common, but had an almost identical distribution pattern as in the Tweed.

(v) Present in the upland tributaries Biggar, Lyne, Yarrow and Ettrick; also in two 0.5 km lengths in the Till, but absent in all other lowland tributaries.

The mean altitude for its occurrence in the Tweed was 185 m, thus indicating a preference for upland sites. The availability of suitable substrata was almost certainly a major influencing factor. Although the Biggar was the most upland tributary surveyed, because of its canal like nature Acrocladium was very rare.

(vi) Present on the banks of the N. Tyne, Tyne, Wear and Tees. Watson (1919) found this species at the edges of rivers, including slow flowing ones, where it would be liable to occasional submergence only.

Acrocladium giganteum (B)

(i) 78,79.

(ii) This species can be separated in the field from A. cuspidatum by its more robust, bushy habit and its less tightly packed leaves which produces indistinct spear headed shoot tips.

(iii) Found in similar habitats as A. cuspitatum, but in only two localities in the upper stretches, namely km 14.0 and 21.0.

(iv) Absent.

(v) Absent in all tributaries surveyed, although present in Megget Water above St. Marys Loch. Its presence there, and in the upper reaches of the Tweed limited its presence to rivers at high altitude that have soft water.

Amblystegium serpens (B)

(i) 79,80.

(iii) Recorded only twice at the bases of trees under the dense Alder shade in km 65.5 and 67.0.

(iv) Single record from km -32.0 below Hawick.

(v) Absent in all other tributaries surveyed. This very slender, inconspicuous moss often resembled Leskea polycarpa and was often common in the woodlands and on tree stumps at the sides of the river. However, only at the sites mentioned was Amblystegium observed to grow down to the low flow water mark.

Amphidium mougeotii (B)

(i) 78,79,80.

(iii) 7/7,6/6,1/1,1/1,*,*,*,*,*,*,*,*,*,*,*.(15/15)

Present in the upper reaches only, and not common. Amphidium was restricted to damp rock surfaces which usually receive splash from small waterfalls or fast flowing stretches. Other moss species commonly found in its association were Barbula recurvirostra, Cinclidotis fontinaloides and Grimmia alpicola.

(iv) *,*,*,*,5/5,4/4,3/3.(11/11)

Identical habitat and distribution as in Tweed.

(v) Absent in the upper reaches of the Yarrow.

A Tweed altitude mean of 255 m (highest mean of any species) and its restriction to the upper reaches of the Teviot and Yarrow indicate a dependence on waterfall type river conditions which supply the plant with permanent moisture but rare submergence.

(vi) The presence of this species only in upper reaches was also evident in rivers in N-E. England. This was well illustrated by Holmes *et al.* (1972) tor the N. Tyne and Tyne.

Atrichum crispum (B)

(i) 78.

(iii) A very rare species recorded from km 3.5 and 7.0 only. In both localities, *A. crispum* was found rooted in sand which had collected in large cracks upon rock surfaces.

(iv) Absent.

(v) Absent.

Atrichum tenellum (B)

(i) 78.

(iii) In four localities only, namely km 20.5, 27.5, 33.5 and 41.5, all being new v.c. records. In km 27.5 *A. tenellum* was found on clay, but at the other three sites sandy particles formed the substrate.

(iv) Absent.

(v) Absent.

Barbula cylindrica (B)

(i) 78.

(iii) *B. cylindrica* was common at many sites by the river side, but only in km 5.0, 7.0, 15.0, 17.0, 30.5 and 33.0 did it grow at levels near the low water mark.

(iv) Absent.

(v) Absent.

Barbula fallax (B)

(i) 78,80.

(iii) Restricted to the clay banks of km 27.5, 35.0 and 107.5. B. fallax was a colonizer of bare ground and as such the isolated records indicate three sites in the Tweed with bare clay banks.

(iv) Absent

(v) Absent.

Barbula recurvirostra (B)

(i) 78,80.

(ii) Easily confused in the field with Dichodontium pellucidum, but the invariable presence of bright, brick red lower leaves is a very characteristic feature. Its previous name of B. rubella was more appropriate (Dixon, 1924).

(iii) Present at infrequent intervals in the upper 50 km. Only large boulders covered with soft sand, or those with soil filled crevices were colonized. Plants never occurred near the low flow water mark, but most frequently so high up on boulders that they would be submerged only very infrequently. For this reason the species was not recorded as a river macrophyte.

(iv) Present in identical habitats as described above, but also on smaller boulders and rocks at the edge of the river. The species was more common in the Teviot than the Tweed.

(v) Absent.

(vi) Rare in N. Tyne, Wear and Tees, but absent in the Tyne. In the rivers where present, it was only recorded in the upper reaches, as in the Tweed.

Barbula spadicea (B)

(i) 78.

(iii) One isolated record in km 5.0 where it grew on loose sandy material among Acrocladium cuspitadum, Bryum pseudotriquetrum and Philonotis fontana.

(iv) Absent.

(v) Absent.

Blasia pusilla (B)

(i) 78.

(iii) Rare, present on detritous at the edge of the river in km 5.0 and 6.0 only.

(iv) Absent.

(v) Absent.

Blindia acuta (B)

(i) 78,80.

(iii) Present in km 0.5, 2.5 and 19.0 on boulders receiving a more or less constant splash of water. Tufts of Blindia were found on such boulders among Grimmia alpicola and Cinclidotis fontinaloides.

(iv) Absent.

(v) Absent.

(vi) Watson (1919) reported Blindia to be most common on banks liable to flooding.

Brachythecium mildeanum (B)

(i) 78.

(iii) A single record for km 32.0 was a new v.c. record for Peebleshire. Although found on sandy ground near the water level, B. mildeanum normally grows only in damp clayey fields (Watson, 1962).

(iv) Absent.

(v) Absent.

Brachythecium plumosum (B)

(i) 68,78,79,80,81.

(iii) 20/64,20/55,8/11,7/7,4/5,*,*,*,*,*,*,*,*,*,*.(59/142)

This species was confined to the upper third of the river, and in the highest 20 km it was most abundant. Here, dense mats were formed on boulders that are usually in the splash zone immediately above the low flow water mark. Many large boulders in the middle of the river, as well as at the edge were often more or less totally covered by B. plumosum. Only rarely were loose sandy substrata colonized.

Although restricted to fifty nine 0.5 km lengths, B. plumosum had an identical abundance value as B. rivulare (see below). The latter however had a wider distribution, and records for one hundred and two 0.5 km lengths. This is indicative of the different habitat preferences and the fact that B. plumosum was usually the dominant macrophyte where it occurred, whereas B. rivulare shared its habitat with many other species.

(iv) *,*,*.2/2,16/24,18/34,4/5.(40/66)

Similar habitat and distribution pattern as in the Tweed. In the Teviot B. plumosum was confined to above Hawick, where it was frequently recorded but never as abundantly as in the Tweed.

(v) In the upland tributaries, B. plumosum was absent from the slow flowing Biggar, but present in the Lyne, Yarrow and Ettrick. In the lowland tributaries B. plumosum was present only in the upper stretches of the Till, Blackadder and Whiteadder with as few as eleven 0.5 km records between them.

(vi) Tributary data, and a Tweed altitude mean of 235 m confirms Watson (1968), who suggested that B. plumosum seldom occurs by slow flowing mature, rivers. It was common in N.Tyne, where it was recorded from identical habitats as described for the Tweed. Although not reported, in the upper Wear and especially the Tees, B. plumosum was common.

Brachythecium rivulare (B)

(i) 68,78,79,80,81.

(iii) 16/23,15/17,18/32,17/25,17/23,4/4,1/1,*,3/4,4/4,1/2,6/7,*,*,*.
(102/142)

B. rivulare was most frequent in the upper stretches of the river, but it remained present throughout the river at intermittent intervals until well below Kelso. Unlike B. plumosum, B. rivulare was a species of the flatter damp loose sandy margins of the river where it was associated with Acrocladium cuspidatum, Bryum pseudotriquetrum and Philonotis fontana.

(iv) 1/1,1/1,5/5,4/8,10/15,18/30,4/4.(43/67)

Similar habitat preference resulting in a similar distribution pattern as in the Tweed.

(v) Present in all tributaries except the Biggar and Leet, both of which are slow flowing with silty overgrown margins. B. rivulare was never common in any tributaries except the Lyne, with the Till being the most colonized of all the lowland tributaries. A Tweed altitude mean of 180 m however, shows a preference for upstream habitats. Although B. rivulare had an altitude mean of 180 m in the Tweed indicating a preference for upstream habitats, its presence at low altitudes in tributaries below Kelso showed its ability to colonize any damp sandy ground, regardless of altitude.

(vi) Common in most rivers in the N-E., being present further downstream than the previous species. Watson (1919) listed B. rivulare as a species capable of forming pure stands at the edges of rivers. In the Tweed and rivers in N-E. England , it was B. plumosum that formed mono-specific stands.

Brachythecium rutabulum (B)

(i) 68,77,78,79,80,81.

(ii) Several strange specimens resembled Leptodictyum riparium, but the microscopic denticulate margin of B. rutabulum is diagnostic.

(iii) 4/5,2/2,1/1,12/12,10/12,17/22,15/18,11/11,16/21,20/29,20/25,16/16, 17/17,2/13,16/20.(189/224)

B. rutabulum was a species of wide distribution, being rarest in upland stretches, common in mid and lowland Tweed, and especially common in the 20 km above Teviot Foot. The preferred habitat was shaded muddy banks where it frequently grew over the matted rootstock of Phalaris arundinacea.

(iv) 6/6,7/8,4/4,6/8,7/8,4/4,*.(34/38)

In the Teviot B. rutabulum was present in similar habitats as in the Tweed, yet never so abundant.

(v) Present in all tributaries, being most common in the Biggar and the last 10 km of the Till. In Yarrow, Ettrick, Blackadder and Whiteadder it was rare.

This Brachythecium species was the only member of the genus that thrived most in lowland reaches of the Tweed Basin. Its abundance in the Biggar showed that providing suitable habitats were available, it could occur, and be frequent at any river site, irrespective of altitude.

Bryum alpinum (B)

(i) 78,80.

(ii) Easily identified in the field by its deep red colour and metallic sheen.

(iii) Present only in the upper 10 km at km 0.0, 0.5, 1.5 2.0 and 6.0, where it grew in the cracks of boulders. Such boulders were usually in mid stream where the plants were exposed except when intermittently submerged. The cracks colonized were normally deep and well packed with soil which reduced chances of desiccation during low flow.

(iv) B. alpinum was restricted to a single record for km -51.0. The reduced number of records was almost certainly due to few sites resembling that described above.

(v) Not recorded in any of the tributaries surveyed, although none of them were surveyed in their upstream reaches. B. alpinum was present in the Megget at a higher altitude than any of the tributaries surveyed for macrophytes.

Bryum calophyllum (B)

(i) 80.

(iii) Absent.

(iv) A single record at km -46.0, where it occurred on sand at the waters edge.

(v) Absent.

Bryum pallens (B)

(i) 79,80.

(ii) Easily confused in the field with B. pseudotriquetrum, but in most cases its reddish tint and smaller size are distinguishing features.

(iii) Rare, recorded only in km 3.0, 9.5, 17.5, 19.0 and 39.0. In these stretches B. pallens was found on wet detritus at the sides of the river, except for the latter record which was from a vertical clay bank.

(iv) Three records only at km -45.5, -54.0 and -59.0, also on wet detritus.

(v) Absent.

(vi) Present in the N. Tyne, but absent from the Tyne. The present author has also found this species at the edges of the upper stretches of both the Wear and Tees, but as in the Tweed, it was absent from lowland stretches.

Bryum pseudotriquetrum (B)

(i) 68,77,78,79,80,81.

(iii) 20/38,18/33,14/21,22/16,6/8,*,1/1,*,*,*,*,1/1,*,*,*.(72/118)

B. pseudotriquetrum was present in all 0.5 km lengths in the upper 10 km but gradually decreased downstream until becoming absent below km 50.0, except at km 71.0 and 114.0. It was absent from bare rock surfaces, but common on sandy material, in soil filled crevices on rocks or on boulders carrying a thin covering of silty material. In such habitats the species was associated with Acrocladium cuspitadum, Brachythecium rivulare, Philonotis fontana and Solenostoma triste.

(iv) 5/5,1/1,1/1,2/2,19/26,20/40,4/5.(52/89)

Common in the upper stretches where it was often locally abundant at the edge of the river. In the last 10 km however, large boulders in midstream were colonized.

(v) Present only in the Biggar, Lyne, Yarrow, Ettrick, Till and upper Whiteadder. As indicated by tributaries and a Tweed altitude mean of 225 m, B. pseudotriquetrum was predominately an upland species. On the sandy banks of the Till it grew at low altitudes however.

(vi) The preference shown by this species for upstream sites, especially those on nutrient poor soils has been reported by Watson (1919). In rivers in N-E. England, Bryum pseudotriquetrum is frequent at high altitudes.

Calypogeia fissa (B)

(i) 78.

(iii) A single record at km 16.0 on a shaded, moist clay bank.

(iv) Absent.

(v) Absent.

Campylopus atrovirens (B)

(i) 78.

(iii) Single record at km 0.5 where it occurred on a large boulder above the low water mark. The plant was constantly moist due to splash water.

Ceratodon purpureus (B)

This species was present at the edges of the Tweed and most of its tributaries. It however never descended down to levels where it would be permanently submerged. For this reason its distribution has not been critically examined. It did however frequently grow among Cinclidotus fontinaloides and Dichodontium pellucidum at levels subject only to infrequent submergence.

Chiloscyphus polyanthos (B)

(i) 78,79,80,81.

(iii) *,5/5,12/12,18/19,8/8,8/11,14/18,18/11,3/5,5/5,2/2,1/1,2/2,*,*. (88/97)

Chiloscyphus was most abundant in mid and mid-upper stretches of the river where in shaded areas it grew among Brachythecium rutabulum, Leskea polycarpa and Marchantia polymorpha. In such localities, Chiloscyphus grew on soil surfaces or on tree roots or stumps. The only rocks colonized were those with a thin covering of soft silt. This species was never present in positions which are permanently submerged, although it appeared to demand more or less constant moisture. This may be the reason why shade is important, and why bare rock surfaces were not colonized.

(iv) Absent.

(v) Present only in the Ettrick and Yarrow where it again showed a preference for very loose loamy soil under tree shade.

(vi) This species was absent from hard water tributaries of the Tweed. Watson (1919), described Chiloscyphus as a common river bank species, particularly on those liable to occasional submergence. Backhaus (1967), recorded this species as one of few bryophytes in the headwaters of the Danube.

Cinclidotus fontinaloides (B)

(i) 68,78,79,80,81.

(ii) Small plants often resemble Orthotrichum rivulare, however a hand lens is sufficient to observe the characteristic thickened leaf margin.

(iii) 15/41,16/26,16/31,20/41,13/26,13/15,15/22,11/16,18/30,13/27,15/22, 12/15,6/6,3/3.(201/347)

Almost totally restricted to levels subject to periodic desiccation, although tolerant of strong currents when submerged. Cinclidotus thus shared with Grimmia alpicola and Orthotrichum rivulare the surface of large boulders which occur both in mid stream and at the waters edge. Distribution down the river was more or less governed by the presence of suitable rock surfaces, although in the upper stretches there was competition with Brachythecium plumosum. In the lower stretches, supports of bridges and wooden flood breaks were frequently colonized. Cinclidotus was the fourth most abundant bryophyte in the river.

(iv) 11/16,6/9,9/13,7/38,17/48,3/3,*.(65/129)

Found in similar habitats; the reduction in abundance in the upper stretches of the Teviot being indicative of the stony, unconsolidated nature of the substratum, and absence of rock sheets and large boulders.-In the Teviot it was the third most abundant bryophyte.

(v) Present in all tributaries, but only common in the rocky Yarrow and Ettrick Waters.

(vi) Often abundant in N. Tyne, but much less common in the Tyne. Whitton and Buckmaster (1970), recorded its presence at two sites in the Wear, and Butcher et al. (1937), reported the species as rare in the upper Tees. Observations made by the present author would suggest that the records for this species reported above are a marked underestimation of its abundance in these rivers. The distribution pattern of this species in the Tweed reflects notes made concerning its ecology by Watson (1919). He reported, its abundance in rocky stretches of rivers, even in slow currents.

Climacium dendroides (B)

(i) 78,79,80.

(iii) 11/12,9/13,2/2,*,*,*,*,*,*,*,*,*,*,*,*,*.(22/27)

Climacium was confined to the upper 23 km where it never grew permanently submerged, but was most commonly rooted firmly in sand at the waters edge.

(iv) *,*,*,*,*,3/3,2/2.(5/5)

Present only in five 0.5 km lengths in the upper 10 km.

(v) Absent in all tributaries except the Yarrow. Climacium dendroides had a Tweed altitude mean of 255 m, which is above the height of all tributaries surveyed. For this reason Climacium was not expected to be recorded.

Conocephalum conicum (B)

(i) 68,78,79,80,81.

(iii) 20/31,7/7,9/11,18/26,15/25,10/12,18/21,15/19,13/14,17/21,14/15, 4/4,4/7,5/5,6/6.(175/224)

Conocephalum was frequent on wet rocks, soil and especially common upon heavy clay. Shaded habitats were preferred, where the species was often associated with Dichodontium pellucidum. In more alluminated sites Marchantia polymorpha replaced it. Its distribution pattern in the upper two thirds of the river was variable, depending on conditions, however below Teviot Foot it was consistently much less common.

(iv) 8/10,9/9,6/6,16/22,16/21,19/29,4/5.(78/102)

Slightly less common than in the Tweed, but likewise showing maximum abundance in extreme upland localities.

(v) Present and usually fairly common in all tributaries, but in the Biggar and the Till it was rare (the former with soft muddy banks and the latter with predominantly soft porous sandy banks).

Conocephalum was recorded in more 0.5 km lengths and was more abundant than any other liverwort in the Tweed, Teviot and the other tributaries.

(vi) This species is also present on banks of other rivers in N-E. England, and Holmes et al. reported that Conocephalum was the most abundant liverwort in the N. Tyne and Tyne. Watson (1919), described this species as typical of banks which are liable to submergence.

Cratoneuron commutatum (B)

(i) 78,80.

(ii) There are two rather distinct forms which are often separated into C. commutatum var. commutatum and C. commutatum var. falcatum. The former is characteristic of calcareous bogs and waterfalls has small leaves and a highly plumose nature; the latter is characteristic of moorland flushes and has a less plumose shoot structure and larger leaves.

(iii) The two plants recorded from km 0.5 and 1.5 were referable to var. falcatum.

(iv) On the right bank of the Teviot in km -8.5 a vertical wall receiving a constant trickel of water was colonized by the var. commutatum. Other species present which are characteristic of calcareous flushes were Ctenidium molluscum and Rivularia biasolettiana. In km -61.0 a single plant of the var. falcatum was found.

(v) At two sites on the Lyne the var. falcatum was found.

In the Tweed Basin, the var. falcatum was recorded from five mountain flush areas, growing on sand at the waters edge. The single var. commutatum site was a vertical wall constantly wetted by a small calcareous stream. The plants collected were easily referrable to their respective vars, but whether they were genetically different or mere habitat modifications is unknown.

(vi) The var. commutatum was recorded from a waterfall at the edge of the N. Tyne, in an almost identical micro-habitat as described for the Teviot.

Cratoneuron filicinum (B)

(i) 68,78,79,80,81.

(iii) 15/15,14/20,19/24,20/37,10/13,6/6,3/3,1/1,3/3,2/2,4/4,2/2,1/1,3/3, 2/2.(105/136)

C. filicinum had a distinct upstream dominance, being present in seventy eight 0.5 km lengths in the upper one-third of the river, but present in only 27 in the lower two thirds. This species was most common on loose sandy or gravelly ground at the edge of the river. It was rarely present on mud or boulders and usually at levels only infrequently submerged. In such areas it grew with Acrocladium cuspidatum, Brachythecium rivulare and Dichodontium pellucidum.

(iv) 1/2,3/3,5/6,13/16,18/20,20/34,4/13.(64/104)

An almost identical distribution pattern as in the Tweed, but with an even more pronounced upstream domination.

(v) This moss was present in all tributaries, usually being more common in their upper reaches where between stones, sand rather than mud predominates.

(vi) This species was reported by Watson (1968) to be most characteristic of wet, calcareous conditions, but in the Tweed it appeared indifferent to changes in water chemistry.

Ctenidium molluscum (B)

(i) 80.

(iii) Absent.

(iv) Present only in km -8.5 on a constantly moist limestone wall at the edge of the river.

(v) Absent.

(vi) Watson (1968) described this species as a species confined to calcareous habits.

Dichodontium pellucidum (B)

(i) 68,78,79,80,81.

(ii) D. pellucidum is a very variable species and plants in the Tweed showed great range from the typical form to ones corresponding to var. flavescens. The latter was not common and is included under the type name.

(iii) 20/45,16/21,16/20,15/25,19/12,7/7,3/3,2/2,4/4,2/2,4/4,3/3,*, 1/1.(102/149)

A species with a near identical distribution pattern as the previous species with 76 records in the upper one-third,and 26 in the lower two thirds. Dichodontium was less common in open sandy situations than C. filicinum, but it also occurred in shaded areas as well as upon open rock surfaces. In the latter habitat cushions were formed, with the var. flavescens being more common.

(iv) 7/8,6/7,12/12,16/18,20/30,20/25,4/7.(85/107)

More frequent than in the Tweed, the records in the lower 20 km being more or less confined to large boulders at the edge of river.

(v) Present, but usually rare in all tributaries.

(vi) In the N.Tyne and Tyne,Holmes et al. (1972) reported this species to be frequent,the var. flavescens being the most frequent form. As in the Tweed, the var. was more frequent than type specimens on open rock surfaces.

Dicranella palustris (B)

(i) 78.

(iii) Confined to four sites in the upper Tweed in km 2.5, 10.0, 19.0 and 21.0 where its bright clear green colour made it most conspicuous.

Its habitat was generally in water holding hollows at the edge of the river which receive an almost constant splash from the river.

(iv) Absent.

(v) Absent.

Dicranella rufescens (B)

(i) 78,80.

(ii) Recognized in the field by its small size and red colouration.

(iii) Two records only, at km 12.0 and 21.5 where it grew on fine sand with Acrocladium cuspidatum and Cratoneuron filicinum.

(iv) A single record in the lower half of the river at km 24.0 in a similar habitat as described for the Tweed.

(v) Absent.

Dicranella varia (B)

(i) 68,80,81.

(iii) Present with Physcomitrium pyriforme on a clay bank in km 119.0

(iv) Present on a bank in km -8.5.

(v) Single record at the edge of the Blackadder (km -32.5).

(vi) Records in the Tweed Basin confirm the findings of Watson (1968) who reported D. varia to be usually present on moist, calcareous clay banks in lowlands.

Dicranum scoparium (B)

(i) 78.

(iii) Dicranum scoparium was found in a similar locality as Dicranella palustris in km 10.0 only.

(iv) Absent.

(v) Absent.

Drepanocladus uncinatus (B)

(i) 78,79,80.

(iii) In km 6.5, 7.0, 11.5 and 28.0. D. uncinatus grew in the shade of large rocks at the side of the river in places submerged only at times of high flow.

(iv) In similar habitats as in the Tweed where it occurred in km -48.0, -48.5 and -55.5.

(v) Present in only two stretches of the Lyne Water, and two stretches in the Ettrick above the Yarrow. D. uncinatus was thus confined to upland localities.

(vi) This species was not found in the N. Tyne or Tyne. In the most extreme reaches of the Wear it was rare, but in the upper reaches of the Tees it was common. It therefore has a scattered distribution on other rivers.

Eurhynchium praelongum (B)

This species and E. swartzii were often present on the banks of the river under the shade of overhanging trees. Since they both rarely extended into the water, they were not included into the recording of species from every 0.5 km length.

Eurhynchium riparioides (S)

(i) 68,77,78,79,80,81.

(iii) 20/26,30/32,20/51,20/68,20/65,20/55,20/61,20/25,20/51,20/43,20/36, 13/16,16/22,11/14,7/7.(267/582)

Eurhynchium was the only macrophyte to be recorded in every 0.5 km length above Teviot Foot. It was also the second most common species in the river based upon abundance values, although Myosotis scorpioides and Phalaris arundinacea were recorded in more 0.5 km lengths. In places, it often covered the entire bed of the river from one side to the other. The species reduction in the river below Teviot Foot is indicative of its requirement for flowing water and a rocky substratum. In these lower stretches which are predominantly deep and relatively slow-flowing, the moss was represented only by occasional plants growing on rocks in faster flowing reaches and on boulders at the waters edge. Eurhynchium was rare in deep water, being most common in the third of a metre below the low flow water mark. Few plants are exposed, except in near drought conditions.

(iv) 20/71,20/40,20/42,20/73,20/81,20/69,4/4.(124/380)

The only species present in all 0.5 km lengths and also, by far the most abundant species. In the lower, most productive stretches of the Teviot, many rocks had three tiers of vegetation. On the immediate rock surface there was Hildenbrandia rivularis which was often overlaid by Eurhynchium. Rooted in the moss and sandy material that collected among it were often found small Ranunculus spp. plants which grew out and spread downstream (see Fig. 7.3b).

(v) Present in every single 0.5 km length studied except for those stretches of the Till which flow over alluvium. In such areas the flow is slow and rocks and boulders rare.

Eurhynchium was tolerant of the wide variations in water chemistry found in the Tweed Basin. The species was recorded in more 0.5 km lengths and was more abundant than any other species.

(vi) In the N. Tyne Eurhynchium was the most abundant species, and in the Tyne, common. In the Wear, Whitton and Buckmaster (1970) referred to it as the species with the widest distribution, and Butcher et al. (1937) reported it to be one of only few common bryophytes in the Tees. Butcher (1933) also recorded this species in fast flowing, rocky stretches of the Wharfe and Dove. It is one of the most recorded bryophytes in British rivers.

Watson (1919) found Eurhynchium in a wide range of river habitats, including on both silicous and calcareous rockbeds, permanently submerged either in fast or slow flowing stretches, or in areas only periodically submerged. Roll (1938) for mainland Europe only found it in stretches of river with fast currents. Backhaus (1967) failed to find this species in the headwaters of the Danube, although it was present, if only rare, lower downstream (Szemes, 1967). Weber (1967) found this species common in Bavarian streams.

Fissidens adianthoides (B)

(i) 78,79,80,81.

(iii) *,3/3,3/3,6/8,3/5,5/6,2/2,1/1,5/5,3/4,9/13,*,*,*,*.(40/50)

F. adianthoides was never common and was absent in the river below Teviot Foot. In the places where it did occur, it was rarely permanently submerged but more commonly found on loose soil under the shade of higher plants.

(iv) *,1/1,2/2,5/5,7/7,*.*.(15/15)

Similar habitat and distribution pattern.

(v) Found only in the Yarrow, Ettrick and Leet where in damp shaded localities it occurred only infrequently.

(vi) Occasional or rare on the banks of other rivers in N-E. England. Watson (1919) also found F. adianthoides restricted to banks liable to periodic submergence.

Fissidens crassipes (S)

(i) 68,80,81.

(iii) *,*,*,*,*,*,*,*,*,*,*,12/17,10/11,13/18,3/3.(38/49)

F. crassipes was confined to the river below Teviot Foot where it was locally frequent, and in fact more abundant than Fontinalis antipyretica. The microhabitats where it occurred in greatest abundance were the vertical faces of boulders which carry (if only temporarily) a thin layer of fine mud. Such boulders occur only in slow flowing reaches and are totally submerged except during periods of exceptionally low flow. Unlike *F. adianthoides*, *F. crassipes* was almost always submerged.

(iv) 10/15,2/2,*,3/3,1/1,*,*.(16/21)

In similar habitats as in the Tweed, although higher up the Teviot *F. crassipes* was often found exposed during low flow.

(v) Present only in the Leet and lower Till. In the former it was scattered, but often locally common, whereas in the latter it was more frequently recorded, but when so always rare.

F. crassipes had a lowland distribution favouring the more calcareous waters and dependence on rocky substrata.

(vi) *F. crassipes* was occasional in the N. Tyne and Tyne, and described by Whitton and Buckmaster (1970) as a species characteristic of the lower Wear. In the Tees it was confined to reaches below the Skerne (Butcher, *et al.*, 1937), the Skerne being responsible for increasing Ca levels in the Tees.

Fissidens rufulus (S)

(i) 78,81.

(ii) Closely resembles the previously described species, but *F. rufulus* is usually tinted red. The two species are separated microscopically by the shorter and more obtuse leaves, and smaller incrassate cells of *F. rufulus*. Separation is difficult since forms in between the two species are common (Dixon, 1924).

(iii) Absent.

(iv) Absent.

(v) Restricted to the upper Ettrick and Whiteadder. In the former river the species was common on rocks in fast flowing stretches, either just above or just below the low flow water level. The rocks colonized were generally of a soft flakey shaley nature not commonly found in the Tweed.

The habitats that F. rufulus colonized were in direct contrast to those favoured by F. crassipes; the former in rapids, and the latter in waters with negligible flow. Since the structure of both species is very similar, it is possible that they may be mere habitat variations.

(vi) This species is reported by Dixon (1924), to be restricted to mountain streams and to be rare.

Fontinalis antipyretica (S)

(i) 68,77,78,79,80,81.

(iii) 20/58,20/58,20/51,20/42,20/43,20/48,20/41,20/32,18/36,17/30,12/12, 7/7,11/13,5/6,3/4.(233/481)

The second most common moss in the Tweed, with its main abundance in the upper 30 km of the river. In these reaches F. antipyretica was absent from the fastest rapids but was the main colonizer of calmer water at the edges of the river. Further downstream it was locally abundant in the slower flowing stretches, present in faster stretches, but absent in rapids. In the lower half of the river it began to become less common in slow deep stretches which were heavily colonized by higher plant species.

In general, F. antipyretica had a higher vertical range than Eurhynchium ripariodes, the former colonizing further up boulders, bridges and wooden flood breaks. In addition to the greater tolerance to longer periods of desiccation, F. antipyretica also grew to greater depths. This may be due to its more lengthy straggly nature, compared to the more compact growth of Eurhynchium which has its stems closely and firmly attached to the substratum.

(iv) 18/38,17/33,20/41,20/45,20/30,19/32,4/9.(118/228)

Second only to Eurhynchium, being present in all but six 0.5 km lengths. However Ranunculus pencillatus var. calcareus also had a greater abundance total.

(v) Common and locally abundant in all tributaries, being least common in the Blackadder and Whiteadder. Like Eurhynchium riparioides, it was tolerant of the wide fluctuations in chemistry encountered in the Tweed Basin; the two species relative abundance probably being governed more by physical parameters than water chemistry.

(vi) Common throughout almost the entire lengths of rivers in N-E. England. Whitton and Buckmaster (1970), however, reported that F. antipyretica was very rare in the upper reaches of the Wear where it was recorded only twice in the uppermost 18 km. Eurhynchium was, however, very common there. This conflicts with findings in the Tweed. Butcher et al. (1933) reported F. antipyretica from all rivers in which Eurhynchium was present, and also from the slower and highly calcareous southern rivers Itchen and Lark. Macrophyte surveys of rivers in mainland Europe have indicated that Fontinalis is more frequent than Eurhynchium. They also showed that the distribution in the Tweed is more typical than that of the Wear. Backhaus (1967) showed F. antipyretica to be abundant in the head waters of the Danube. In streams in Bavaria, Weber (1967) found it to be the most abundant species alongside Myriophyllum alterniflorum. Kohler et al. (1971) found it common throughout the Moosach, as did Weber-Oldecop (1974) in streams in the Harz mountains.

Fontinalis antipyretica var. gracilis (S)

(i) 78,79,80.

(ii) Much more slender yet tougher than the type species. Usually reddish black.

(iii) 2/2,*,*,1/1,*,*,1/2,1/1,*,1/1,*,1/1,*,*,*.(7/8)

F. antipyretica var. gracilis was confined to permanently submerged sites in rapids where the force of the current was greatest. The var. had a wide distribution, but was never abundant.

(iv) Absent.

(v) Only recorded from the Yarrow, and the Ettrick below the former affluent.

(vi) The var. gracilis is reported by Dixon to be the " usual form in swiftly flowing mountain streams ". In the Tweed Basin and rivers in N-E. England (Holmes et al., 1972), it was never an abundant species in the highest reaches of the rivers, yet it was occasionally recorded from torrent conditions anywhere in the river systems, even at low altitude.

Funaria hygrometrica (B)

(i) 68,78,79,80,81.

(iii) 3/3,5/5,3/3,5/5,1/1,2/2,3/3,2/2,3/3,1/1,2/2,1/1,1/1,*,*.(32/32)

Funaria most commonly colonized vertical walls of drying soil and clay at the margins of the river. Other habitats in the upper reaches were the protruding surfaces of soil covered boulders either in mid-stream or at the edges. This species was never common, although widely distributed throughout the length of the river.

(iv) *,1/1,2/2,3/3,4/4,2/2,1/1.(13/13)

As for the Tweed.

(v) Present in all tributaries except Biggar, Ettrick and Eden. A total of only twenty 0.5 km records from all the tributaries is indicative of the species rareness. Funaria was never recorded from permanently submerged localities. Its presence nevertheless gave some indication of the presence of bare vertical clay or soil walls at the rivers edges.

Grimmia alpicola var. rivularis (B)

(i) 68,78,79,80,81.

(iii) 20/54,20/44,17/24,12/13,11/13,9/9,7/7,6/6,8/9,4/5,7/7,6/6,4/4, 2/2,1/1.(134/204)

Grimmia was a species restricted to the surfaces of large boulders which are subjected to periodic wetting and drying, although tolerant of strong currents when submerged. In the upper parts of the river, exposed rocks formed ideal habitats, but on passing downstream they become less frequent, yet protruding boulders and the concrete supports of bridges formed equally good substrates. The species was thus abundant in the upper 20 km but gradually decreased in abundance on passing downstream.

(iv) 2/3,4/5,11/14,7/8,20/37,20/43,4/9.(68/119)

Similar distribution pattern resulting from a similar habitat requirement. In the upper reaches even quite small boulders were colonized.

(v) Present in all tributaries except the Leet. Grimmia was most common in the rocky uplands of most tributaries, and rarest in the slow flowing Biggar and Till; both tributaries have few boulders.

Grimmia was commonly associated with Cinclidotus fontinaloides, however the former was usually slightly higher upon on the rock surfaces and very rarely at levels which are predominately submerged. Grimmia, with a Tweed altitude mean of 165 m against 125 m for Cinclidotus indicated the former species thrived most in the upper reaches.

(vi) In rivers in N-E. England , this species was often frequent, and reported to be present in the rocky stretches of either the upper or lower reaches of the Tees by Butcher (1933). Grimmia was described by Watson (1968) as most typical of mountain streams, with the same habit as Cinclidotus fontinaloides. The distribution in the Tweed agrees most closely with these observations.

Gymnostomum aeruginosum (B)

(i) 80.

(iii) Absent.

(iv) Rare. Present on damp splashed rocks in km -46.5 and 47.5 only.

(v) Absent.

Gymnostomum recurvirostrum (B)

(i) 78,80.

(iii) Present on boulders in mid stream that are frequently splashed, and also at the edge of the river where trickles of water enter the main river. This species was restricted to the upper 20 km of the river in km 1.5, 7.0, 11.5, 13.5 and 16.0.

(iv) As above in km -47.0, -57.0, -58.5 and -61.0.

(v) Absent. Like many other high altitude species, G. aeruginosum and G. recurvirostrum were not recorded in the tributaries since most of the partial surveys were from stretches at lower altitudes.

Hedwigia ciliata (B)

(i) 78.

(iii) A group of plants on a large boulder in km 38.0 represented the only record for the whole of the Tweed. The loose cushions formed by this species were made very obvious by the white hair-points of its leaves. The plants were among tight Grimmia alpicola cushions, well above the water level at the time, but no doubt would be submerged during periods of above average flow.

(iv) Absent.

(v) Absent.

(vi) The single record is included since Watson (1968) refers to the species as being 'fond of lake-side boulders'.

Hygroamblystegium fluviatile (S)

(i) 68,78,79,80,81.

(iii) 20/45,20/51,19/43,20/48,20/49,16/26,13/20,19/28,14/21,14/15, 18/23,10/10,7/7,9/11,6/6.(225/403)

Present in all but one of the upper one hundred 0.5 km lengths, but in the lower two-thirds of the river it became gradually less abundant, but nevertheless was more common than *Fontinalis antipyretica* in the lowest one-third of the river. *Hygroamblystegium* was most common at, or just below the low flow water mark, either in fast or sluggish conditions, mostly upon rock surfaces, but also upon wet mud. This was the third most abundant moss and eighth most abundant of all species.

(iv) 10/13,17/22,20/26,20/36,10/12,10/13,1/1.(88/125)

Lack of stable rock surfaces at the low flow water mark accounts for the species rarity in the upper reaches compared with the Tweed. In mid-river more stable conditions predominate allowing the species to grow in every 0.5 km length. As in lower Tweed, the deep muddy stretches of the last 10 km of the Teviot had banks dominated by flowering plants and were not suitable habitats for this moss. However, it still was the fourth most abundant moss.

(v) Present, and usually recorded frequently in all tributaries. A common species and like most of the mosses in the Tweed Basin having a distribution pattern which appears to reflect physical conditions related to its habitat rather than chemical differences.

(vi) Frequent and often very abundant in the N. Tyne and Tyne. Whitton and Buckmaster (1970)* failed to find the species in the upper third of the Wear, but Butcher *et al*. (1937) found it throughout the Tees. The latter author (1933) also reported it from the Wharfe and Dove.Watson (1968)

* The authors have since recorded the presence of *Hygroamblystegium* in the upper reaches, and reported that in the original survey that it was probably overlooked.

reported H. fluviatile to be most typical of limestone, whereas Dixon (1924), regarded it as a species principally of siliceous areas, and rather rare. The distribution in the Tweed, and observations made by the present author for rivers in the N-E. would suggest that it is a most common river moss.

Hygrohypnum luridum (S)

(i) 78,79,80,81.

(iii) 20/62,20/59,11/26,2/3,*,*,*,*,*,*,*,*,*,*,*.(53/150)

The most abundant species in the upper 20 km where it was recorded from all 0.5 km lengths. Below this, it became less abundant until disappearing from the river in km 34.5. H. luridum most characteristically formed soft carpets on rocks in fast flowing stretches, usually on surfaces facing to the side or downstream. Where current velocity was less, boulders and many wooden posts that have been sunk into the river also had their upstream, as well as side and downstream surfaces colonized. This moss was never deeply submerged, yet rarely would be exposed to desiccation except during times of exceptional low flow.

(iv) *,*,*,12/28,20/53,20/35,4/9.(56/125)

Common in similar habitats and restricted to the upper half of the river, where like the Tweed it was present in all 0.5 km lengths in the upper 25 km.

(v) Frequently recorded throughout the Lyne, Yarrow and from the upper stretches of the Ettrick and Whiteadder.

(vi) H. luridum was characteristically a species of fast flowing mountainous stretches of the Tweed and rivers in N-E. England, but Watson (1968) has reported it as present in the middle reaches of the Thames. In the Tweed and Teviot, even though it was abundant in the upper reaches of both rivers, it never occurred at low altitudes. In contrast, Fontinalis antipyretica var. gracilis, another species which in the Tweed was confined to stretches of river with high current velocity, was rare in the upper stretches, yet present in fast flowing stretches further downstream. It is therefore somewhat surprising that H. luridum does not occur in at least a few isolated localities in the lower half of the Tweed Basin.

Hygrophynum ochraceum (S)

(i) 78,79,80.

(iii) 10/17,10/15,8/12,8/11,*,*,*,*,*,*,*,*,*,*,*,*,*.(36/55)

Much less frequent than H. luridum, although recorded from the same region of the river. H. ochraceum was confined to rapids where it colonized only flat, near horizontal surfaces. with its soft long stems closely appressed to the surface. Unlike the previous species, H. ochraceum was always observed to grow just below the low flow water mark

(iv) *,*,*,*,5/5,*,*.(5/5)

Even more rare than in the Tweed, being confined to five reaches between km -41.5 to -45.0 where rapids combined with sheet like substrata. H. ochraceum. like Hygroamblystegium fluviatile found the unconsolidated substratum of upper Teviot less suitable than the more consolidated conditions in upper Tweed.

(v) Present in the Ettrick and Yarrow only, but here too, it was rare.

(vi) Absent in the Tyne, and rare in the N. Tyne and upper reaches of the Wear and Tees. This species is rarely recorded in published works of river macrophytes; however, Backhaus (1967) recorded its presence in the headwaters of the Danube, and both Ackenheil (1944) and Sirjola (1969) noted its presence only in stretches with high current velocity.

<u>Leptodictyum</u> <u>riparium</u> (B)

(i) 68,78,78,79,80,81.

(iii) *,*,*,*,5/7,2/2,1/1,3/3,2/2,1/1,2/2,4/4,3/3,8/9,6/6.(37/40)

<u>Leptodictyum</u> was most commonly found straggling over damp soil, stones carrying a thin film of mud, or on drying wood. Such substrata were colonized only in the immediate vicinity of the low water mark. The species was thus normally either damp or only shallowly submerged. In the Tweed, <u>Leptodictyum</u> although never common showed a preference for the lower regions of the river, and only colonized more upstream localities below major or minor effluent outflows. The most upstream limit of this species was below Peebles Sewage Works, the works filter beds themselves having luxuriant plants growing upon them.

(iv) 6/9,4/5,2/3,1/1,*,*,*.(13/18)

The most upstream record was below a small sewage effluent in km -37.5, although it did not colonize the banks of the river below Hawick sewage works. Apart from this single record the species was confined to the lower 25 km of the river.

(v) In the tributaries which discharge into the upper half of the Tweed, <u>Leptodictyum</u> grew only in the Biggar, and in the Ettrick below Selkirk Sewage Works. On the other hand, the species grew in all the tributaries that discharge into the lower half of the Tweed. In the Blackadder, <u>Leptodictyum</u> was confined to the river below Langton Burn in which tributary it was also most common. Langton Burn carries the sewage of Duns. In the Whiteadder the species most upstream record was on the right bank immediately below the entry of the Blackadder.

The Tweed altitude mean of 50 m and data from the tributaries indicate a predominately lowland distribution. However Leptodictyum could grow in more upstream localities providing there was abundant nutrients available, as indicated by its presence in the Biggar Water and below the sewage pipes of Peebles and Selkirk. The 0.5 km lengths surveyed on the Leet were at approximately 30 m, and the water was harder and more nutrient rich than all other tributaries . Leptodictyum was more common in the Leet than any other tributary, being recorded in all 0.5 km lengths and often locally most abundant. It was also the most abundant moss, and fourth most abundant species in that river.

(vi) In the N. Tyne, Leptodictyum was rare and confined to short stretches of the river immediately below sewage effluents. In the Tyne, Wear and Tees the species was often common, but confined to the lower stretches. The distribution in the Tweed agrees with findings of Watson (1919), who found this species most commonly in slow flowing rivers on banks liable to frequent submergence.

In mainland Europe however, Backhaus (1967) found Leptodictyum common in the headwaters of the Danube, and Weber-Oldecop (1974) in rivers in the Harz mountains. The latter author reported its presence among Scapania undulata and noted that species growing in that area demanded cool water, low levels of electrolytes and high oxygen. This conflicts with findings in the Tweed Basin.

Leskea polycarpa (B)

(i) 68,78,79,80,81.

(iii) *,*,2/4,10/15,3/4,*,*,*,*,*,*,*,*,*,*.(15/23)

Leskea was never in positions where it would be permanently submerged, but present usually at the medium flow water mark and above. In such areas it was only common on the roots and trunks of trees, although soil or stones flush against the trees were also sometimes colonized. Plants were small and possibly in some stretches overlooked. In the Tweed the species was restricted to the lower half of the upper stretches of the river.

(iv) *,1/1,5/5,4/4,2/2,*,*.(12/12)

Present in heavy shaded conditions where roots of trees descend into the water. Although slightly fewer records than for the Tweed, in the Teviot Leskea had a slightly wider distribution.

(v) Present in only seven 0.5 km lengths in all the tributaries; two in the Yarrow, one in the Eden and four in the Till.

(vi) The presence of this species in rivers in N-E. England has not been reported. The microhabitats where the species was most frequent in the Tweed supports the observations made by Watson (1919), who reported it to be confined to river banks which receive only periodic submergence.

Marchantia polymorpha (B)

(i) 68,78,79,80,81.

(ii) Similar to Lunularia cruciata but since the goblet shaped gemma cups of Marchantia were normally present, identification presented little difficulty.

(iii) 7/7,8/8,6/7,10/10,13/15,11/11,3/4,9/9,6/6,4/4,6/6,3/3,8/8,6/6, 2/2.(102/106)

Marchantia was most common on loose moist soil on the banks of the river just above the water level. Although sometimes associated with Conocephalum conicum, Marchantia preferred more loose substrata, whereas the former species tended to colonize heavy, compacted clay or rock surfaces. Marchantia had a wide distribution down the Tweed, being present in exactly one third of the 0.5 km reaches and most abundant in the upper and mid reaches of the river. The species was absent from the upper 6 km where loose substrata at the sides of the river were of a sandy rather than soily nature.

(iv) 10/11,8/8,4/4,13/13,*,*,*.(35/36)

Marchantia had a more restricted distribution in the Teviot being absent in the upper 20 km where the banksides are predominantly of loose stones.

(v) Present in Yarrow, Jed, Eden, Till, Blackadder and Whiteadder, but not common.

(vi) Frequent and often locally abundant in rivers in N-E. England. Watson (1919) found Marchantia especially common on poor soils, that are periodically submerged.

Mnium longirostrum (B)

(i) 68,78,79,80,81.

(iii) 2/2,11/14,8/8,10/12,6/7,4/4,12/12,7/7,4/4,3/3,10/11,4/4,3/3,2/2,5/5. (91/98)

M. longirostrum was found most commonly straggling among other mosses on moist soil, stones or upon wood. The species appeared to flourish most in shaded localities just above water level. M. longirostrum shared similar habitats and had a distribution pattern similar to Marchantia polymorpha, the former also being absent in the extreme upper reaches of the river.

(iv) 5/5,4/4,1/1,6/6,14/15,14/18,4/6.(48/55)

Unlike Marchantia, in the Teviot M. longirostrum colonized the upper stretches of the river, although less common than the former in the lower stretches. The latter species being of a straggly nature managed to grow on the shingle in the shade of the numerous Carex spp. and other bankside flowering plants of the upper reaches.

(v) M. longirostrum was present in all tributaries except the Leet and Till. This species was more common in the upland stretches of tributaries than Marchantia.

Mnium punctatum (B)

(i) 68,78,79,81.

(iii) 10/10,9/9,3/3,2/2,1/1,*,*,*,*,*,*,*,*,*,*.(25/25)

M. punctatum was confined to the upper third of the river, being most common in the most upstream reaches and gradually became less common on passing downstream. This species, which is more robust and upright than the previous Mnium described, was most common in moist crevices and hollows between large boulders.

(iv) *,*,*,3/5,3/4,5/5,2/2.(13/16)

Similar habitat and distribution as in the Tweed.

(v) Confined to tributaries which discharge into the upper half of the Tweed, and the most upstream 0.5 km lengths surveyed on the Whiteadder. M. punctatum was thus a species absent from the lowland stretches of the main river and its tributaries, having a Tweed altitude mean of 245 m.

(vi) The different distribution patterns of the two Mnium species in the Tweed Basin agrees with Watson (1968). He described both species as typical of moist habitats, with M. punctatum more frequent in mountainous districts.

Orthotrichum anomalum (B)

(i) 78,80.

(iii) Present only in km 10.0, 20.5, 38.0 and 42.5 where it formed tight cushions on the surfaces of protruding large boulders. The cushions were normally just above Grimmia alpicola or Cinclidotis fontinaloides plants.

(iv) O. anomalum occurred on a boulder at the side of the river in km -2.0 where O. rivulare was also present, in addition to two similar habitats as described for the Tweed in km -44.5 and -45.0.

(v) Absent.

Orthotrichum cupulatum var. nudum (B)

(i) 78.

(iii) A specimen collected from a boulder in km 7.0 represented a new v.c. record for Peebles. The loose cushion was among Grimmia alpicola plants just above the water level.

(iv) Absent.

(v) Absent.

Orthotrichum rivulare (B)

(i) 68,78,79,80,81.

(ii) Resembles small Cinclidotis fontinaloides plants more than any other Orthotrichum spp., being easily identified by its obtuse leaves and strongly ribbed capsule with its immersed stomata.

(iii) 1/1,3/3,3/3,6/6,2/2,1/1,1/1,3/3,2/2,6/7,6/8,2/2,2/2,3/3,*.(41/44)

O. rivulare was widely distributed down the length of the river, yet never common. The species most favoured habitat were boulders protruding a little way out of the water and rocks at the side of the river. Boughs of trees that bent down near the surface of the water were also colonized, but these were usually dominated by Tortula mutica.

(iv) 2/3,1/1,4/4,3/3,2/2,2/2,*.(14/15)

Similar wide distribution of few records.

(v) Present in Ettrick, Jed, Till, Blackadder and Whiteadder, but never common.

Pellia endiviifolia (B)

(i) 68,78,79,80,81.

(ii) This species differs from the following Pellia sp. in its smaller size, lack of fibrous thickenings, inwardly curved margins and more dichotomously branched thallus. However, young material is difficult to separate.

(iii) 3/3,*,3/3,5/5,3/3,2/2,*,*,*,*,*,1/3,3/4,4/4,*.(24/27)

Far less common than P. epiphylla. In the upper reaches of the river P. endiviifolia colonized open habitats, was absent in mid river but reappeared again below Teviot Foot where shaded areas were colonized. Like Conocephalum conicum compacted heavy soil and rock surfaces were preferred.

(iv) 3/3,4/4,1/1,3/3,4/4,*,*.(15/15)

Not common but widely distributed.

(v) Present in all lowland tributaries, but the only upland tributary where P. endiviifolia grew was the Lyne. (see P. epiphylla).

(vi) Frequent in N. Tyne and Tyne, but its distribution in the Wear is not known. Watson (1919) concluded that P. endiviifolia probably occurred in habitats more susceptible to submergence than P.epiphylla; there was no evidence to support this from the Tweed Basin however.

Pellia epiphylla (B)

(i) 68,78,79,80,81.

(iii) 10/15,9/12,7/7,7/9,6/7,4/4,12/12,6/6,4/4,5/5,6/6,5/7,4/5,7/7,2/2. (94/100)

Much more common than the previous related species, growing in similar habitats and distributed down the whole length of the river.

(iv) 5/7,2/2,1/1,1/1,10/11,19/20,3/5.(41/47)

In the upper stretches of the Teviot, P. epiphylla was much more common than in the corresponding reaches of the Tweed, but in the lower stretches less abundant.

(v) Almost opposite distribution to P. endiviifolia. The present species was recorded in all the upland tributaries but not from the lowland tributaries except at a few sites in the upper Whiteadder.

The presence of P. endiviifolia in the upper stretches of the Tweed resulted in the two Pellia spp. having identical Tweed altitude means of 130 m. However P. epiphylla was replaced by P. endiviifolia in the more lowland tributaries that have higher conductivity, Ca and Mg levels. It is noteworthy that the only upland tributary colonized by P. endiviifolia was the relatively hard watered Lyne. The species was most common on the banks of the Leet, the most calcareous stream surveyed.

Philonotis fontana (B)

(i) 68,77,78,79,80,81.

(ii) Not all plants were looked at critically, It is possible therefore, that P. calcarea was present, although none of the tributaries where the genus occurred, flowed over limestone.

(iii) 20/38,15/24,12/19,6/12,3/3,*,*,*,*,*,*,*,*,*,*.(56/96)

Confined to the upper one third of the river, being common in the first 10 km but gradually becoming less abundant downstream. Philonotis colonized a wide range of habitats, including cracks on rocks in mid stream which were subject to long periods of submergence. These plants tended to be bare and black coloured, although during very low flow periods they would grow quickly and produce bright yellow fleshy growing tips. More commonly, plants were rooted in sandy detritous among Acrocladium cuspidatum and Bryum pseudotriquetrum.

(iv) *,*,*,1/1,4/8,20/40,4/7.(29/66)

In the Teviot too, Philonotis was confined to the upper stretches, and was particularly common on tussocks at the sides of the river in the extreme upper reaches.

(v) Confined to the Biggar, Lyne and upper reaches of the Yarrow, Ettrick, Till and Whiteadder.

Philonotis was common at high altitudes, but absent or rare elsewhere, with a Tweed altitude mean of 230 m.

(vi) In rivers in N-E. England., Philonotis frequently occurs in the upper reaches, and Holmes et al. (1972) reported that both P. calcarea and P. fontana were present in the N. Tyne.

Physcomitrium pyriforme (B)

(i) 68,78.

(iii) Two records only, both on vertical clay banks in km 19.5 and 119.0.

(iv) Absent.

(v) Absent.

(vi) Szemes (1967) included this as one of the few bryophyte species reported for the Danube.

Plagiochila asplenioides (B)

This species was most common in damp shaded wooded areas next to the river, and occasionally it occurred at the edge of the river near the water level. Since plants would be submerged only during above average flows, this species was not formally recorded, although most common in the middle section of the river.

Pohlia delicatula (B)

(i) 68,78,80.

(iii) This species was a frequent colonizer of bare vertical clay banks, but only in km 42.0, 56.5, 107.5 and 120.5 did it grow at levels near the low flow water mark. On other clay banks where it occurred it would only be submerged during very high flows.

(iv) A clay bank in km -47.5 supported delicate tufts of this species just above the water level.

(v) Absent.

Other Pohlia spp., including P. annotina (Hedw.) Loeske, P. bulbifera (Warnst.) Warnst. and P. nutans (Hedw.) Lindb. all occurred on clay banks but never at levels subjected to constant submergence. Although many plants would be occasionally submerged, they were not included in the survey.

Polytrichum aloides (B)

(i) 78,80.

(iii) This small species was found in km 10.0 in a minute soil-filled crevice of a stone that was being constantly moistened by splash water.

(iv) P. aloides was recorded in four 0.5 km lengths of the Teviot, namely km -48.0, -52.5, -55.0 and -60.0. Several plants in km 52.5 grew in a similar habitat as that described for the Tweed specimens, but other Teviot plants were found on drying soil and clay at the edge of the river.

(v) Absent.

Polytrichum nanum (B)

(i) 80.

(ii) A species resembling the latter, but usually smaller and with non-papillose capsules.

(iii) Absent.

(iv) Present in similar habitats as P. aloides in km -61.5 and -62.0.

(v) Absent.

Polytrichum piliferum (B)

(i) 78.

(iii) Single record in km 33.5 where it occurred in a similar habitat as the previous two species.

(iv) Absent.

(v) Absent.

Polytrichum urnigerum (B)

(i) 80.

(iii) Absent.

(iv) In km -55.0 and km -60.0 P. urnigerum grew alongside P. aloides. The only other site colonized was km -57.5.

(v) Absent.

All Polytrichum species recorded were confined to the upper reaches of either the Tweed or Teviot, or both. They were all rare, and almost always above low flow water levels.

Priessia quadrata (B).

(i) 78.

(iii) A single plant was observed in km 5.0 growing on a sheet like boulder that just protruded above the low flow water level.

(iv) Absent.

(v) Absent.

(vi) The record is surprising since P. quadrata is normally a species of calcareous districts (Watson, 1968).

Rhacomitrium acicularis (B)

(i) 78,79,80.

(ii) A confusing name since the broadly rounded leaf tips are the diagnostic feature of this species which seperates it from other members of the same genus.

(iii) 7/7,*,1/1,2/2,*,*,*,*,*,*,*,*,*,*,*.(10/10)

This species was rare and restricted to the upper reaches of the river. R. acicularis was present on rock surfaces only, usually at or above the low flow water mark.

(iv) *,*,*,*,*,3/4,2/2.(5/6)

Restricted to the upper stretches where it was rare and present on similar rock surfaces as described for the Tweed.

(v) The only tributary in which R. acicularis was present was the Yarrow (see R. aquaticum)

Rhacomitrium aquaticum (B)

(i) 78,79,80.

(iii) 5/5,5/5,*,1/1,*.*.(11/11)

R. aquaticum was found on similar rock surfaces as R. acicularis; however the more straggly growths of the former were usually found furthest from the water mark.

(iv) *,*,*,*,*,5/7,2/2.(7/9)

As for R. acicularis, restricted to two 0.5 km lengths in the Yarrow.

Both Rhacomitrium spp. were rare, and had obligate requirements for moderate to high altitude conditions. In similar physical habitats downstream they were absent. However Cinclidotus fontinaloides and Grimmia alpicola which were frequent on the same rocks as Rhacomitrium in the upper stretches could grow in lowland localities. The Lyne is an upland tributary which is physically similar to the upper reaches of the Tweed, but its chemistry is much harder and more nutrient rich. Both Rhacomitrium species were absent there. The data from the Tweed would suggest that aquatic Rhacomitrium species require a combination of rocky substrata and soft, nutrient poor water.

(vi) Watson (1968) described both R. acicularis and R. aquaticum as conspicuous members of the boulder flora in non-calcareous streams in mountainous districts. The distribution in the Tweed would appear to confirm this.

Rhytidiadelphus squarrosus (B)

(i) 78,79,80.

(iii) *,3/3,1/1,*,2/2,*,*,*,*,*,*,*,*,*,*.(6/6)

Found only rarely in the upper one third of the river. It was usually found associated with Acrocladium cuspidatum on soft, sandy silt at the edge of the river.

(iv) *,*,*,*,*,3/5,2/2.(5/7)

As above.

(v) Only present on the banks of the Yarrow.

Rhytidiadelphus was more commonly found in waterlogged grassy fields adjacent to the rivers.

Scapania undulata (S)

(i) 78,79,80.

(iii) 10/10,5/7,7/10,3/3,1/1,*,*,*,*,*,*,*,*,*,*.(26/31)

Scapania was restricted to the upper one-third of the river and was never common. The most robust specimens were found in mid stream, usually upon flat surfaces that are shallowly submerged during low flow. Although almost always growing at approximately the low water mark, some plants at the edge of the river often spread towards the bank to become associated with Bryum pseudotriquetrum and Solenostoma triste.

(iv) *,*,*,*,*,3/5,*.(3/5)

Rare, undoubtedly due to the instability of the river bed and the loose stony nature of its banks.

(v) Present only in the Lyne and upper Yarrow.

(vi) In the Tweed Basin the micro-habitat of Scapania and its distribution pattern agree with the comments made for the species by Watson (1968). He stated that the most robust plants occur in fast flowing streams, but the species also occurs at the edges of mountainous streams, where plants are usually smaller.

Scapania is frequently recorded from the Continent also. Three examples are: in upper Danube (Backhaus, 1967); Bavarian streams (Weber, 1967); and in streams in the Harz mountains (Weber-Oldecop, 1974).

Scorpidium scorpioides (B)

(i) 78.

(iii) In km 20.0 and 38.5 S. scorpioides was present at the side of the river. In both stretches the plants were found in small shallow pools cut off from the main river during low flows.

(iv) Absent.

(v) Absent.

Solenostoma triste (B)

(i) 78,79,80,81.

(iii) 17/32,9/9,7/7,6/6,6/7,*,*,*,*,*,*,*,*,*,*,*.(45/61)

Much more common than Scapania undulata, although present in an identical region of the Tweed. Solenostoma, although occasionally submerged, was far more common on damp rock surfaces and sandy detritous at the edge of the river. In general, close knit patches of Solenostoma were more common on rocks, with a more straggling form common on gravel.

(iv) *,*,*,*,*,2/2,2/2.(4/4)

Very rare, for the same reasons given for the previous species.

(v) Present in the Lyne, Yarrow, Etrrick and upper Whiteadder, all records being from damp gravel at sites of at least moderate altitude.

Solenostoma was more common than Scapania, but both were confined to the upper reaches of rivers. The former had a Tweed altitude mean of 230 m and the latter 235 m.

(vi) This species has been frequently recorded from the upper reaches of rivers in N-E. England, and Holmes et al. (1972) showed that Solenostoma spread further down the Tyne than Scapania, as it did in the Tweed.

Thamnium alopecurum (B)

(i) 68,78,79,80,81.

(iii) *,2/4,4/5,3/3,*,*,1/1.*,4/4,3/3,*,*,1/1,*,*.(18/21)

Quite rare, yet with a distribution spanning most of the river. Thamnium was confined to wet vertical rocks. In more open situations (e.g. the waterfalls in km 10.5). There was a requirement for continuous wetting by splash water, whereas in shaded areas this appeared to be unnecessary. In several sites this moss formed complete carpets, usually with the lower portion permanently submerged.

(iv) 7/7,*,*,5/11,4/11,*,*.(16/29)

Thamnium was particularly common in the Teviot around km-40. There it occupied habitats that upstream were dominated by Brachythecium plumosum.

(v) Absent in the Biggar, but present in all the other more upstream tributaries of the Tweed, but absent in the lowlands.

(vi) Present in rivers in N-E. England , and as stated by Holmes et al. (1972), this species is nearly always restricted to vertical wet rock faces.

Thuidium delicatulum (B)

(i) 78,80,81.

(iii) Recorded from km 10.5 only, where it grew on a vertical rock face alongside Thamnium alopecurum.

(iv) Absent.

(v) Present in a single site on the Jed, and at two sites on the Whiteadder. On the former river it was present on a shaded, constantly splashed wooden flood break. In the Whiteadder plants were found in a similar habitat, as well as straggling over stones and shingle..

Tortula mutica (T. latifolia) (B)

(i) 68,78,79,80,81.

(iii) *,*,4/4,6/7,7/9,9/9,17/24,14/19,10/10,6/6,4/4,2/2,3/3,4/4,2/2.(88/103)

T. mutica was most abundant in the middle of the river, becoming gradually less common both upstream and downstream. In the upper 25 km it was absent. This species was rare upon rocks and only grew on large boulders that carried a very thick layer of mud on their surfaces. Roots and boughs of trees above the low flow water mark were the dominant substrata colonized. Tortula was rarely present in well alluminated localities, and it reached its maximum abundance in mid river where the extent of tree shading was greatest.

(iv) 4/6,3/3,18/21,4/4,*,*,*.(29/34)

Identical habitat and distribution as in the main river.

(v) Absent in Biggar and Ettrick, present in all other tributaries but never common in any of them.

7.24 Angiosperms

Butomus umbellatus (B)

(i) 68,81.

(iii) Absent.

(iv) Absent.

(v) Present in the Adder Waters. In the Blackadder Butomus was common, locally abundant and recorded from all but three 0.5 km lengths surveyed. In the Whiteadder its distribution was restricted to three lowland localities only, where it was common. Butomus, like Rorippa nasturtium-aquaticum (a species that was in frequent association), was usually found rooted at the waters edge, where flow was negligible or sluggish. Plants were rarely totally submerged, but more generally emergent from a partially submerged rootstock. Although described by Clapham et al. (1962) as a 'perennial up to 1.5 m', in the Blackadder, several plants exceeded 2.0 m in height.

(vi) In America, Dansereau (1957) reported how Butomus became established in the Great Lakes and the St. Lawrence River where it replaced indigenous Scirpus lacustris and Sparganium erectum. Its spread into the Mississippi was predicted, and this has recently occurred (Roberts, 1972). The latter author reported Butomus to be present in similar habitats as it occurred in the Tweed Basin. Judging from the spread of the species in rivers in America, it might be suggested that in future, it may also widen its distribution in the Tweed Basin. Little information is available to be able to gauge whether the species is more abundant in the Tweed Basin now, than it was 10 years ago.

Callitriche hermaphroditica (S)

(i) 80,81.

(ii) Easily identified in the field by its yellowish colour and compact, entirely submerged habit. The leaves are widest at the base and taper to an emarginate apex.

(iii) Absent.

(iv) Limited to one plant at km -9.5 in shallow, medium paced flowing water.

(v) Again limited to one 0.5 km length in the Whiteadder Water at km -18.5; however several plants were observed there. The habitat in the Whiteadder was similar to the Teviot except the substratum in the former river was of a more rocky nature. From the sparse records, it is concluded that material was washed into the rivers from pond habits. If low flow conditions continue, a downstream colonization is predicted.

Callitriche other sp(p). (S)

(i) 68,78,79,80,81.

(ii) Doubts on precise species identification (with the exception of C. hermaphroditica) forced this unsatisfactory dumping of all other species under Callitriche other sp(p).

Callitriche is taxonomically a difficult group since leaf shape depends upon whether the leaves are submerged or floating, and upon the depth and flow rate of the water. C. stagnalis, C. polymorpha, C. verna and C. obtusangula are virtually inseparable on vegetative characters alone, yet the fruits are all diagnostic. In most cases fruits were unavailable and no attempt was made in the laboratory to enforce fruiting.

At km 21.5 (below Tweed Ford) many plants were observed over a two year period. Plants with broad spatulate rounded leaves, usually produced by plants with a more or less distinct rosette habit usually developed C. stagnalis fruits. On the other hand, those with more linear leaves and ill-defined rosette habit usually developed C. polymorpha fruits. However this was not always true, for C. stagnalis if deeply submerged lacked a distinct rosette habit and had narrow-spatulate linear leaves. If C. polymorpha grew on damp mud, a vegetative form more similar to C. stagnalis was observed.

(iii) 16/17,17/17,16/19,8/8,12/12,5/6,3/3,4/4,3/3,1/1,2/2,4/4,5/5,4/4, 10/4.(110/114)

The presence/abundance ratio indicates that wherever Callitriche occurred, it did so only infrequently. Its preferred habitat was among stones covered with damp mud at the waters edge, where at periods of extreme low flow they are above the water level, but at most periods of the year they are at least partially submerged. The upper reaches of the Tweed provide such a habitat. Downstream most stony areas dry out too much for Callitriche and the damp muddy margins are occupied by thick growths of Phalaris arundinacea, Sparganium erectum, or other more robust bankside species.

(iv) *,1/1,1/1,1/1,1/1,3/5,1/1.(8/10)

Although found in similar habitats as in the Tweed far fewer specimens were recorded in the Teviot due to lack of suitable habitats.

(v) Most common in the upland tributaries Biggar and Lyne, but with only single records from the Ettrick and Yarrow. The former two rivers have muddy margins whereas the latter two have characteristically rocky margins with negligible silt deposition. Infrequent records for the Till, Whiteadder and Blackadder and its absence in the other lowland tributaries indicates its inability in slow muddy rivers to compete against more robust bankside genera.

(vi) This is one group where the taxonomy of the genus was not critically analysed, and apart from the most easily seperated C. hermophroditica, the distribution of the other species was not mapped. This was unfortunate, for Westlake (1975) regarded this as an important genera in rivers, for which correlations between distribution and critically identified members of the genus was badly needed.

Caltha palustris (B)

(i) 68,77,78,79,80,81.

(iii) 9/9,17/17,14/15,18/18,15/15,16/16,19/19,16/16,14/15,6/6,12/12,10/11, 6/6,6/6,12/14.(190/195)

A commonly recorded water-side plant growing mainly on mud and silt, yet capable of growing among more or less permanently submerged stones in the upper stretches. In the lower stretches of the rivers where deeper more vertical banks, or Phalaris arundinacea/Sparganium erectum stands predominate, Caltha was less common, although capable of occasionally growing in the dense shade of the species mentioned. On the wider more open surface of the tidal mud flats Caltha was more common.

(iv) 15/17,8/9,6/9,8/8,11/13,8/9,3/3.(59/68)

Similar distribution and habitat preference as described for the Tweed, reaching maximum abundance on muddy banks among Sparganium in the last 10 km.

(v) Common in all tributaries, with the exception of the Leet from which it was absent, and the Till from which it was only infrequently recorded. In the tributaries, Caltha grew in similar habitats as described for the Tweed, however the scanty records for the Till showed its inability to grow on unstable sandy banks which drain rapidly. The absence in the Leet could indicate intolerance of hard, nutrient rich waters.

(vi) In the Tweed, this species was most frequent on damp mud banks, and it was rarely emergent. When Caltha was found with its base immersed in water, it was so only in very slow currents. This was also reported by Ackenheil (1944).

Carex acuta (B)

(i) 68,78,81.

(iii) A single record only, on the left Berwickshire bank of km 88.5 just below Dryburgh Footbridge. In late August 1971 several tufts of non-fruiting Carex sp(p). were recorded on the shingly bank of a slow stretch. In June the following year the plants were fruiting, one with C. acuta fruits, the remaining ones proving to be C. acutiformis.

Several Carex other sp. records may well be C. acuta but since not all could be checked during the fruiting season this is uncertain.

(iv) Absent.

(v) Common on the banks of Lyne Water in km -0.5 where again, associated with C. acutiformis it grew forming thick stands at the edges of deep stretches. All plants had at least their roots permanently submerged and many had the basal parts of their shoots underwater. C. acuta was also recorded from similar localities on the banks of the lowest 10 km of the Till.

Carex acutiformis (B)

(i) 78,80,81.

(ii) See C. riparia.

(iii) Single record only for km 88.5 (see C. acuta).

(iv) *,*,*,1/1,5/10,4/12,*.(10/21)

Although only infrequently recorded, when present, C. acutiformis was often locally very abundant forming thick tufts at the edge of the river where it was confined to the upper reaches above Hawick. This is an anomolous distribution pattern when considering Clapham et al. (1962) description of C. acutiformis as a species of slow-flowing rivers, canals and ponds. However, in the lower stretches of the Teviot, suitable habitats were inhabited by dense growths of Sparganium erectum or Phalaris arundinacea whereas the many slow stretches above Hawick have stonier banks which are much more suitable for Carex species. The species ability to grow on shallow, yet permanently submerged shingle and stony banks accounts for its distribution pattern in the Teviot.

(v) A single record in Lyne Water in a habitat identical to that described for the Teviot.

Carex hirta (B)

(i) 80.

(iii) Absent

(iv) *,*,*,*,*,4/4,*.(4/4)

Only present in the upper stretches of the river, usually among C. nigra or C. rostrata. Plants occurred just above the low water mark on muddy rocky substrata .

(v) Absent in all others.

The presence of C. hirta in identical habits as C. nigra on the banks of the R. Teviot, but its absence in the Tweed, Ettrick and Yarrow may indicate an inability to grow on the banks of extremely base poor waters.

Carex nigra (B)

(i) 78,79,80.

(iii) 9/10,17/18,5/5,2/2,1/1,*,*,*,*,*,*,*,*,*,*.(34/36)

A species sharing its habitat with Cochlearia alpina, although C. nigra always grew among other fringe species including C. rostrata, Mentha aquatica Mimulus guttatus and Myosotis scorpioides.

Cochlearia, together with Mimulus & Myosotis have a straggly nature which results in them spreading away from the wall of species at the waters edge into the water itself, where, in shallow water at low flow they became rooted. The erect growth habit of C. nigra prohibits this, resulting in its presence in a more or less straight line at the immediate waters edge.

(iv) *,*,*,*,9/11,12/32,3/7.(24/40)

Identical habitat and distribution patterns as in the Tweed, being restricted to the stony banks of the upper stretches.

(v) Again, like Cochlearia, confined to the Western tributaries Biggar, Lyne, Yarrow and upper Ettrick. Clapham et al. (1962) suggest as a habitat - 'beside water, on acid soils' which is in general confirmed by most records, although the Lyne and Teviot could not be described as acidic. This description may well have arisen because in Britain most upland areas have a non-calcareous bedrock and hence tend to be neutral or acid. For a bank species such as this, it is not known whether distribution is most influenced by the soil, or the water chemistry or by both. How they are interrelated is also unknown.

Carex ovalis (B)

(i) 80.

(iii) Absent.

(iv) *,*,*,*,2/2,7/9,4/4.(13/15)

An upland species recorded only infrequently from the stony drier margins of the river. Not regarded as a critical fringe species since it often grew away from the river bank onto the rough drier ground surrounding the river.

(v) Absent.

Carex paniculata (B)

(i) 68,79.

(iii) Absent.

(iv) Absent.

(v) Restricted to the Yarrow, Ettrick and upper Till. In these tributaries, C. paniculata grew rooted in sandy substrates with a shallow covering of water. The confined distribution indicates preference for sandy banks rather than stony banks or muddy areas.

Carex riparia (B)

(i) 68,81.

(ii) Similar to, and often confused with C. acutiformis, but can be separated in the field by its larger size, wider leaves and ovate, obtuse ligules. In the flowering state, the large inflorescence provides additional differences to assist in identification.

(iii) Absent.

(iv) Absent.

(v) Confined to the Berwickshire rivers Leet (in which it was common and locally very abundant) and Blackadder, and a single record in Cheviotland in the Till at km -5.5. In all sites, C. riparia was found at the edge of the river rooted directly in the mud of slow flowing stretches that have a permanently high water mark. The Leet Water, with its nutrient rich water and its numerous slow reaches flowing over fertile alluvium formed ideal habitats. The Blackadder, with many similar reaches, also supported healthy growths. More than a single record in the last 20 km of the Till might have been expected, however the sandy porous nature of the banks were probably too dry for this species.

Carex rostrata (B)

(i) 68,78,79,80,81.

(iii) 3/3,5/5,11/14,4/4,6/8,4/6,1/1,5/5,1/2,*,2/2,3/3,1/1,3/5,12/26.(61/85)

The most widespread of all Carex species in the river, being present in the very highest reaches and also found well into the tidal reaches. Although often associated with the C. nigra assemblage described under that species, C. rostrata continued to be present down the whole length of the river until it reached its maximum abundance in the freshwater tidal area. Here, on the muddy banks where a high water mark is guaranteed at least twice daily it was common and locally very abundant.

(iv) 1/1,*,*,1/1,4/10,10/26,3/4.(19/42)

In the Teviot, C. rostrata was also the most widespread and common of all Carex spp., and had its maximum abundance in the upper reaches.

(v) Present in all tributaries except Jed, Eden and Till and most common in Leet Water.

From its distribution in the Tweed and tributaries, C. rostrata appears to have two distinct habitats: (a) among vegetation, between pebbles and small stones at the damp flat margins of fast flowing water, (b) at the sides of slow flowing reaches which have shallow water logged margins, a continuous high water mark and abundant mud. In ·pper Tweed, Teviot, Lyne, Yarrow and Ettrick the species was found in the former habitat (a), and its abundance in tidal Tweed, Biggar, Leet and Blackadder was due to features described in (b). Neither features (a) nor (b) are found in the Till, possibly accounting for its absence there.

(vi) Reported from the banks of the N. Tyne, Tyne and Wheel of the Tees. Rarely quoted in the literature, but Ackenheil (1944) found it confined to very slow stretches rooted in mud.

Carex other spp.

(ii) By late August and September 1971 many Carex species had lost their fruits. Non-fruiting material was recorded as Carex other spp. and many of the sites were revisited in the preceding two years when fruits were abundant. It was impossible to resurvey all sites and 25 0.5 km lengths had to be left unchecked, and the presence of Carex recorded to genus level only.

(iii) 4/4,4/4,2/2,*,*,1/1,1/1,*,4/4,*,3/3,3/4,3/3,*,*.(25/26).

The distribution is plotted, but a discussion is futile.

Cochlearia alpina (B)

(i) 78,79,80.

(iii) 13/13,19/19,2/2,*,*,*,*,*,*,*,*,*,*,*,*.(34/34)

A species of similar distribution as Ranunculus flammula, both of them being restricted to the highest stretches of the river only. However Cochlearia was a species which was often partially submerged, even at low flow. Its preferred habitat was between stones which had a weak and shallow flow of water over them.

(iv) *,*,*,1/1,2/2,6/6,4/5.(13/14)

Identical habitat as the Tweed but less common.

(v) Recorded only from the western side of the Tweed Basin, which includes the Biggar and Lyne, and the upper 10 km of the Yarrow.

(vi) The distribution in the Tweed might suggest confirmation of the description of Cochlearia by Clapham et al. (1962), who stated that it is "a local plant in mountain streamlets and flushes, and on wet rock ledges".

Eleocharis palustris (B)

(i) 68,77,78,79,80,81.

(iii) *,6/7,7/7,8/9,11/15,11/21,12/13,15/18,14/19,16/27,18/28,18/32,16/19, 18/24,15/23.(185/262)

In the Tweed, Eleocharis was often found in the same localities as Sparganium erectum, however the former extended further up the river, and was more abundant in the lower stretches. Presence/abundance ratios indicate that in the upper reaches, whenever Eleocharis was present, it never formed pure stands on the river bank, but its thin vertical stems often appeared through the vegetation of other fringe species. In the lower stretches pure clumps of Eleocharis became more common, usually with their roots embedded in waterlogged mud.

(iv) 14/34,13/21,12/21,2/2,8/12,8/11,2/2.(59/103)

A very similar distribution pattern as in the Tweed with its most prominent occurrence in the last 10 km. The species was also present in the extreme upper stretches.

(v) Present in all tributaries, but most common in the upper 20 km of the Blackadder and to a slightly lesser degree in the Whiteadder also (see Sparganium erectum)

(vi) Eleocharis has been recorded from the banks of rivers in N-E. Engl--and, and as the Tweed, it was usually most frequent at the edges of very slow flowing stretches, and only occasional from those with moderate to fast current velocities. In the Teuronjoki, Sirjola (1969) found Eleocharis confined to stretches with very low current velocities. In both the Tweed and Teviot, Eleocharis occured much further upstream than Sparganium, however, Sirjola reported that the tolerance of the former species to high current velocity was half that of the latter species.

Elodea canadensis (S)

(i) 68,78,79,80,81.

(iii) *,*,10/16,17/29,20/58,20/66,20/39,20/48,20/50,20/52,20/46,20/31, 20/29,18/40,16/50.(241/554)

Absent in the upper 23 km where there were no stretches deep and slow enough for this species. The most upstream record for Elodea was two kilometers above the influx of Biggar Water. From km 34.5 to km 133.0, Elodea was present in every 0.5 km length. This species was often abundant and was third only to Ranunculus penicillatus var. calcareus and Eurhynchium riparioides in total abundance. Elodea, although occasional on shingle in quite fast flowing water, was most characteristically a species of the slowest stretches of the river. Reaches approximately 1.0 m deep which had substrata of fine mud were the most favoured habitat of this species.

(iv) 19/33,19/41,18/42,14/36,*,*,*.(7Q/152)

Distribution as in the Tweed but less abundant. In the Teviot Elodea was only eighth in total abundance.

(v) Absent in the Yarrow, Ettrick and Jed and the most upstream sites surveyed on the R. Till and Blackadder. Elodea was most abundant in the Biggar.

(vi) The physical characteristics of the main river and tributaries where Elodea was found agree closely with findings of the following workers: Iverson (1929) who found the species only in neutral to alkaline waters, and Sirjola (1969) and Haslam (1971), who correlated Elodea with slowly flowing water and fine substrata, yet capable of growth in medium paced water. In the Moosach, Elodea was present throughout the length of the river, regardless of the state of pollution (Kohler et al. 1971).

Elodea is possibly the most documented aquatic plant species found in this country. Probably the first paper published was by Marshall (1852 and 1852a), several others followed, but a more comprehensive paper dealing with its habit and distribution appeared in 1885 by Siddall. All papers of the nineteenth century referred to it as the American Pondweed (Anacharis alsinastrum Bab.)

Elodea was originally a native of North American rivers and was introduced into this country in a still unknown way. The first locality in which it appeared in mainland Britain was in the Tweed area in the lakes of Dunse Castle, on the banks of the Whiteadder, on the third of August 1842 by G. Johnston. By 1847 Johnston (1851) reported that it had spread into its receiving stream and also to the Whiteadder itself. In 1850 the

Whiteadder had become almost choked by it, so much so that it had to be dredged to stop flooding at Gainlaw Bridge (km - 1.5), and the "Tweed was so full of it as to be a serious hindrance to its salmon fisheries" (Siddall 1885). By 1850 *Elodea* had spread to many rivers and reservoirs in Great Britain. Marshall (1852,57) reported its recent appearance in the Great Ouse and Cam which was causing serious navigation and drainage problems. The problem became so serious in the Fen District that Mr Rawlinson was appointed by the Government to look into, and advise on the best way to counteract its danger. By 1880 it had spread not only all over the whole of Britain, but also over the greater part of Europe (Ridley 1930). This speed of invasion, and subsequent domination by *Elodea* of its habitat are phenomena unparalleled in Britain (Siddall, 1885; Walker, 1912; Sculthorpe, 1967). The above authors also discussed the fact that the dominance of the species and the problems that it caused rarely lasted more than seven years.

Equisetum fluviatile (B)

(i) 68,78,79,80,81.

(iii) *,11/11,11/13,7/9,7/7,9/13,7/7,7/7,6/6,7/8,15/17,4/4,10/12,9/11, 3/3.(113/128)

Absent in the upper 10 km, but below this, recorded at infrequent intervals , depending on local conditions. *Equisetum* was rarely submerged, but more commonly rooted in shallow mud between stones, on damp sandy silt, or even straggling over the drier loose stones on the bank side where its long roots penetrated to the damp sand below. Apart from this latter habitat, Equisetum was often found growing with Juncus acutiflorus. The upper 10 km of the Tweed with its few silted edges was an unsuitable environment for Equisetum.

(iv) 4/4,6/6,8/9,10/13,17/20,16/18,4/8.(65/80)

Found in similar habitats as in the Tweed which accounts for its rarity in lower Teviot and its abundance in the upper stretches. Physical features of the upper stretches of the Teviot and Tweed contrast strongly.

(v) Absent in the Biggar, Lyne and Jed, and present, but rare in other tributaries.

(vi) Occasional at the edges of all N-E. rivers, including the Wheel of the Tees. When Equisetum was found submerged, it was so only in slow current velocities. This agrees with the findings of both Ackenheil (1944) and Sirjola (1969).

Filipendula ulmaria (B)

(i) 68,77,78,79,80,81.

(iii) 6/6,20/22,16/16,16/20,17/20,12/14,7/7,9/9,6/6,7/9,13/14,8/9,3/3, 2/2,1/1.(143/158)

A liking for similar habitats as Caltha palustris resulting in a distribution pattern resembling it. However, Filipendula was much more common in the upper stretches and less frequent than Caltha in the tidal region.

(iv) 10/12,12/17,4/4,10/10,20/23,17/28,4/6.(77/100)

Similar distribution as in Tweed, being most common on moist rough ground adjacent to the river.

(v) Present in all tributaries in similar habitats as previously described,

In the Tweed Basin, this species usually occurred in habitats that receive only periodic submergence.

Glyceria fluitans (B)

(i) 68,77,78,79,80,81.

(iii) 5/5,3/3,5/5,7/11,15/19,9/13,4/4,9/9,4/4,3/3,5/5,10/12,13/16,8/8, 3/5.(103/122)

Never abundant but present in all 10 km stretches of the river. Glyceria was only capable of growing rooted in soft mud in slow flowing, shallow water at the sides of the river; as a result, it gradually increased down stream as more suitable habitats increased. In apparently suitable habitats in the lower stretches it became less abundant, possibly due to competition from other bank species.

(iv) 5/5,4/4,12/13,13/14,14/25,17/32,4/6.(69/99)

Growing in similar habitats as in the Tweed where the plants spread from the bank with their stem and leaves floating on the surface of the water and their floral shoots erect above the rest. Glyceria was more common in upper Teviot than in any 10 km of the Tweed, however further downstream, it became less abundant as in the Tweed, and possibly for the same reasons outlined above.

(v) In similar habitats as described above in all other tributaries. Glyceria shows a very wide distribution effected by physical and competitive factors, but not chemistry. Its distribution, habitat preference and straggling growth pattern was most similar to Juncus acutiflorus. However, Glyceria was most strict in its needs to be rooted in soft mud or sand, and to be always at least partially submerged, which probably accounts for it being less common.

(vi) Recorded from the N. Tyne and Tyne where it was as common as in mid-Teviot; and present in the lower Wear and Tees. Backhaus (1967) and Szemes (1967) reported it to be common throughout the Danube, including the headwaters Breg and Brigach. Both Ackenheil (1944) and Sirjola (1969) found this Glyceria species in very slow to moderately flowing water. In the Tweed, however, it was restricted to slow flowing water.

Iris pseudacorus (B)

(i) 68,78,79,80,81.

(iii) *,*,3/3,1/1,2/2,*,3/3,3/3,*,1/1,3/3,2/2,*,2/2,1/1.(21/21)

Isolated records down the whole length of the river from km 21.5 Iris had a similar habitat preference as Sparganium erectum for slow flowing stretches with muddy banks.

(iv) 7/10,*,*,1/1,1/1,1/2,*.(10/14)

Rare, except in the slow, near stagnating lower stretches with their banks of deep mud.

(v) Absent from Eden Water and present but never common in other tributaries except in the Leet and Blackadder. In particular, the latter with its slow flowing hard water and soft muddy banks had abundant growths of Iris. These features were particularly favourable for the species which grew with Butomus umbellatus and Sparganium erectum in large continuous stands to the exclusion or reduction of many other bank side species.

(vi) Rare in the N. Tyne and Tyne, not reported for the Wear although present, and occasional in the lower stretches of the Tees. Although in the Tweed Basin, Iris was present in the same stretches as Sparganium, Ackenheil (1944) and Sirjola (1969) both found that the latter was capable of growing in twice the flow rate as the former.

Juncus acutiflorus (B)

(i) 68,77,78,79,80,81.

(iii) 11/11,20/21,20/22,14/17,10/12,12/16,9/9,7/7,12/14,14/17,13/14,6/7, 10/10,17/18,14/14.(189/209)

A species equally healthy rooted among other vegetation between damp stones or on mud and sand at the waters edge or partially submerged. J. acutiflorus had an unbroken distribution from source to mouth but with a reduction in abundance in mid-river due to heavy shading by trees and other bank species. However in the wider tidal limits with its flatter muddy expanses and constantly changing diurnal water level it again increased. This was the fifth most abundant bank species.

(iv) 4/4,5/5,13/15,6/6,16/24,20/45,4/7.(68/106)

Like Glyceria fluitans, J. acutiflorus most abundant distribution was in the upper reaches of the Teviot and was likewise adversely affected by competition for bank space in the lower stretches. It was also the fifth most abundant bank species in the Teviot.

(v) A common species, recorded from most lengths surveyed and present in all tributaries.

Juncus effusus (B)

(i) 68,77,78,79,80,81.

(iii) 17/18,18/20,20/23,19/11,9/10,13/16,4/4,2/2,6/6,8/10,5/5,1/3,2/2, 3/3,2/2.(119/135)

J. effusus more or less gradually decreased downstream, being frequently recorded in the upper stretches, but only rarely below Teviot Foot. In the upper stretches it was common either rooted in soft mud or on firmer moist ground among stones. The latter habitat becomes rarer downstream, while the former is colonized by many other species.

(iv) 4/4,3/3,6/6,1/1,5/5,19/28,4/7.(42/54)

Identical habitat and distribution pattern as in the Tweed.

(v) Present in all tributaries except Jed Water, being least common in the Ettrick and Whiteadder and most common in the Till and Blackadder.

(vi) *J. effusus* is a common species in rivers in N-E. England. It is also common in rivers in mainland Europe, as illustrated in the Danube : Backhaus (1967) and Szemes (1967) reported its presence from the uppermost reaches of the Breg to the lowermost delta region.

Juncus inflexus (B)

(i) 68,80,81.

(iii) *,*,*,*,*,*,*,*,*,*,*,1/1,4/4,1/3,*,4/4.(10/12)

Confined to the lower stretches of the river where it was recorded only rarely. *J. inflexus* was present only on soft muddy banks just above the water level, but unlike *J. effusus* never grew on damp stony ground.

(iv) 8/10,2/3,10/12,*,*,*,*.(20/25)

Like the Tweed, *J. inflexus* in the Teviot was restricted to habitats in downstream localities, but was more common.

(v) A species of distinct lowland distribution being absent from all tributaries above the Teviot, but common in all tributaries below it. *J. inflexus* was least abundant in the Whiteadder, and most common on the soft, sandy banks of the Till.

Lemna minor

(i) 80,81.

(iii) Absent.

(iv) 6/8,*,*,*,*,*,* (6/8)

Confined to the bottom 5 km of the Teviot where it was by no means rare. *Lemna*, owing to its physical form as a small floating thallus was confined to the deep slowly flowing stretches of the river. In these stretches it was always absent from the centre of the river where the flow was at its maximum but present nearer the margins where flow was minimal and the thalli were held by larger rooted macrophytes such as Potamogeton perfoliatus, P. salicifolius and Myriophyllum spicatum.

(v) Absent in all tributaries except the Leet Water in which it was locally very abundant in the last three 0.5 km lengths and in the Blackadder Water at km -30.5. In the Leet, Lemna was held in the long and copious growths of Enteromorpha flexuosa, whereas in the Blackadder Ranunculus fluitans and Myriophyllum spicatum retained the thalli.

Lemna minor is probably the only genuine free floating macrophyte recorded from the Tweed Basin. Its confined distribution in Lower Teviot, Leet and single locality in the Blackadder suggests that in addition to a requirement for slow flowing water, Lemna also had a requirement for hard water rich in nutrients. This is probably due to all nutrient uptake being from the water and lack of rhizoidal or root absorption from the substratum. More than any other angiosperm, the distribution of Lemna was dependant on flow rate and flood conditions.

(vi) Lemna has not been reported from the N. Tyne, Tyne or Tees, but Whitton and Buckmaster (1970) reported its frequent occurrence in the Wear during summer.

In other British, and also European rivers, L. minor has been recorded many times. Haslam (1971) regarded the species in rivers as an "opportunist", confined to still or very slow flowing stretches. A wider habitat range than seen in the Tweed was reported by Iverson (1929) who found L. minor to be capable of growing in either very strongly acid or alkaline waters. This was confirmed in the Danube by Backhaus (1967) and Szemes (1967), the former reporting its presence in the Brigach, "an acid and nutrient poor" headwater, and the latter throughout its lower sections including the delta region. Both Kohler et al. (1971)

for the Moosach, and Wølek (1971) for the Dunajec found the distribution of L. minor to be unaffected by the nutrient status of the water. Iverson and Ohlsen (1943) described it as a eutrophic species.

Mentha aquatica (B)

(i) 68,78,79,80,81.

(iii) 1/1,12/16,13/15,10/10,13/13,4/5,3/3,4/4, * ,6/7,4/4,3/3,*,1/1, 1/1.(75/85)

Mentha was common on damp stones, gravel or course mud at the sides of the river, but rarely extended down into the river to be permanently submerged. It was absent from the most upper stretches of the river, becoming common below this, but lower downstream where Phalaris arundinacea becomes the dominant waterside species, Mentha was restricted to fewer localities where it occupied the stonier banks. This appears to be due to the inability of the tough matted rhizomes of Phalaris to penetrate a tight stony substratum, while the Mentha habit can take full advantage of this.

(iv) 10/11,3/4,4/5,7/8,15/20,15/21,4/5.(58/74)

Similar distribution and habitat as in the Tweed, however in the Teviot, Mentha was frequently permanently rooted in shallow water accounting for its increase in abundance in the lower 10 km. In the upper 20 km, Mentha was more common than in any stretches of the Tweed. The numerous damp stony banks favouring abundant growths of Carex spp., also supported Mentha in large quantities.

(v) Common on the banks of all tributaries and often very abundant, and on the banks of the Till, Blackadder and upper Whiteadder Mentha was particularly abundant. These tributaries, with their unstable sandy, soft muddy or more solid stony banks all represent habitats where Mentha thrives.

Mimulus guttatus (B) (see Fig. 7.3b)

(i) 68,78,79,80,81.

(iii) 17/21,20/26,19/21,20/26,19/21,19/25,13/14,9/9,14/16,13/17,16/16,
13/14,9/9,12/12,11/14.(224/274)

Similar habitat and distribution as Myosotis but with a distinct upstream preference. Damp mud among stones at the immediate edge of the river was the preferred habitat, although in some stretches Mimulus was often common on raised stones in the middle of the river where during low flow, water drains to either side. Mimulus was rarely tolerant of shade and was always absent among the thick fringe of bank species, but present away from it, nearest to or partially submerged at the water edge. Mimulus was the third most abundant bank species.

(iv) 20/24,20/26,19/28,15/15,15/18,15/22,4/9.(108/142)

In the Teviot, Mimulus was frequent between Sparganium erectum stands in the lower stretches and was less abundant further upstream. This species was the most abundant bank species in the river.

(v) Mimulus was absent in the Eden and Leet Waters and from the lowest 10 km of the Till, but elsewhere was common, especially in the upper Till and the whole of the Whiteadder. The absence in the Eden and Leet and its rare occurrence in the Blackadder suggests that Mimulus had a distinct lack of preference for the nutrient rich and hard water tributaries which had high conductivity, Ca and PO_4-P levels.

(vi) Present, and often frequent in all rivers in N-E. England. Butcher (1933) only reported Mimulus from the Dove and Itchen, both of which he described as highly calcareous rivers. The distribution in the Tweed does not suggest preference for calcareous habitats.

Myosotis scorpioides (B)

(i) 68,77,78,79,80,81.

(iii) 10/10,20/20,20/22,20/28,20/33,20/29,16/17,16/17,18/24,18/26,20/30, 19/21,20/21,20/25,18/20.(275/344)

Ubiquitous species, straggling among other more vertical fringe species on either muddy, sandy or stony substrata. *Myosotis* was recorded in more 0.5 km lengths than any other species.

(iv) 20/24,19/23,20/26,17/19,17/18,4/5.(97/116)

Distribution as in Tweed, again showing tolerance of shade caused by other fringe species. Less common than in the Tweed, being the fifth most recorded species.

(v) Abundant and recorded from nearly all 0.5 km lengths of tributaries surveyed. Unlike *Mimulus guttatus*, *Myostis* was common in Eden, Leet and lower Till, possibly being less affected by differences in water chemistry. The wider distribution might also be in part, due to the shade tolerance of *Myosotis*.

(vi) *Myosotis* is often frequent in rivers in N-E. England. In the Tweed and its tributaries, *Myosotis* was least abundant in upper reaches. Szemes (1967) found the same for the Danube, but Kohler *et al*. (1971) reported it more common in the upper stretches of the Moosach. Siedlecka-Binder (1967) found it remained vegetatively obvious throughout the year in an upland stream in Poland. Ackenheil (1944) reported *Myosotis* to be capable of growing in strong currents, however in the Tweed, it was very rarely submerged.

Myriophyllum alterniflorum (S)

(i) 77,78,79,80,81.

(iii) 18/33,16/26,20/39,20/48,20/57,19/45,20/39,20/32,18/24,19/31,17/27, 1/1,*,*,*.(208/402)

A permanently submerged macrophyte common from km 0.0 right downstream to Teviot Foot. With the influx of harder water and new species from that tributary, M. alterniflorum completely disappeared except for two plants which were recorded a little way downstream. M. alterniflorum was most commonly rooted in course sand between loose stones - the predominate substratum in the Tweed above Kelso in stretches with medium flow. However in the least favoured habitats of slow flowing stretches or in rapids, it was rooted in soft mud or in sand filled cracks between rocks respectively. This species was the only permanently submerged angiosperm present, and indeed common in the upper 20 km.

(iv) *,*,*,2/2.10/20,7/11,1/1,*.(20/34)

A vastly reduced distribution and abundance, being confined to twenty 0.5 km lengths between km 26.5 and 53.5. The upper Teviot with its unstable substratum was unsuitable for any permanently submerged angiosperms, and in the downstream slower stretches, M. alterniflorum was replaced by M. spicatum.

(v) Common and locally often abundant in all the upland tributaries Biggar, Lyne, Yarrow and Ettrick being present in all but three 0.5 km lengths studied. However M. alterniflorum was absent in the Jed, Eden Leet and Till. In the larger Berwickshire rivers Blackadder and Whiteadder, the Myriophyllum species occurred together. In the Blackadder M. alterniflorum was common in three 0.5 km lengths (-41.5, -42.0 and -42.5) at Greenlaw where it grew with M. spicatum. Below this, it was absent except for a scruffy rooted specimen (presumably a washed down fragment) in km -30.0. In the Whiteadder above Blackadder Foot, M. alterniflorum was present and usually most abundant in all 0.5 km lengths surveyed while M. spicatum was absent. Here M. alterniflorum was more abundant than in any other region of the Tweed Basin. Below Blackadder foot both species grew alongside each other, with M. alterniflorum showing preference for faster shallower stretches. On passing downstream M. spicatum dominated and M. alterniflorum disappeared from the last 10 km.

(vi) Occasional in N. Tyne, very rare in Tyne, absent in Wear and restricted to the Wheel of the Tees. The distribution in the Tweed Basin agrees closely with findings of Iverson (1929), and Iverson and Ohlsen (1943). They report M. alterniflorum to be restricted to very weak acid, neutral or very weak alkaline waters. The species also more commonly occurred in nutrient poor waters. Both Ackenheil (1944) and Sirjola (1969) agree that although M. alterniflorum is capable of growing in slow flowing water, it thrives most in rapid currents. This was also evident in the Tweed.

Myriophyllum spicatum (S)

(i) 68,80,81.

(iii) *,*,*,*,*,*,*,*,*,*,*,3/3,19/25,20/25,20/44,18/38.(80/155)

Once the Tweed was provided with an inocula of M. spicatum from the the Teviot in km 108.5, it occurred in all but one 0.5 km length between Teviot Foot and km 148.5 . This point in the estuary was also the last time Potamogeton pectinatus, P. perfoliatus, P. pusillus, and Ranunculus fluitans x? were recorded. Being a species confined to the lower stretches, M. spicatum showed more of a preference for deeper water than M. alterniflorum. However, in the Tweed the deepest slow flowing stretches were dominated by Elodea canadensis and Potamogeton spp. with M. spicatum growing most healthily and abundantly in fairly deep water with a moderate current. In shallowest faster stretches M. spicatum was rare and Ranunculus species dominant.

(iv) 20/66,20/68,20/44,12/24,*,*,*.(72/202)

Restricted again to downstream localities where it was more abundant than in any stretches of the Tweed. Many of the slow stretches in the Teviot are shallower than those of the Tweed which allowed M. spicatum to grow among the Potamogetans except in the deepest stretches. However, M. spicatum's greatest abundance was on the shingle stretches with moderate flow where many such regions turned a reddish colour from one bank to the other because of its abundance. Second most abundant angiosperm in the Teviot.

(v) Absent from the M. alterniflorum dominated tributaries Biggar, Lyne, Yarrow and Ettrick, but common in those rivers where the other species was absent, namely Jed, Eden Leet and Till. The Eden record was based on a few plants which extend up the tributary from the Tweed no more than 20 m.

M. spicatum was frequent in the Leet and Till. In the former it was often rooted in thick mud in deep water in near stagnant conditions. In the latter it was absent in the upper reaches which have a faster flow rate and a highly unstable substrate and it had a reduced abundance in the lower 10 km where it competed unsuccessfully against Potamogeton X suecicus. In the Blackadder, M. spicatum was common down its whole length and like the Teviots influence on the Tweed the Blackadder introduced the species into the Whiteadder. (For factors governing distribution see 9.2).

(vi) Absent in the N. Tyne and Tyne, rare in the Wear and locally frequent in the lower Tees from where it was described by Butcher et al. (1937). Butcher (1933) and Haslam (1971) both reported M. spicatum to thrive most in a moderate current flowing over mixed gravel or fine stones. The latter also reported that the species was strongly correlated with wide rivers.

M. spicatum has only been reported from moderate to highly calcareous rivers; Butcher et al. (1931, 1933 and 1937) Westlake (1968 and 1970) and Wølek (1971). Of the 50 sites described by Iverson (1929), M. spicatum was present in 13 out of 18 alkaline waters, but absent from all acid and neutral ones.

The distribution in the Tweed Basin confirms the findings of other workers in terms of physical characteristics and water chemistry. Seddon (1972) in his study of Welsh lakes found M. alterniflorum at an average height of 230 m as opposed to M. spicatum at an average of 70 m. His lowland sites, like those of the Tweed Basin were of greater hardness.

Phalaris arundinacea (B)

(i) 68,77,78,79,80,81.

(iii) *,16/17,18/23,19/38,20/49,20/46,20/40,20/43,20/42,20/36,20/33,20/27, 19/25,20/44,20/32.(272/495)

By far the most abundant bank species, being present (usually as frequent) in all but one 0.5 km lengths surveyed downstream from km 30.5. Occasionally small plants were found rooted in mud and shallow water, but most commonly the tightly knit fibrous rhizomes spread forming mats to the exclusion of other angiosperm species on the damp soil margin of the river. Because of this growth habit, Phalaris was unable to grow at the margins of the upper rocky stretches and was totally absent in the first 10 km. However as soon as the margin became less rocky Phalaris became common, although unable to compete with Sparganium for the muddier water-logged margins.

Under the dense shade produced by this tall reed like grass, the moss Brachythecium rutabulum was often common. In the slower stretches Polygonium amphibium, Myosotis scorpioides or Equisetum fluviatile often grew over the top of the rhizome mats and into the water.

(iv) 20/26,20/33,20/27,20/24,7/7,6/7,*.(93/124)

Identical distribution pattern as in Tweed, but with a reduced abundance in the lower stretches due to Sparganium dominance of the very muddy banks.

(v) The most ubiquitous of all angiosperms, being present in all but eight of the 0.5 km lengths studied in the rivers receiving partial survey only. In the Biggar and lower Ettrick it was particulary abundant. Phalaris, due to its matted rhizomes acted as bank stabiliser reducing considerably the effect of erosion and flood damage.

(vi) Holmes et al. reported Phalaris to be frequent at the edges of both the N. Tyne and Tyne, possibly indicating that the species is a frequent coloniser of river banks in rivers in N-E England.

Phragmites communis (B)

(i) 68,80.

(iii) Absent.

(iv) *,3/5,*,*,*,*,*.(3/5)

Restricted to the margins of deep slow stretches of the river between km -17.0 to -19.5. Its restricted distribution and its absence in the Sparganium erectum dominated lower reaches was surprising.

(v) Present only in the Till and again confined to one region (km -13.5 -14.0 and -14.5) where it was common. These Phragmites plants, like those in the Teviot, were rooted in shallow water and grew to a height in excess of 2.5 m. The absence of this species in other stretches of the Till and in the Leet, Blackadder or lower Whiteadder is surprising. The abundance of two species with overlapping habitat preference - Sparganium at the margins of the muddier stretches, and Phalaris arundinacea on the slightly drier banks could have resulted in Phragmites exclusion from many suitable sites.

(vi) This is a species that is characteristic of 'swamp' conditions (Clapham et al., 1962), and as such would only be expected to occur at the edges of slowly flowing stretches of river. This it did do in the Tweed Basin.

Polygonum amphibium (B)

(i) 68,78,79,80,81.

(iii) *,*,4/4,5/5,5/9,2/2,6/6,10/11,9/11,9/11,11/18,15/20,12/15,16/21, 7/9.(111/144)

A true amphibious species, rooted in mud at the waters edge from which it spreads away from the bank with stems and leaves floating on the surface of the water. This growth habit demands slow flow conditions which accounts for its absence in the upper 20 km and gradual increase down stream. The reduced abundance in the last 10 km results from the ever changing water level influenced by the tides.

(iv) 20/24,9/12,10/12,7/8,2/4,*,*,*.(48/61)

Identical distribution as for the Tweed. In the last 10 km Polygonum was more abundant than in any other region in the Tweed Basin.

(v) Absent in Yarrow, Ettrick and Jed, the two former tributaries being physically similar to the upper stretches of the Tweed. In the Biggar, Lyne and Eden, only solitary localities were recorded, while there were only infrequent records for the Till, Blackadder and upper Whiteadder. Only in the slow flowing Leet and parts of the lower Whiteadder was Polygonum ever common. Distribution appeared to be unaffected by differences in chemistry, the primary influence being availability of very slow flowing stretches with shallow muddy margins.

Potamogeton berchtoldii (S)

(i) 81.

(ii) Exceedingly difficult to separate from P. pusillus when growing in flowing water and microscopic examination is required for critical identification. The distinguishing features are the absence of lacunae along the midrib and tubular stipules of P. pusillus.

(iii) Absent.

(iv) Absent.

(v) Only present in the Blackadder and Whiteadder where it was common, and locally very abundant, especially in the lower 10 km of the Blackadder. In both Adder Waters it extended from the lowest to the highest reaches surveyed being absent from only four 0.5 km lengths.

In recent times, P. berchtoldii has been recorded on several occasions from v.c.68,78,79,80 and 81 from lochs all within the Tweed catchment area. Of the rivers, only in the Whiteadder has the species been recorded in modern times, although R. D. Thompson did collect a plant from the Tweed at approximately km 120 in 1831. The reported presence in the Blackadder is thus a new and previously unknown locality.

Potamogeton x cooperi (S)

(i) 81.

(ii) Distinguished from P. olivaceus by the amplexicaul leaves, derived from P. perfoliatus; and separated from P. perfoliatus (a parent species) by the fewer longitudinal nerves in the leaves, by the flattened stem and by sterility. The minute serrations on the leaf margin are also a diagnostic feature, derived from its other parent, P. crispus.

(iii) Absent.

(iv) Absent.

(v) Present only in Blackadder Water at Langton Burn Foot (km -24.0) where it was rooted among pebbles at a depth of 1.5 m at the edge of a very deep pool. P. x cooperi has never previously been recorded from Blackadder Water although in the early 1940's G. Taylor recorded it from four localities in the lower reaches of the Whiteadder. These localities were searched most thoroughly, but without trace of P. x cooperi. The exceptional floods of 1947 may have claimed this rare species. No records exist for the Tweed or any of its other tributaries.

P. x cooperi has been reported from numerous scattered localities in the British Isles suggesting random hybridization. The presence of this hybrid immediately below the site where the two parent species grow side by side, certainly suggest in situ hybridization either in ancient or more modern times. Since the Blackadder flows into the Whiteadder (from which river previous recordings exist) and then into brackish tidal Tweed, there was a reduced possibility of subsequent spread into the Tweed.

Potamogeton crispus (S)

(i) 68,77,78,79,80,81.

(ii) *,*,7/11,11/11,11/16,9/11,15/21,17/25,11/16,13/20,11/11,9/15,12/14, 13/16,11/11.(150/198)

The most common and widely distributed Potamogeton, yet never as locally abundant as several other lowland species its distribution spanned the Tweed from km 26.0 downstream to the estuarine reaches in km 148.0.

In the upper stretches P. crispus was totally absent,but on passing downstream it became common at the edges of slower flowing stretches which had muddy substrata. As current velocity was reduced on passing downstream it occupied the more stonier stretches,and was not confined to the shelter of the bank. In the lowest stretches,the deep,slow,muddy reaches were dominated by larger Potamogeton spp., but P. crispus still occurred in the shallower stretches - which in the lower Tweed is a more or less physical equivalent of the deep slower stretches in upper and mid Tweed.

In slow flowing water, typical P. crispus - robust and with crinkled leaves predominates, but in the faster flowing water a small, reddish form with smooth translucent leaves was more common.

(iv) 19/28,16/27,18/30,17/46,*,*,*.(70/131)

Much more abundant than in the Tweed and again the most widespread pondweed. The furthest upstream record was from km -38.0 where a weir above Hawick produces a large deep muddy stretch, in which Elodea canadensis and P. crispus both have their upstream limits. Above this point, the unstable substratum proves unsuitable.

(v) Absent only in the Yarrow and upper Ettrick, but common elsewhere, thus adding the Biggar, Jed and Eden Waters to the previous list of known localities. A solitary record collected by R. D. Thompson for Leet Water in 1831 was also confirmed. In the Blackadder, and in particular the Whiteadder, P. crispus was most abundant, and in the latter river in slow stretches was the dominant plant.

(vi) This species was common in the N. Tyne, Tyne and Wear. In the latter river, P. crispus had a wide distribution, and like the Tweed, it was absent only from the upper reaches. Butcher (1933) reported this species to be frequent in the lower Tees, and like other aquatic angiosperms absent from the river above the entry of the Skerne except in the Wheel. Butcher (1933) reported P. crispus to be the most widespread Potamogeton species in British rivers, being absent only from acid waters.

In macrophyte surveys of European rivers, P. crispus is also almost always recorded: examples include Roll (1938), Weber (1967), Backhaus (1967), Szemes (1967), Kohler (1971), Wølek (1971) and Weber-Oldecop (1973). The above might suggest that the wide distribution of the species in the Tweed is typical.

Potamogeton lucens (S)

(i) 68,80,81.

(iii) *,*,*,*,*,*,*,*,*,*,*,*,*,*,*,1/2,3/7.(4/9)

Three localities in four 0.5 km lengths in the last 20 km indicates the restricted nature of this species distribution. P. lucens was present near Till Foot (131.5) Horncliffe (143.0) and common in the area of Union Bridge (145.0 and 145.5). All these localities have previous known records, and P. lucens was also recorded from near East Mill Ednam (km 114) and at Norham (km 138) by G. Taylor in 1941/42, but these records were not confirmed. Johnston (1829) also found P. lucens in the Tweed at Union Bridge.

(iv) 2/6,*,*,*,*,*,*,*.(2/6)

Again a restricted distribution of only two localities. The lower locality, near Teviot Foot (km -1.0) has been known since A. Brotheston first collectd specimens there in 1870, however the specimen at Kalemouth Bridge (km -9.0) has only been known for ten years.

(v) Absent in all tributaries except the Till where it extended up the last 100 m only. This more or less stagnant, very deep stretch with its thick soft muddy substratum was apparently an ideal habitat for P. lucens which more or less covered the river from bank to bank.

With the exception of some plants at Kalemouth Bridge on the Teviot, all records are from similar habitats as described for the Till. However, above Kalemouth Bridge, under the shade of over hanging trees on the right bank a few P. lucens plants were present rooted among rocks at a depth less than 0.5 km.

The old records indicate that P. lucens was capable of with standing the gross pollution in the Teviot and to a lesser extent that in the Lower Tweed reported in the nineteenth century. However they also serve to show that P. lucens in over 100 years has spread into few if any new localities. If upstream migration is discounted, it is logical to suggest that the Teviot was most likely to be responsible for the inoculation of fragments into the Tweed which have become rooted at Till Foot and in the tidal Tweed. From its scattered distribution, fragmentation and subsequent rooting is a rare occurrence in the river. Fragmentation presumably is confined to flood periods and if this is so, the localities where P. lucens has become rooted in the Tweed are somewhat predictable. Often the Tweed and Teviot may be in flood while the Till is not, and under these conditions plant fragments might collect in the deep water at Till Foot. Similarly, in the tidal area at high tide the advancing sea water holds back the fresh water, resulting in plant fragments collecting and being held, and possibly, subsequently becoming rooted. This could possibly account for the lack of colonization in many other suitable habitats, and its presence in those described.

(vi) P. lucens is not present in rivers in N-E. England. Butcher (1933) reported its presence only in the Lark, a highly calcareous, slow flowing river where in the slowest and muddiest reaches it was the dominant plant. Szemes (1967) and Krause (1971) reported P. lucens to be present in the lower stretches of the Danube, and in deep alcoves in the Rhine, respectively. The above authors would suggest that as in the Tweed, P. lucens only occurs in rivers where the substratum is muddy, and current velocity is slow.

Potamogeton natans (S) (see Fig. 7.3b)

(i) 68,78,80,81.

(iii) *,*,2/2,*,*,*,*,*,*,*,*,*,*,*,1/1,1/3.(4/7)

Restricted to four localities at km 21.5, 27.5, 132.5 and 145.5. The first three records were from small alcoves and thus, although directly affected by changes in the water level of the river they were not in the direct current of the river. The latter record was from the same tidal stretch in which P. lucens was so common.

(iv) 3/7,1/1,*,1/1,*,*,*,(5/9)

Although not previously recorded from the Teviot, P. natans had a wider distribution than P. lucens, being present in km -0.5, -1.0, -9.0, -19.0 and -38.0, the upper record being from the dammed deep muddy stretch above Hawick which is also the upper limit for P. crispus and Elodea canadensis. Muddy but not excessively deep slow stretches at the side of the river where the preferred habit of P. natans, although at Kalemouth Bridge it grew on a stonier substratum in the main current of the river.

(v) P. natans was present in the Biggar, Jed, Blackadder and Whiteadder, although previously not recorded in any of these tributaries. In the Biggar, with its predominately soft muddy substrat and canal like character, P. natans was the fourth most abundant macrophyte. In the Blackadder, P. natans was common in slow flowing stretches of water above Greenlaw and in km-29.5. The two lowland localities in the Whiteadder were physically very similar to the stretches in the tidal reaches of the Tweed where P. natans was present.

P. natans was recorded in 1939 from the Lyne Water at Ramanno Bridge which is well above those reaches I surveyed. It has also been recorded from Bowment Water, a tributary of the Till, and a century ago from two localities in the Tweed just below Teviot Foot.

P. natans showed tolerance of a wide range of altitudes and water chemistries but was mostly restricted to slow stretches of rivers, not exceeding 1.0 m in depth but with muddy substrata. The preferred substratum was often of a black organic nature.

(vi) Present in the N. Tyne, Tyne, Wear and Wheel of the Tees. In these rivers it was always restricted to the edges of slow flowing stretches, and rooted commonly in black mud. Although widely distributed, Butcher (1933) only recorded P. natans in the Lark. This species has been recorded as common from many European rivers. In the Aller, Weber-Oldecop (1973) reported P. natans to be a most abundant species.

The scattered distribution in the Tweed Basin suggested ability to grow in a wide variety of water chemistries. Iverson (1929) found P. natans in waters ranging from strongly acid to alkaline. Sirjola (1969) only found this species in the very slowest currents, but Ackenheil (1944) recorded that although most common in still or slowly flowing water, P. natans was also capable of growing in waters with a moderate current. The findings of the latter author agree with the observations made by the present author for the species in the Tweed Basin.

Potamogeton x olivaceus (S)

(i) 68,78,79,80,81.

(ii) This species is a hybrid cross of P. alpinus and P. crispus. Plants have features of both parent species, the hybrid loosing the P. crispus crinkled, serrated and often rounded leaf structure, although in habit the species most resembles that parent.

(iii) *,*,10/12,17/29,18/38,13/35,4/5,4/4,3/3,2/2,1/1,1/1,*,1/1,*.(74/131)

Previously only recorded from the Tweed in v.c. 78 (Peebles) from which it had been intermittently recorded for the past 100 years. P. x olivaceus was first recorded in the Tweed at km 24.0, two kilometers above the upper limit of P. crispus. Both species shared similar habitats but P. x olivaceus preferred moderately deep stretches of medium flow and muddy substrata. For the lower 40 km of the Tweed in Peebleshire

P. x olivaceus was common and locally abundant, being particulary common below the Peebles sewage outflow pipe. However, on passing downstream it becomes progressively less abundant, and was only recorded in three isolated 0.5 km lengths in the last 50 km of the river. The presence of the species in Selkirk (v.c. 70) and Roxburgh (v.c. 80) were the first records for the counties.

(iv) Absent.

(v) Present in the Lyne, Eddleston, Blackadder (new record) and Whiteadder. In the latter river, P. x olivaceus had been known to exist there in several sites since 1942. A record by R. D. Thompson in 1831 for the Leet Water was not confirmed, but a sufficiently intensive search was made in the exact locality to point to its disappearance since that date.

P. x olivaceus was recorded in two 0.5 km lengths in Lyne Water but each represented single small plants. It is noteworthy that D. J. McCosh in 1972 recorded it from Tarth Water, a small tributary that flows into Lyne Water at km -7.8. In the Eddleston Water at Peebles it was noticed to be present at the chemical sample point. In the lower Blackadder and Whiteadder below Blackadder Foot, P. x olivaceus had an intermittant distribution. However it was often most abundant, in the former river particulary around Langton Burn Foot (km -24.0) and in the latter, around Hutton Castle (km -14.5).

P. x olivaceus is a rare hybrid known in Britain only from a few Scottish rivers that flow into the North Sea. They are the Tweed and its tributaries, the Earn in mid Perth and the Ytham in North Aberdeen.

It is possible that P. x olivaceus in the Tweed and its tributaries is an ancient clone that persists in the rivers in the absence of one parent species P. alpinus. It is not impossible that this P. x olivaceus clone originated in the Tweed, since one parent species P. crispus is ubiquitous and the other, P. alpinus is present within the basin. However it is noteworthy that both ancient and modern records for P. alpinus are from small lochs and burns flowing into tributaries that do not contain the hybrid. In the last 20 years P. alpinus has been recorded in several localities at approximately 340 m on the moors above Ale Water, a tributary of the Teviot where the hybrid is absent. Other modern records are for recently made reservoirs.

In 1881 P. alpinus was recorded from Gordon Moss which is within the Eden Water area, and G. Johnston (1853) describes P. rufescens (a synonym of P. alpinus) from the Eden and ditches leading to it.

Since upstream migration of P. x olivaceus from the Tweed has not occurred up the Ettrick, Teviot, Till and other small lowland tributaries, and there is only evidence for downstream migration of other Potamogeton spp., it is suggested that the species did not migrate up the Whiteadder and then up the Blackadder.

With this in mind, there are two main possible explanations of the unusual distribution pattern of P. x olivaceus in the Tweed Basin. (a) The hybrid was at one time a common species of the Tweed and its tributaries and possibly in many other rivers too. Perhaps, due either to climatic or human changes in the rivers it became rare, and the present localities represent its refuge. If the mills of the early 19th Century were responsible for the extermination in the Tweed Basin, then the distribution pattern that exists today is explicable. Suitable physical habitats on the Ettrick are confined to the stretches below Selkirk and similarly with the Teviot below Hawick. The mill effluent would thus have entered the river at or above the upstream limit of the species if they were present at that time. In the Tweed, the Peebles mills, and further downstream the Gala mills could have had a similar effect, however suitable localities above Peebles would allow P. x olivaceus to remain, and then spread downstream when the river was cleaner. The Churnside industries caused pollution of the Whiteadder but apart from domestic and farm eutrophication, the Blackadder has received little or no industrial pollution. P. x olivaceus could thus have remained there too. If the industrial effluent was sufficient to kill P. x olivaceus, it would have disappeared from those stretches of the river mentioned. With the improvement in river conditions it would then be able to reinvade former localities.

(b) The other possibility is that the upper Tweed and Berwickshire populations arose in situ, one parent, P. crispus remaining, while the other, P. alpinus became extinct in most localities. The upper Tweed and Berwickshire populations would thus be separate clones.

Both theories could explain the present distribution pattern and the former might suggest that P. x olivaceus may increase still further in the future.

Potamogeton pectinatus (S)

(i) 68,80,81.

(iii) *,*,*,*,*,*,*,*,*,*,*,3/4,20/58,20/47,16/31.(79/192)

The upper limit of distribution for P. pectinatus was the immediate 0.5 km length below Teviot Foot (km 108.5), and the lower limit was km 148.5. Between these points it was common, locally abundant and present in all but two 0.5 km lengths.

P. pectinatus was absent from very shallow water, showing a preference for stretches between 0.5 m and 1.0 m with a moderate to fast flow rate. In deeper stretches with little current, plants rarely looked healthy and were commonly covered by a thin film of fine mud. The species thus predominately occupied a 'middle of the river' position, being rarer in the deeper slow sections.

(iv) 14/38,*,*,*,*,*,*,*.(14/38)

Very common in the bottom thirteen 0.5 km lengths, but above this, recorded in only one locality (km -9.5). The preferred habitats were the same as in the Tweed.

(v) Absent in all upland tributaries, and present only in the three most lowland affluents, Leet, Till and Whiteadder.

P. pectinatus had previously been recorded from Leet Water in 1837 where in the lower 1.5 km it was not rare in 1972. As the lower 0.5 km length received Tweed water via a mill lade, backward migration for the short distance upstream either in ancient or modern times most probably accounts for its presence here.

The presence of P. pectinatus in the R. Till is of particular interest and significance and is discussed later under P. x suecicus. Its very scattered distribution in only five localities in the lower 20 km are the first records for the river, although in 1870 A.Brotherston collected plants from Yetholm Loch. This loch drains into Bowment Water, which flows into the Till five km above the highest record for P. pectinatus. This species is thus possibly present in Bowment Water also. In the White-adder, P. pectinatus was very abundant, but restricted to the lowest few kilometers only, where, Johnston (1829) reported it to be 'plentiful' at the turn of the nineteenth century.

The overall distribution pattern in the Tweed Basin shows P. pectinatus to be a distinct lowland species, and with the exception of the Till, to be one that thrives wherever it is present. Records of over a century ago indicate that the distribution of P. pectinatus has changed little over this period. Even the single record in the Teviot upstream of the main, heavily populated area was recorded in 1869, with no collections from the river between the two. As stated previously this species was also known from many sites on the Tweed as well as the Leet and Whiteadder. The only new records are from the R. Till, in which it was rare, and probably been overlooked by previous collectors. P. pectinatus was also collected in 1960 (J. E. Dandy, personal communication) in a small mill stream at Oxnam, a tributary of the Teviot.

(vi) P. pectinatus was not present in the nearby N. Tyne and Tyne, although locally frequent in the lower stretches of the Wear and Tees.

Arber (1920) reported that in Britain P. pectinatus was a very common species that only flourished at low altitudes. However, she pointed out that elsewhere, including Venezuela and Tibet it could thrive at a height of 5000 m. Hynes (1960) referred to P. pectinatus as an indicator of silted waters. In European rivers the species is very common, and Iverson (1929) found that it was confined to alkaline waters. In the Tweed Basin, P. pectinatus occurred only at low altitude, and in calcareous water.

Potamogeton perfoliatus (S)

(i) 68,80,81.

(iii) *,*,*,*,*,*,*,*,*,*,*,1/2,1/2,2/2,17/54,18/49.(39/109)

P. perfoliatus was probably inoculated into the Tweed from the Teviot, for its most upstream occurrence was in the immediate 0.5 km length below Teviot Foot. However, it was recorded only four times in the next forty six 0.5 km lengths. Immediately below Till Foot (km 132.5) it was abundant and remained so downstream in all 0.5 km lengths until, like all other permanently submerged higher plants except Zannichellia palustris, it disappeared below km 148.5. The sudden and consistent presence of P. perfoliatus below Till Foot coincides with a marked reduction of P. x salicifolius, although the former had a much wider habitat range. P. perfoliatus although sometimes found in deep slow water was far more common in deep or shallower water with at least a moderate flow rate. In the tidal area some specimens were found to be only partially submerged during low tide.

(iv) 5/9,*,*,*,*,*,*.(5/9)

Present in five localities only, all within the last 10 km. P. perfoliatus was common at the most upstream (km 9.0) and most downstream localities but in the other three intermediate sites was rare.

(v) P. perfoliatus was a lowland species, found extending up Eden Water for a distance of 15 m, and at three sites in the last 10 km of the R. Till where it was rare. Apart from the lower Tweed the only other site where it grew at all commonly was in the last 10 km of the Whiteadder where it has been common since the turn of the nineteenth century, (Johnston 1829).

In the Blackadder, it was present in quite shallow fast flowing water rooted in cracks in calciferous sandstone. This new record in three consecutive 0.5 km length above Langton Burn was of particular interest with the finding of P. x cooperi in the kilometer below it.

With the exception of a record by Syme in 1841 for the Whiteadder at Allanton, (immediately below Blackadder Foot) all previous recordings have been verified. P. perfoliatus had a much wider distribution in the Tweed Basin than from the river localities described. It has been recorded from v.c. 78 and 79 from lochs of particular interest are the records from the Loch of Lowes and St. Mary's Loch at the head of Yarrow Water.

(vi) P. perfoliatus is a frequently recorded species in rivers, as indicated by Butcher (1933), who reported its presence in the lower Tees, Wharfe, Tern, Dove and Lark. In most rivers it is confined to lower reaches, although capable of growing on shingle or mud, and in a wide variety of flow regimes. In rivers of mainland Europe, P. perfoliatus is less frequently recorded than P. pectinatus, but as in the Tweed, it usually had a wider habitat range. For instance, the former was present throughout the whole length of the Danube, including its headwaters, whereas the latter was only present in the river below Austria. Iverson (1929) found _P. perfoliatus_ in weak acid or alkaline, as well as strong alkaline waters. Both Ackenheil (1944) and Sirjola (1969) observed _P. perfoliatus_ to grow in slow to moderately fast currents. These authors findings agree with observations made for the Tweed Basin.

Potamogeton polygonifolius (S)

(i) 78,79.

This species was not found in any of the stretches of river surveyed for macrophytes. It was however found in the Tweed above km 0.0, and in the Megget above St. Mary's Loch. It has previously been found from many burns or marshlands in the area.

Potamogeton pusillus (S)

(i) 68,80,81.

(ii) See _P. berchtoldii_

(iii) *,*,*,*,*,*,*,*,*,*,*,2/3,11/11,14/14,11/11,10/10.(48/50)

Absent in the Tweed above Teviot Foot, but below it, _P. pusillus_ was present in more than half the 0.5 km lengths, but as the presence/abundance ratio indicates it was never common. This was the most delicate pondweed recorded in the river, being absent in the fast flowing stretches and confined to muddy reaches. Owing to its delicate nature, _P. pusillus_ always competed unsuccessfully with larger species for dominance in suitable habitats.

(iv) 5/5,8/8,7/9,*,*,*,*.(20/22)

Present in the lowest 30 km, of the Teviot in similar habitats as in the Tweed. Although the former river provides the inocula for the latter, _P. pusillus_ was in fact less common in the Teviot.

(v) P. pusillus was found extending up the R. Till, and as new records in the Blackadder, and in the Whiteadder below the former affluent. In the last two, it was recorded from few localities in which it was often common.

Johnston (1829) describes P. pusillus as 'frequent in the Tweed and Whiteadder', however, there were no specimens collected at this time or at any later date from the Whiteadder. However, numerous specimens of P. berchtoldii have been collected in the Whiteadder since then, the earliest being in 1838. It is quite possible that Johnston confused these species. If so, the question remains, at what time, and how did P. pusillus invade the long established berchtoldii territory in the Blackádder and Whiteadder Waters? My new records would point to a recent introduction, but this is not conclusive, since in the five sites where P. berchtoldii was previously collected between 1838 and 1966, P. pusillus is at present still absent. The other possibility is that the P. pusillus specimens collected recently are relics of an ancient population that has been more or less replaced by P. berchtoldii.

In the rest of the Tweed Basin, P. pusillus has been recorded from several lakes and ponds in addition to a record in Jed Water at Jedburgh.

(vi) Present, but rare in N. Tyne, Tyne and Lower Tees. and absent from the Wear. Butcher (1933) only found P. pusillus at low altitudes, but in a wide range of water chemistries. The extremes were the New Forest streams which are soft and acid, and the Itchen and Lark which he described as highly calcareous. On the Continent, Iverson (1929) found it in waters ranging from weakly acid to alkaline. As observed in the Tweed, Ackenheil (1944) found this species confined to very slow flowing stretches of river which had muddy substrata. The presence of this species in rivers in N-E. England and a number of other rivers with a wide variety of water chemistries might suggest that changes in water chemistry were not responsible for its sudden appearance in the Tweed, but due to the provision of an inocula from the Teviot.

Potamogeton x _salicifolius_

(i) 68,80,81. (S)

(ii) Very similar in appearance and habit to _P. lucens_, but critically separated however by its sessile or semi-amplexicaul leaves which are smaller than those of _P. lucens_, and also by its sterility.

(iii) *,*,*,*,*,*,*,*,*,*,*,*,2/4,16/46,18/39,17/35,4/10.(57/134)

Another species confined to the lower Tweed with its upper limit immediately below Teviot Foot. In deep slow muddy stretches _P._ x _salicifolius_ formed huge thick beds along the river bank often continuously for many hundreds of metres. This tendency to form large mats is due to the underground expansion in soft mud of the strong growing root stock. Other _Potamogeton_ spp., _Elodea canadensis_, _Myriophyllum spicatum_ and _Ranunculus_ spp. all had a marked reduction in abundance in these localities, although washed down _Oedogonium_ and _Enteromorpha_ thrived. In the last 10 km, where tidal influence is experience most, _P._ x _salicifolius_ was much less common.

(iv) 12/42,*,*,*,*,*,*,*.(12/42)

An upper limit in km -9.0 at Kalemouth Bridge along with _P. lucens_ and _P. perfoliatus_. Like _P. pectinatus_, _P._ x _salicifolius_ was absent between km -9.0 and km -6.0, but in the lowest six kilometers it was common and usually very abundant. In the Teviot, the large stands of this hybrid often spread from one bank to the other, and in the 6 km of the river where present, it reached a greater abundance than in any equivalent 10 km of River Tweed. In both the Tweed and Teviot, _P._ x _salicifolius_ occupied very slow deep water, reaching maximum abundance near the bank ; _P. pectinatus_ on the other hand, occurred in slightly shallower water where current velocity was more rapid. The former was therefore usually most abundant at the edge of the river, and the latter was most frequent in mid river.

(v) Absent in all other tributaries although Taylor recorded it extending up Leet Water in 1939, but it was absent in 1972.

Specimens exist at the British Museum that were collected from the Teviot and Tweed in 1875 and R. D. Thompson (1807) reported *P. decipiens* (synonym) as present at that time in v.c. 80 and 81. There is evidence to suggest that in 150 years, the boundaries of the distribution of this species in the Tweed Basin have changed little.

P. x salicifolius has a wide but scattered distribution in the British Isles, which might suggest random *in situ* hybridization. In the Teviot at Kalemouth, the two parent species *P. lucens* and *P. perfoliatus*, and the hybrid *P. x salicifolius* grew together. For each of the three species this was the limit of their upstream distribution. It is suggested that the Tweed Basin clone of *P. x salicifolius* was 'born' here, at least two centuries ago. The sterile hybrid consequently spread by fragmentation downstream and into the Tweed where it was first recorded in the first decade of the nineteenth century.

Potamogeton x suecicus (S)

(i) 68,81.

(ii) Appears most similar to *P. pectinatus* but with blunt leaves, and tubular leaf sheaths - a character not found in *P. pectinatus*, which has open sheaths. These two features are used to separate the parent species *P. pectinatus* and *P. filiformis* in the absence of fruits. However in this hybrid, the characters mentioned are by no means constant, the leaf apex varies considerably, although more obtuse than in *P. pectinatus*. The sheaths vary too, some are obviously tubular, but others show a tubular nature at the very base only when subjected to careful anatomists techniques

(Bance, 1946). The variation mentioned is too wide for P. filiformis in which the leaf apex is never acute and the sheaths are always manifestly tubular. This instability of vegetative characters also extends to the flower spikes. The visably normal young spikes when ageing abnormally elongate to show a barren state incapable of developing viable pollen and thus never fruiting. In the absence of fruits, the carpels are examined showing a constant form resembling P. filiformis in having broad sessile stigmas lacking a stylar neck characteristic of P. pectinatus.

P. x suecicus, on account of its sessile stigmas and tubular sheaths cannot be referred to P. pectinatus, though it closely resembles it in habit and general appearance; on the other hand it cannot be referred to P. filiformis because of instability in sheath and leaf structure. Due to the characters described its hybrid origin is easily deduced. In addition, a non-flowering, robust, broad leaved form also occurs which can develop into plants up to 2.5 m, and showing no resemblance to the flowering forms or its parent species.

(iii) *,*,*,*,*,*,*,*,*,*,*,*,*,*,5/6,2/3.(7/9)

Restricted to the fastest shallow stretches of the river below Till Foot. In km 142.5, immediately above St. Thomas's Island, the robust non-flowering form was frequent.

(iv) Absent in all tributaries except the Till where it was confined to the lower 10 km only. There it was present in all but the last 0.5 km length surveyed, and was much more common than in the Tweed, often being most abundant. The gravelly or sandy stretches with fast flow were dominated by the sterile robust form. The species remained vegetative and appeared to be healthy and in an active state of growth throughout the winter - a feature more in common with Ranunculus spp., than Potamogeton spp.

In the Tweed and particularly in the Till, after periods of flood many plants were observed to be uprooted and either washed up on the banks or still drifting in quieter water. This susceptibility to flood is probably exaggerated in the Till because of the sandy unstable substrata, the majority of specimens washed up on the Tweed probably originate from this tributary. Dandy and Taylor (1946) report the common occurrence of fragmentation of this species, and the probable influence it has on the distribution and establishment of the species in new localities. This could account for the presence of P. x suecicus in the Tweed only below Till Foot.

(vi) P. x suecicus is a rare species with several isolated clones scattered around Scotland, and in the R. Wharfe and R. Ure in Yorkshire (Dandy and Taylor 1946). In the Tweed and Yorkshire rivers, the hybrid grows far removed from the present-day distribution of P. filiformis. This parent is a boreal species that grows in mainland Britain as far south as Coldingham Loch (Berwickshire, but not within the Tweed Basin). There is fossil evidence, however, that in glacial periods it extended as far south as Middlesex. It is most likely (as discussed by Dandy and Taylor) that the Tweed clone, like that of the Yorkshire one, is a relic of of immediate post-glacial times.

Ranunculus aquatilis agg. (S)

(i) 77,78,79,80.

(ii) Plants in vegetative conditions are often impossible to separate from R. pencillatus var. calcareus. Its generally finer leaves, less robust nature and dull, lighter green colour were features removed from P. penicillatus. When flowering, the present of entire leaves, however variable, is sufficient to discount R. penicillatus.

However, the real problem occurs when trying to force specimens into particular species. With the exception of a plant collected from the

Biggar, not one other specimen could be described as 'good type' material. Most plants had the characters of at least two species, e.g. R. aquatilis leaves with R. peltatus flowers and straight pedicels (hybrid characteristic). Others were worse, often with misformed leaves and multiple petalled flowers that had individual characters referable to many species. It appears there is more than one genetic unit, however many, and what they are is not possible to say. At least some plants are hybrids of R. peltatus, the other parent being either R. aquatilis or R. penicillatus var. calcareus. C. D. K. Cook (personal communication) looked at many of the specimens collected and found them impossible to separate. He suggests that there is a hybrid swarm involving R. peltatus/R. aquatilis/R. penicillatus.

(iii) *,*,14/18,16/23,20/60,20/30,12/14,8/12,4/4,3/3,*,*,*,*,*.(97/164)

Like all submerged Ranunculus species, R. aquatilis agg. was absent in the upper 20 km of the R. Tweed. The aggregate species was the first to colonize the river in km 21.0 and was present, in 75% of the 0.5 km lengths surveyed downstream as far as Peebles. Immediately below the towns sewage works and for about 7.0 km below, the species was most abundant, much more so than R. penicillatus. Downstream from here it gradually became less abundant and recorded from fewer 0.5 km lengths until it disappeared completely from the river by km 96.5.

This species, although only present in the upper two thirds of the river was intolerant of fast flowing water. In the highest reaches where it was recorded, plants were found only at the more sheltered edges of the river that had abundant silt. In more downstream stretches R. aquatilis agg.plants were found occasionally in mid-stream, but only where the river was wide, fairly deep and gently flowing over beds of abundant silt. In such stretches, R. penicillatus grew in association, but usually in the slightly faster more rocky areas. These stretches served to indicate the comparative flood resistance of the two species. After high water in summer, most of the R. penicillatus would remain, while large patches of R. aquatilis agg. would be ripped out. In the winter the former remains large and healthy looking, while the latter "dies back" to a mere shadow of its summer proportions. Since R. aquatilis agg. was only rooted on a soft substratum, by 'dieing back' after its summer growth period, it reduced the possibility of it being scoured out during winter floods.

(iv) *,*,*,*,*,4/7,*.(4/7)

Rare, present only in the extreme upper reaches in sheltered muddy alcoves at the side of the river.

(v) Present only in the Biggar, and in the Ettrick below Selkirk Sewage Works. Although not surveyed, it was noticed that R. aquatilis agg. was common in Eddleston Water also. The species was restricted to the western areas of the Tweed Basin.

(vi) Backhaus (1967) made particular comment that R. aquatilis was the most common macrophyte in the middle reaches of the Brigach. This he associated with an increase in hardness there, but more particularly the effect of increased nutrients resulting from town sewage. This is comparable to findings above and below the town of Peebles in the Tweed.

In southern Polish rivers, Turala and Wølek (1971) found similar plants as found in the Tweed. In vegetative and floral morphology the specimens were most akin to R. aquatilis. The origin and parentage of these was also unknown.

Ranunculus circinatus (S)

(i) 81.

(ii) Easily identified in the vegetative condition owing to the sessile, repeatedly branched submerged leaves which are perfectly circular in outline. R. circinatus lacks floating leaves and the fruiting stalks are many times longer than the leaves.

(iii) Absent.

(iv) Absent.

(v) Present only in the Blackadder where in the upper stretches it was common, but absent further downstream. This species, and its hybrid derivative described later, are the only truely aquatic angiosperms not to be passed downstream from a donar tributary where they were common, into their recipient river. It was not therefore, present in the Whiteadder.

R. circinatus was present only in slow flowing stretches with a depth of about 1 m. In slightly faster flowing water it occasionally occurred where dense growths of other plants reduced the flow rate.

(vi) R. circinatus is described by Cook (1966) as the most common species in eutrophic conditions, and usually confined to lakes and slow flowing rivers or canals. It has not been recorded from rivers in N-E. England or any described by Butcher (1933). Wølek (1971) for the Teuronjoki, and Kohler et al. (1971) for the Moosach both described their rivers as calcareous, and R. circinatus was common. The latter author found that the species was indifferent to the changes in eutrophication shown throughout the length of the river. Iverson (1929) found that this species was confined to alkaline waters. The presenee of R. circinatus only in the Blackadder, the largest hard water tributary of the Tweed, would support the observations of the authors quoted

Ranunculus circinatus x R. penicillatus var. calcareus (S)

(i) 81.

(ii) Shows features of both species but resembles neither one in overall appearance.

(iii) Absent.

(iv) Absent.

(v) Present only in the Blackadder where it grew in the upper stretches with its two parent species and also extended further downstream than either of its parents. It showed a preference for faster, shallower water than R. circinatus. The presence of this hybrid in the Blackadder where the two parent species occur together for the only time in the whole area, strongly indicates in situ hybridization.

Ranunculus flammula (B)

(i) 78,79,80,81.

(ii) 6/6,8/8,2/2,*,*,*,*,*,*,*,*,*,*,*,*.(16/16)

Restricted to the upper stretches where substrata of shingle, mixed sandy gravel or mud were colonized. R. flammula was always above the low flow water mark although absent from all but the dampest margins.

(iv) *,*,*,*,1/1,5/5,2/3.(8/9)

Similar habitat as in the Tweed.

(v) Restricted to the Biggar, Lyne, Ettrick, Yarrow and above Greenlaw on the banks of the Blackadder. Its absence in the lowland tributaries was expected, however the absence in the upper stretches of the Till was at first sight surprising. R. flammula, however, preferred a more or less permanently damp habitat which is above water level; this was absent in the Till. The soft sand drains quickly, leaving its banks much drier than others in the basin.

Ranunculus fluitans x ? (S)

(i) 68,79,80,81.

(ii) Plants in vegetative condition resembled 'type' R. fluitans with the leaves rarely being more than four times forked. However, the flower stalks frequently showed the beginning of floating leaves and sometimes even completely expanded leaf segments. Similar specimens have been found by Cook in the Danube and Rhine, but his specimens were fertile with glabrous receptacles and were certainly R. fluitans i.e. 2n = 16.

Many thousands of plants were closely examined from the Tweed and its tributaries, and on no occasion in three years were fruits found. Cook has found similar infertile material in the R. Pea at Peakirk growing among 2n = 48 peltatus and 2n = 32 fluitans. This was a hybrid of the two species, with2n = 40. The Tweed material however, had floating leaves more like R. aquatilis. The most plausable name for the material is R. fluitans x R. aquatilis. 2n = 40, but the situation is complicated further by R. fluitans having diploid and tetraploid races.

(iii) *,*,*,*,*,*,*,*,*,12/38,20/55,20/36,20/52,20/52,20/54,18/47.(130/334)

The most upstream limit of R. fluitans was only 2.0 km above the beginning of the Old Red Sandstone. From its most upstream point of km 84.0, the species was present in every downstream 0.5 km length until it disappeared in km 148.5. The species was usually recorded as at least common, but was least abundant between km 100-110 where the river flows over hard basaltic igneous rocks.

Fast flowing stretches between 0.5 and 1.0 m in depth were frequently smothered by plants that often exceeded 4 m in length. In several stretches (e.g. 114.0) such large amounts of growth occur that it necessitates cutting.

(iv) 14/44,*,*,*,*,*,*.(14/44)

R. fluitans was abundant where present, but confined to the lowest 7.0 km. Why the species was confined to such a short distance at the end of the river is unknown. No geological, physical or chemical changes occur in the river at the sudden point where on one side, it is absent, and the other it is very abundant.

(v) Present in only the lowland tributaries. In the Eden, Till (except for its upper reaches) Blackadder and Whiteadder, R. fluitans was present in all but one 0.5 km length surveyed. In all reaches it was at least as common as in the Tweed.

In these tributaries where R. fluitans was abundant, R. penicillatus was absent or very rare. In the Eden it was absent, and in the Till it was recorded only twice in the lower 40 km but was dominant to R. fluitans in the upper stretches. In the Blackadder and lower Whiteadder R. fluitans was by far the dominant species, but in the upper Whiteadder both species were common. R. fluitans was absent from the upper half of the Tweed basin, and the upper reaches of those tributaries which discharge into the lower half of the Tweed. The more upstream occurrence of R. penicillatus compared with R. fluitans can be illustrated by reference to Table 9.7a ; the mean altitude for the occurrence of the former was 80 m, and for the latter, 30 m.

Whether this hybrid population originated in situ and then drove the parents out, or whether it invaded unoccupied water is not known. The only material at the British Museum (Natural History) from the Tweed area is a plant labelled R. fluitans, collected 16.7.1900. Notes with it state that similar material was present in the Tweed, Whiteadder and Blackadder. Although labelled R. fluitans, it was hybrid material. This might suggest that the hybrid was not recently synthesized in situ, but probably invaded from other sites.

(vi) Type R. fluitans was common in the lower stretches of the Tees, and has gradually spread in the Wear after being planted by Mr S. Pepper, the river bailiff in 1959. No plants of R. fluitans derivative grow in the N. Tyne or Tyne.

The hybrid R. fluitans in the Tweed area behaves in a very similar way to type R. fluitans in Britain and Europe. The most complementary data are furnished by Turala (1970) for the R. Nysa, Poland. In the upper reaches of two headwaters, only R. penicillatus was present. In the lowest stretch below their confluence, only R. fluitans was present, however, in the middle reaches both species grew together.

Hybrids similar to those found in the Tweed have been found growing alongside parent R. fluitans in the Rhine (C. D. K. Cook, personal communication) and in the Moosach (Kohler et al. 1973). In the former river the other parent was R. aquatilis, and the hybrid has become more abundant than the parents. In the latter, the other parent is R. trichophyllus, which although less common than the hybrid, has a wider distribution.

Ranunculus hederaceus (B)

(i) 78.

Not recorded in any of the rivers surveyed, but nevertheless present in the upper River Tweed (above km 0.0). R. hederaceus was frequent there in shallow muddy stretches and often associated with Potamogeton polygonifolius.

Ranunculus penicillatus var. calcareus. (S)

(i) 68,77,78,79,80,81.

(ii) Type material with abundant fruits as described by Cook (1966). Turala (1970) points out that the taxonomic ecological significance, and distribution of various vars. is still very unclear.

(iii) *,*,19/21,14/23,19/50,20/59,20/47,20/65,20/61,20/52,20/45,20/56, 20/56,20/59,16/33.(239/637)

Below Biggar Foot, R. penicillatus although present in three localities above, first becomes common in the R. Tweed. The affluent itself being choked by the species probably reintroduces plants after scouring in the main river. Gradually the species increases downstream to become the most abundant species in the river, although recorded in fewer 0.5 km lengths than six other species.

Like R. fluitans x?, R. penicillatus was most abundant in fast flowing water where it occurred firmly rooted among shingle, stones and rocks. Deep muddier sheltered regions were also colonized, but plants seldom thrived and rarely flowered there. During periods of exceptionally low flow several patches of R. penicillatus became exposed above the water. These plants continued to grow but from the bottom instead of the tips and often flowered and set fruit. Over the three year period, it was noticed that after a long period of summer low flow plants had increased their shoot growth greatly, but their root system if anything had decreased, perhaps due to lack of a pulling strain on the shoots. Plants seemed most susceptible to being uprooted by floods after a long period of low flow.

(iv) 20/81,20/77,20/77,5/6,1/1,*,*.(66/242)

Present in identical habitats as in the Tweed and by far the most abundant angiosperm, although nine others were recorded more times. Both the Tweed and Teviot show that wherever R. penicillatus does occur it is usually abundant.

(v) Present in the Biggar, lower Ettrick, upper Till, Blackadder and Whiteadder. The species also occurred in the lowest stretch of the Leet Water that receives Tweed Water via a mill lade.

As described under R. fluitans, R. penicillatus always occurred in greatest abundances in more upstream localities than the former.

(vi) This species is present in the nearby N. Tyne, abundant in the Tyne, recently invaded the Wear, and is absent from the Tees.
In 1968 R. penicillatus was absent in the Wear, but by 1973 it had become locally quite frequent in the lower half of the river. Unlike

R. fluitans the colonization has been from an unknown source (Whitton and Buckmaster,1970).

Data presented for the Tweed Basin agree closely with that given by Cook (1966). He indicated that R. fluitans was a species characteristic of large stable rivers, and R. penicillatus of unstable rivers.

Although occasionally requiring cutting in certain stretches of the Tweed, R. penicillatus does not reach such massive proportions as reported by Butcher (1933) & Westlake (1960, 1968, 1970 and 1973), for many southern chalk streams. The plants reach such high densities that flooding results if it is not cut. This,however,stimulates its growth, and makes the plants less susceptible to scouring by floods (Ladle and Casey, 1971). The effects that cutting has on the genus in the Tweed has not been measured, it may however, reduce scouring by winter floods.

Rorippa amphibia (B)

(i) 68,78,79,80,81.

(ii) Difficult to separate from R. sylvestris L. and R. islandica (Oedor) Borbas, although the fruits should be quite distinct. Of the specimens found in the Tweed Basin,many plants had variable fruits ranging from the long fruits with a distinct stigma of R. sylvestris,to the rounded fruit giving way to an indistinct stigma, characteristic of R. amphibia. In addition, petal to sepal size also varied greatly, with many not showing a petal length twice that of the sepals. Due to its presence only on the banksides, this Rorippa was not critically taxonomically examined, although over 60% of the recorded data was without doubt R. amphibia.

(iii) *,2/2,*,*,2/2,6/6,8/8,12/12,20/25,20/27,20/25,17/18,20/21,18/24, 18/20.(163/190)

Distribution in the upper 50 km restricted to only four 0.5 km lengths. As the river descends to lower altitudes R. amphibia became increasingly common, especially in the 30 km above Teviot Foot. It was capable of growing equally well on soft open mud, among Phalaris arundinacea and other bank species, or as the only colonizer of loose stones and pebbles. In this last habitat, excessively long roots penetrated between piled up rounded stones down into the moisture held in the sandy substratum below. This species was always totally above water level during low flow, except in the tidal reaches where many plants were submerged at high tide.

(iv) 8/8,14/14,3/3,5/8,5/5,3/3,*.(38/41)

Similar distribution pattern as in the Tweed with the reduction in abundance in the last 10 km being caused by Sparganium erectum in many stretches forming a very thick fringe that backed directly into deep water and thus eliminating suitable habitats for R. amphibia.

(v) Present only in the lowland Berwickshire tributaries Eden, Leet, Blackadder and Whiteadder where it was rare, and in the Till where in the lower stretches it was more common. In all the tributaries R. nasturtium-aquaticum was far more common.

(vi) Clapham et al. (1962) also reported that R. amphibia is locally common by streams and ditches as far north as Berwick. Th same authors reported it frequently occurs with Mentha aquatica and Phalaris arundinacea.

Rorippa nasturtium-aquaticum (B)

(i) 68,77,78,79,80,81.

(iii) 4/4,14/14,15/16,10/10,12/12,7/7,3/3,5/5,8/10,15/22,11/15,4/4,4/4,
4/4,3/3.(119/133)

A species with a totally different distribution pattern and habitat than the previously described Rorippa species. R. nasturtium-aquaticum was often totally submerged, but more commonly rooted in soft mud with at least a covering of water. In the upper reaches, small alcoves of reduced flow rates which collected mud, produced ideal habitats for this species.

In the river below Teviot Foot suitable habitats are reduced because the many species growing on the bank give way directly to deep water.

(iv) 4/4,6/7,12/14,8/9,9/9,9/9,*.(48/52)

A more or less even distribution along the river, being least common in the lowest stretches and most common in the middle. The instability of the substratum in upper Teviot causes the reduced abundance compared with upper Tweed.

(v) Present in all tributaries and common in all except the Ettrick and Jed. In the Leet, Blackadder and Whiteadder R. nasturtium-aquaticum was particularly frequent and locally abundant. The Leet and upper Blackadder in particular, had their flat, half submerged muddy margins choked by large bushy plants which often spread into the middle of the rivers.

Although the ordination of species in the Tweed (Table 8.64a), and a Tweed altitude mean of 125 m points to R. nasturtium-aquaticum being a more nutrient poor, softer water, and higher altitude species than R. amphibia, this was true only for the Tweed itself. The tributaries show this to be a result of suitable habitat availability, and not a specific altitude or chemistry requirement.

(vi) Haslam (1971) has shown that this species is very strongly correlated with shallow water and narrow streams, but indifferent to speed of current. Westlake (1970 and 1973) described how R. nasturtium-aquaticum was the dominant species of the upper reaches of southern chalk streams, and in mid-summer, in the unmanaged lower stretches also. In the Tweed Basin, the two tributaries most resembling chalk streams, the Leet and Blackadder, were the only streams where it was really common.

Rumex hydrolapathum (B)

(i) 68.

(iii) Absent.

(iv) Absent.

(v) Recorded from only the R. Till in the whole catchment area. R. hydrolapathum was recorded only intermittently in the upper 40 km of the Till, where it grew on the sandy banks, but always with its roots and the bases of its fleshy stem and leaves submerged. Plants were always at the waters edge where the flow rate was negligible.

Its confined distribution in only the R. Till is almost certainly due to the sandy banks, which in the upper 40 km give way only gradually to the main flow of the river, resulting in a wide flat zone of sand. This sand is covered by shallow water of slow velocity. This particular type of habitat was not found elsewhere in the Tweed Basin.

Scirpus lacustris (B)

(i) 68,81.

(ii) Similar in general appearance to S. tabernaemontani but generally taller and with stouter glabrous stems. Other separating features are the smooth glumes (against papillose) and three stigmas (against two).

(iii) One plant only - on the right bank of km 120.5 at the waters edge on a silty mud flat.

(iv) Absent.

(v) Absent in all tributaries except the Blackadder where in km -23.5 it was very abundant on both banks of the river, and in the Whiteadder below Blackadder Foot, where it was recorded in eight out of twelve 0.5 km lengths. S. lacustris grew only at the margins of the slower flowing stretches of the river which afforded a more or less constant high water mark as well as abundant mud or silt.

Its absence in lower Tweed, Leet and Till is somewhat surprising. The Till, affords many slow stretches with permanent high water levels, however, the banks are generally sandy, and not muddy. Thompson (1807) reported that in the Borders, S. lacustris was present only north of the Tweed, and particularly on the banks of the Whiteadder. There appears therefore to have been little change in its distribution in over 150 years.

(vi) In the survey of British rivers by Butcher (1933), S. lacustris was only recorded on the banks of lowland, moderately or highly calcareous rivers, in stretches with slow or medium currents. West (1910) described the species as 'decidedly calcifilous' in Scottish lochs. Apart from its absence from the Teviot, the distribution in the Tweed Basin supports the above findings.

Scirpus sylvaticus (B)

(i) 68,78,79,80,81.

(iii) *,1/1,1/1,4/4,2/2,4/4,10/10,11/14,5/5,5/6,4/5,4/5,4/4,3/3,*.(58/64)

A species always rooted on soft wet substrata just above the low water mark, accounting for its rareity in the upper stretches. S. sylvaticus has its maximum abundance in mid Tweed.

(iv) 12/15,2/2,*,*,*,*,*.(14/17)

In the last 10 km of the Teviot S. sylvaticus was as common as in mid Tweed, but above this there were only two records.

(v) Present, but rare in the Yarrow, Jed, Eden, Leet and Blackadder, being common only on the banks of the Till and lower Whiteadder where in the latter river it grew along side S. lacustris. S. sylvaticus was a species of lowland tributaries but on suitable localities on the Tweed it extended well upstream.

(vi) Scirpus sylvaticus also occurs on the banks of rivers in N-E. England, but is rarely recorded.

Sparganium erectum (B)

(i) 68,77,78,79,80,81.

(iii) *,*,9/11,9/19,14/21,17/35,17/24,16/20,11/13,4/5,9/17,11/20,9/10, 9/18,6/8.(141/221)

A lower upper limit of distribution than Eleocharis and with a maximum abundance in mid river, except between km 90-99.5 where the bed rock was of hard Basaltic Igneous nature. The lack of silt and mud at the river's edge and the hardness of bedrock in this stretch was almost certainly the cause of the reduction. At a few sites the species was observed completely submerged.

(iv) 19/60,14/31,4/6,7/7,1/1,1/1,*.(46/106)

Common only in the lower 20 km of river where it was especially abundant. The numerous slow stretches in lower Teviot, with their soft muddy margin proved ideal habitats for Sparganium, which often thickly fringed the river bank and frequently extended well into the river itself. The species was more abundant here than elsewhere in the Tweed Basin.

(v) Present in all tributaries but never common except in the lowlands. In the small Eden and Leet waters, Sparganium was common and locally very abundant at the edges of the deeper slow flowing stretches. In all but the upper 10 km of the Till (where it was absent) the species was frequent in most 0.5 km. The Blackadder and the Whiteadder below Blackadder Foot with their many slow flowing stretches with muddy margins were thickly colonized by Sparganium. Of the twenty 0.5 km lengths surveyed in the Blackadder, Sparganium was present in all of them.

The main difference between the habitats of Eleocharis and Sparganium is that the former, with its much less robust nature and smaller rhizomes can grow among stones and other species on the river bank, whereas the latter, with its robust rhizomes and large spreading aerial parts is suitable to take advantage of soft muddy habitats . This anatomical difference between the two species might account for the presence of Eleocharis in the upper stretches of the Tweed, and on the flat, stonier banks of the Ettrick and Yarrow. Sparganium, however, dominated the river banks of the lowland Tweed Basin, including lower Teviot, Eden, Leet, Till, Blackadder and Whiteadder.

(vi) Although the distribution in the Tweed Basin suggested that Eleocharis might be more tolerant of higher current velocities than Sparganium, this was not shown by Sirjola (1969). Perhaps the anatomical differences between the two genera which were outlined above, is more relevant when considering the differences in distribution patterns.

Typha latifolia (B)

(i) 80.

(iii) Absent.

(iv) Present as a solitary record for the whole catchment area of the Tweed at km 7.0 on the Teviot. At this point, a particularly slow stretch, a swamp backs on to the river where the boggy silt and organic matter provides an ideal habitat for Typha, and the species extends down to the river side.

(v) Absent.

(vi) Szemes (1967) reported that Typha grew at the edge of the Danube from Austria downstream. Both Ackenheil (1944) and Sirjola (1969) agreed that when present at the edges of rivers this species was confined to those stretches with very slow currents. This was also true in the Tweed.

Veronica beccanbunga (B)

(i) 68,78,79,80,81.

(iii) 8/9,16/16,12/12,10/10,15/18,8/9,*,*,3/3,2/2,3/3,4/4,6/6,11/13, 9/10.(107/115)

A similar habitat as Rorippa nasturtium-aquaticum, although more capable of growing on mud above the water level, and among other bank species, whereas Rorippa often forms pure stands. Veronica was usually rooted on damp firm ground at the edge of the river. Its absence from km 60.0 to 79.5 is rather strange. It is the same 20 km in which S. sylvaticus was most common. After being absent for 20 km, Veronica then gradually increased downstream, becoming common in the tidal stretches.

(iv) 13/15,12/13,16/19,3/3,3/3,10/12,4/6.(61/71)

Similar distribution as in the Tweed, with a mid river reduction in abundance also.

(v) Present in all tributaries, usually common, but especially so in lowland tributaries, Leet, Till, Blackadder and Whiteadder.

Zannichellia palustris (S)

(i) 69,80,81.

(iii) *,*,*,*,*,*,*,*,*,*,*,4/5,14/16,12/13,13/18,11/11.(54/63)

A similar habitat, abundance and distribution pattern as P. pusillus. Like that species and several other permanently submerged higher plants, the Teviot provides an inocula of Zannichellia to the Tweed. However, unlike all the other species, Zannichellia has migrated upstream in the Tweed and now grows in km 106.0, which is 2.0 km above Teviot Foot. Zannichellia also extends further downstream than any other permanently submerged angiosperm. It grows below Whiteadder Foot on the sandy, tidal mud flats that are often exposed at low tide.

Zannichellia, although recorded in well over half the lowland 0.5 km length surveyed, was never common, and no plants exceeded 0.5 m in diameter. Apart from the specimens collected in the estuary, Zannichellia was always submerged, with short, very branched shoots rooted for almost their entire length. This growth habit restricts Zannichellia to sandy and mud substrata, the former usually being prefered.

(iv) 18/43,20/62,19/52,5/8,*,*,*.(62/165)

A distribution more or less identical to Myriophyllum spicatum with the upper limits of both species being within 1.5 km of each other at Hawick. In the lower 30 km of the Teviot, Zannichellia in contrast to the Tweed was common and locally often very abundant. In the last 10 km a slight reduction in abundance was due to Potamogeton dominated slow stretches, and Ranunculus dominated faster stretches.

In sandy stretches with medium depth and flow, several Zannichellia plants exceeded 2 m in diameter, the slender matted rhizomes holding fine sand so as to raise the plants up to 0.25m above the mean substratum level.

(v) Absent from all upland tributaries but present in all the lowland tributaries. In the Leet, Zannichellia was recorded only from the bottom 0.5 km length - that which receives Tweed water via a mill lake. The Till, with its sandy substratum is favourable to the Zannichellia growth habit and from km -33.0 downstream it was common. In the lower 10 km Zannichellia was less common, with Potamogeton x suecicus the dominant species.

In upper Blackadder and Whiteadder, Zannichellia was absent but in the 10 km before they meet and then below, the species was even more abundant than in the Teviot.

Zannichellia, like M. spicatum was a lowland species with a Tweed altitude mean of 15 m. As a result it was more or less confined to the harder waters in the Tweed Basin. Its abundance in the softer waters of the Whiteadder above Blackadder Foot and absence in the upland yet marginally harder Lyne was indicative of its water chemistry tolerance. Clapham et al. (1962) reports Zannichellia to be absent above 210 m.

7.25 Macroscopic microbial communities

purple photosynthetic bacteria

(i) 81.

(iii) Absent.

(iv) Absent.

(v) Macroscopic growths of this microbial community were confined to three rivers in Berwickshire. In the Leet it was often abundant; in the Blackadder it was only rarely recorded, and in the Whiteadder it was confined to an isolated stretch below Blackadder Foot. In all localities recorded, it occurred among mud in stretches with slow current velocities.

"sewage fungus"

(i) 68, 78, 79, 80, 81.

(iii) *, *, *, *, 7/11, 2/3, 1/1, 4/4, 3/3, *, *, 2/2, *, 2/3, *.(21/27).

The most obvious macrophytic growths of sewage fungus occurred immediately below the effluent pipe which discharges the sewage of Peebles into the river (km 43.5). Elsewhere it was found intermittently, usually being confined to short stretches which were directly below sewage outfalls.

(iv) *, *, *, 3/4, 1/1, *, *. (4/5)

Confined to below a small effluent which discharges into the Teviot at km - 41.0, and in three localities around Hawick.

(v) Macroscopically obvious "sewage fungus" was only abundant in the Ettrick below Selkirk, and in the lower-most 0.5 km length of the Leet which received the sewage from Coldstream. In the Ettrick it was particularly obvious during low flow periods when the sewage works of Selkirk were being modernised, and at a time when partially treated sewage was discharged into the river. "Sewage fungus" also occurred in the Biggar and Blackadder, but only in isolated localities.

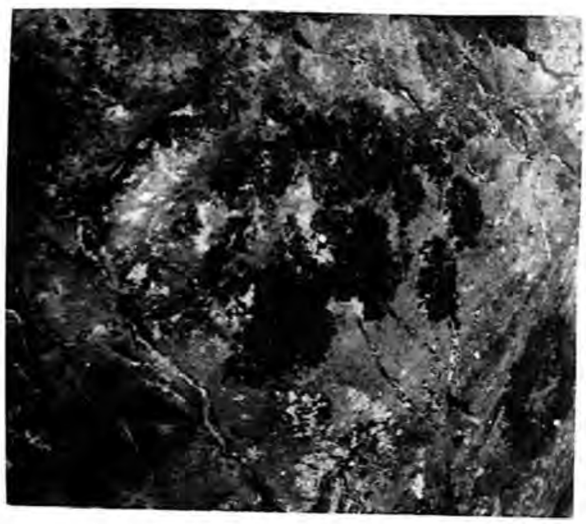
(a) Nostoc rivularis

(b) Nostoc parmelioides

(c) Didymosphenia geminata

(d) Heribaudiella fluviatilis

(e) Hildenbrandia rivularis



(f) Collema fluviatile

Fig. 7.3a Photographs of six macrophytes from the Tweed Basin.

(a) Prasiola crispa in typical habitat on emergent boulder in mid river

(b) Enteromorpha spp. growing only on the right bank of the Tweed immediately below Teviot

(c) Mimulus guttatus in typical habitat in upper reaches of the Tweed

(d) Hildenbrandia rivularis, Eurhynchium riparioides and Ranunculus sp. growing on one stone in the Teviot

(e) Potamogeton natans and Phalaris arundinacea in the Biggar

(f) Cladophora glomerata and other debris washed up on the banks of the Ettrick

Table 7.3b Six macrophytes from the Tweed Basin photographed to show their habitat

8. POPULATION DESCRIPTION, MACROPHYTE COMMUNITIES

8.1 Introduction

The distribution of individual macrophyte species has been described in the previous chapter. The present chapter investigates the extent to which communities may be recognised. The primary data published in Chapter 6 have been used in a variety of ways in order to create some semblance of ecological order. This was carried out to the greatest extent in the formation of "association tables" from the data available from the two rivers surveyed throughout their entire lengths (for method see 2.3).

The importance of not only recording the presence of a species, but also its abundance in 0.5 km lengths has been illustrated in 6.5. Tables 6.5a and 6.5b showed that a recording system based on presence alone could furnish results that differed from one that took into account the species abundance. Since the latter produced more data than one based solely on the knowledge that the species was either present or absent, results based on abundance values are used most in this description of macrophyte communities.

The description of most plant communities has been based largely on submerged macrophyte species. (see 6.1). Although Chapter 7 indicated whether a species was regarded as a bank or submerged macrophyte (see 2.4), Table 8.1a is included as a reference list of the submerged species used in the erection of histograms 8.61 to 8.63c.

Where a river has been surveyed throughout its entire length (Tweed and Teviot) it was possible to summarize vegetation changes that took place from uppermost to lowermost stretches. For the purpose of comparing one region of a river with another, data from 10 km stretches were pooled, and the primary data of Chapter 6 used in three ways.

(i) The subjective abundance figures of each submerged algal, lichen, bryophyte and angiosperm species recorded in the twenty 0.5 km lengths

Nostoc parmelioides	Fontinalis antipyretica
Nostoc other sp.	F. antipyretica var. gracilis
Phormidium spp.	Hygroamblystegium fluviatile
Tolypothrix penicillatus	Hygrohypnum luridum
Hildenbrandia rivularis	H. ochraceum
Lemanea fluviatilis	Scapania undulata
Diatoma spp.	Solenostoma triste
Didymosphenia geminata	Callitriche spp.
Melosira varians	Elodea canadensis
Heribaudiella fluviatilis	Myriophyllum alterniflorum
Chaetophora sp.	M. spicatum
Cladophora glomerata	Potamogeton berchtoldii
Cladophora sp. 'A' (C. aegagropila)	P. x cooperi
Enteromorpha sp(p).	P. crispus
Gongrosira incrustans	P. lucens
Monostroma bullosum	P. natans
Oedogonium spp.	P. x olivaceus
Tetraspora sp(p).	P. pectinatus
Stigeoclonium tenue	P. perfoliatus
Rhodoplax schinzii	P. pusillus
Ulothrix zonata	P. x salicifolius
Spirogyra spp.	P. x suecicus
Charophyta sp(p).	Ranunculus aquatilis agg.
Collema fluviatile	R. circinatus
Verrucaria other spp.	R. circinatus x R. penicillatus var. calcareus
Eurhynchium riparioides	R. fluitans x ?
Fissidens crassipes	R. penicillatus var. calcareus
F. rufulus	Zannichellia palustris

Table 8.1a Submerged macrophytes of the Tweed Basin

of each stretch were added, and the total abundance of all species from one 10 km stretch obtained. Such data from successive 10 km stretches of the Tweed and Teviot are plotted in fig. 8.61a. The data could possibly be interpreted as an indication of the "standing crop" of the river at the time of survey.

(ii) The relative numbers of algal, lichen, bryophyte and angiosperm species recorded in each 10 km stretch were obtained, and plotted in histogram form in figs 8.62a,b.

(iii) The total abundance data for each 10 km ((i) above), were divided into the proportions made up by each of the four taxonomic groups, and plotted as a percentage of the total in figs 8.63a,b,c.

For the completely surveyed Tweed and Teviot, "association tables" were drawn up as described in 2.3 (pp 27-29). The delimination of macrophyte communities in this instance was not decided by non-ecological parameters such as 10 km stretches of river, but a biological one based on the longitudinal distribution of species down the river. The "association tables" include both submerged and bank species, and used data furnished from subjective abundance values. If presence or absence alone had been used, the numbers in the Tables would have been substituted by '+' signs. Reference to both Tables 8.64a and 8.64b show that the ordering of species within communities would have been difficult, and identification of where in the river a species thrived most, less well defined.

The vegetation of the Tweed and Teviot are described in 8.2 and 8.3 respectively. The format follows that described above, first dealing with overall abundances in 10 km stretches, then identifying the major group in each stretch, both in number of species recorded, and their percentage of the total abundance. Finally, with reference to the "association tables", communities are described, and the dominant species identified.

In 8.4 the macrophytic vegetation of partially surveyed tributaries are described. Data are more limited than those given for the completely surveyed Tweed and Teviot. For example, no comparison could be made of the abundance totals in 10 km stretches, since in partially surveyed tributaries the number of 0.5 km lengths surveyed per 10 km was not constant. Sufficient data were not available to erect "association tables". By regarding the data furnished from those 0.5 km lengths surveyed as representative of the vegetation of the whole 10 km stretch, the number of species within each taxonomic group could be ascertained. By relating abundances of one taxonomic group to another in the form of a percentage of the total abundance, results could be compared with those collected from other rivers, whether completely or partially surveyed. The data from complete and partially surveyed rivers in 8.62 and 8.63 are thus comparable.

The macrophytic vegetation of each tributary are discussed individually, the description being divided into three sections.

(i) With reference to Figs 8.62b and 8.63c, the numbers of algal, lichen, bryophyte and angiosperm species recorded in 10 km stretches are described, and related to each taxa's percentage of the total abundance in the same stretch.

(ii) The 10 most abundant species (aggregate of abundance values for every 0.5 km length surveyed within the river, or section of river being described) are initially listed. A short description of the dominant species and types of macrophytic vegetation follows. Species included in the list of the 10 most abundant species in the river are referred to as abundant, and species that were frequently recorded, but were not among the 10 most abundant species, are referred to as frequent. Mention is also made of the presence of any species which was in any way characteristic, unusual, or rare from the rest of the Tweed Basin.

8.2 River Tweed

8.21 Total abundance changes throughout the river

Fig. 8.61 plots the abundance totals of all submerged macrophytes in each 10 km stretch of the Tweed. Immediately it can be recognised, that on passing downstream two very obvious peaks in total abundance occurred. First, a sharp rise occurred between km 40.0 to 49.5. The second, less pronounced peak occurred in the 10 km stretch 110.0 to 119.5.

The upper one third of the river had the two 10 km stretches with the lowest abundance total, (km 0.0 to 19.5), two intermediate values (km 20.0 to 39.5), and the highest in the whole river from km 40.0 to 49.5. It is noteworthy that the peak in total abundance corresponds to the stretch in which Peebles sewage is discharged. From km 50.0 to 109.5 the abundance totals of each 10 km stretch of the Tweed varied little, and were much lower than in the stretch immediately below Peebles. There was an increase in total abundance in the lowest 40 km, and in particular between km 110.0 to 119.5. The increase coincided with the influx of the Teviot.

8.22 Relationship of total abundance to the relative numbers and abundances of algae, lichens, bryophytes and angiosperms

In the previous section, changes in the total abundance of submerged macrophytes per 10 km down the Tweed were described. This section shows the relationship between these changes and the relative importance of the four main groups of macrophytes. The description summarizes information plotted in Figs 8.62a and 8.63a. The former plots the number of submerged macrophytes of each group recorded in each 10 km of river, and the latter plots the abundance totals of each group as a percentage of the total abundances of all four taxonomic groups.

It can be seen that the relationship between the number of species recorded in a group, and their percentage of the total abundance is not always related. Both however, show important information, and will be described together.

The number of algal species recorded in each successive 10 km down the Tweed was high, varying from eight in km 0.0 - 9.5, to 14 in km 100.0 - 109.5. Cross reference to 8.63a shows that it was only in this latter stretch that algae were marginally the most abundant group. Throughout the river, there was only a 15% variation in the percentage abundances of algae per 10 km stretch.

There were only two submerged lichen species recorded, and a maximum abundance percentage of 12 was reached in mid river.

Bryophytes and angiosperms showed very obvious differences from one stretch to another. The number of bryophytes recorded in the upper third of the river was almost double that of the lower two-thirds. The actual number of species recorded was, however, far less than algae. Based upon percentage abundances, the dominance of bryophytes in the uplands was far greater than any other group. Although represented by fewer species than algae, the bryophyte percentage abundance in the upper 20 km was greater than the aggregate of the other three groups. In the lowest 40 km, the bryophyte percentage of the total was less than a sixth it was in the upper reaches.

Angiosperms showed an inverse relation to bryophytes. Only two species were found in the upper 20 km, but the number quadrupled between km 20.0 and 29.5. The number of species present in successive 10 km stretches below this remained almost constant until between km 100.0 and 109.5. Here there was an increase of another six species which was a sudden change observable in km 108.5, immediately below the confluence of the Tweed and Teviot. On both occasions, the increase in number of angiosperm species recorded from one stretch to another was very sudden.

The changes in percentage abundances were however much more gradual. This more gradual change in percentage abundances was also evident with the bryophyte population.

The inverse relationship of bryophyte and angiosperm abundances is best illustrated from the upper and lower 20 km stretches of the river. In the former stretch, the bryophyte to angiosperm percentage abundance ratio was 5:1, and in the latter, lower stretch 1:10.

In the Tweed, the changes in abundance totals for each 10 km (see 8.21) could most closely be related to the number of angiosperms present, and also to their aggregate abundances. In the upper 20 km where the total abundance was lowest, only two angiosperm species were present. Between km 20.0 and 29.5 there was an increase in angiosperm numbers by six. There was no increase in other groups, but there was an overall increase in total abundance. Between km 40.0 and 49.5 the number of angiosperm species recorded remained the same as in the preceding stretch, but there was a reduction in the number of bryophytes by three. Fig. 8.63a shows that the increase in the total abundance was concomitant with an increase in the percentage abundance of angiosperms. The increase in the total abundance in the lower 40 km was also related to the increase in the number of angiosperms recorded.

8.23 Macrophyte communities

The macrophyte communities of the Tweed will now be described with reference to the " association table " (8.64a, p. 405).

In the upper 35 km of the river there were 17 species that were almost totally confined to that region. Only two species, Bryum pseudotriquetrum and Haematococcus lacustris had isolated records further downstream than the upper one third of the river. The dominant species, especially in the higher reaches were Didymosphenia geminata, Hygrohypnum luridum, Brachythecium plumosum and Bryum pseudotriquetrum, with Solenostoma triste and Hygrohypnum ochraceum sub-dominant. It is noteworthy that the community was dominated by bryophyte species, as were the percentage abundance graphs of the same area. This was particularly evident in the most upstream 20 km above the influx of the Biggar. There were no angiosperm species present in this community, also in the same region where this group was at its least abundant in relation to the other groups.

Below this was a second and third group that were most abundant in the upper one third of the river, but nevertheless extended varying distances downstream. The upper community had more bryophyte species than angiosperms, but the reverse was true for the lower community. Myriophyllum alterniflorum and Callitriche spp. were the only submerged angiosperms to be recorded from the highest reaches of the Tweed, the former being the only species frequent in the upper two-thirds of the river, and totally absent in the lowest 37.5 km.

In the middle of the Table are placed the species which occurred more or less from the uppermost stretches of the river, right down into the slightly brackish tidal area. Macrophytes present within this community could be divided into three subgroups: those that were most abundant in the upper stretches such as Fontinalis antipyretica and Hygroamblystegium fluviatile; those with their maximum abundance in mid-river such as Eurhynchium riparioides and Verrucaria spp.; those that were most abundant in the lowest stretches, such as Myosotis scorpioides and Heribaudiella fluviatilis. Some species showed no significant distributional differences between upper and lower stretches, although Veronica beccabunga and Oedogonium spp. were absent in the mid reaches. Members of all four groups of macrophyte were present in this community.

Several groups of species were confined to the middle reaches of the river. Most of these were rarely abundant, although Ranunculus aquatilis agg. and Potamogeton x olivaceus were frequent in the lower sections of the upper half of the river, and Collema fluviatile and Nostoc parmelioides in the upper section of the lower half of the river. A small group including Botrydium granulatum and Fissidens crassipes were confined to the lower one third of the river, yet rarely present in tidal waters.

Many submerged angiosperms were confined to the community where member species were absent from the upper stretches of the river only. The most common submerged macrophytes of this association were Hildenbrandia rivularis, Ranunculus penicillatus var. calcareus, Elodea canadensis, Potamogeton crispus and Cladophora glomerata.

The tendency for submerged angiosperms to be present in more downstream stretches of the river was most clearly illustrated by the communities in the bottom right of the "association table". Of the 10 species listed, all but Enteromorpha sp(p). were submerged angiosperms. The dominant genus was Potamogeton, with six species present.

The relative numbers of bryophytes and angiosperms in each community reflected the overall relationship in terms of abundance values described in 8.22.

8.3 River Teviot

8.31 Total abundance changes throughout the river

Fig. 8.61 shows that the variation in total abundance from one 10 km stretch to another in the Teviot was even greater than in the Tweed. Both rivers were least productive in terms of total abundances in the upper 20 km, the Teviot less so than the Tweed. There was a large increase in the total abundance in the stretch that passed through Hawick (km -39.5 to-30.0). The total abundance in the lowest 10 km was treble that of the most upstream 10 km, and far higher than any equivalent stretch of the Tweed.

8.32 Relationship of total abundance to the relative numbers and abundances of algae, lichens, bryophytes and angiosperms

Reference to Figs. 8.62, 8.63 (pp 398-404) shows that the patterns of the four groups of submerged macrophytes seen in the Tweed, were also evident in the Teviot.

The number of algal species recorded in the uppermost 10 km was half that of the lowermost 10 km. The percentage of the abundance total did not, however, vary greatly from one stretch to another.

Only two submerged lichen species were recorded, and the maximum abundance percentage never exceeded 8% of the total.

Bryophytes and angiosperms showed on passing downstream an inverse pattern of one another, as in the Tweed. Fewer bryophyte species were recorded in the Teviot than the Tweed, and upstream numbers were only just greater than the number recorded in the lowest stretches. More angiosperm species on the other hand were recorded in the upper Teviot than upper Tweed. Although the number of angiosperms recorded in the upper stretches of the Teviot was greater than in the Tweed, the bryophyte to angiosperm percentage abundance ratio was higher, approaching 12 : 1. In the lowermost 10 km, the ratio of bryophytes to angiosperms was 1 : 3.

8.33 Macrophyte communities

With reference to the "association table" (8.64b, p.406) the macrophyte communities of the Teviot can be described. Since the river is much shorter, and fewer major changes occur throughout its length, the communities of the river in comparison with those of the Tweed were less well defined. However, many different patterns of distribution were obvious, some of which will be discussed in relation to environmental factors.

The two communities boxed at the top left of the Table contain almost exactly the same species as found in the upper box of the "association table" of the Tweed. Again more than half the species were bryophytes. The presence of Chamaesiphon spp. and Ranunculus aquatilis agg. in the communities was noteworthy. The former (predominately C. polonicus), was rare in the Tweed, and the latter was confined to the upper half of the river, but was absent in the extreme upper 20 km.

In comparison with the Tweed, bryophytes were much less abundant in the Teviot, particularly so in the highest 10 km. However, they were more abundant in relation to species of other groups. This is illustrated clearly by Figs 8.61a (p.398) and 8.63b (p.402). The former shows that the overall abundance of submerged species in the upper Teviot was lower than in any other stretch of that river, and the latter shows that in relation to other taxonomic groups, bryophytes were dominant.

There were fewer macrophytes that occurred throughout the entire length of the Teviot compared with the Tweed, however, 70% of the species present throughout the former river, were present throughout the latter. It is noteworthy that neither Fontinalis antipyretica nor Eurhynchium riparioides showed greater abundances in any particular region of the Teviot.

Potamogeton crispus, Elodea canadensis and Ranunculus penicillatus var. calcareus were present in the same community. As in the Tweed, the communities were positioned in the same area of the "association table ". The lowest community, like that of the Tweed was dominated by submerged angiosperm species, and in particular the same Potamogeton species confined to the lower stretches of the Tweed. Ranunculus fluitans x ? had a much narrower distribution in the Teviot than the Tweed.

8.4 Partially surveyed tributaries - data illustrated in 8.6 (pp 398-406)

8.41 Biggar Water

(i) In this tributary, more algal species were recorded than submerged angiosperms, however the latter group had a percentage abundance of double the former group. The abundance total of angiosperms was also greater than the aggregate of the other three groups. The only other 10 km stretch in the Tweed Basin where this occurred was in the lowest 20 km of the Tweed. Lichens and bryophytes were not well represented, either in the number of species present, or in their abundances.

(ii) Phalaris arundinacea, Ranunculus penicillatus var. calcareus, Elodea canadensis, Potamogeton natans, Fontinalis antipyretica, Myriophyllum alterniflorum, Potamogeton crispus, Brachythecium rutabulum, Cladophora glomerata and Phormidium spp.

The only abundant alga was Phormidium spp., with Cladophora glomerata, Vaucheria sp(p)., and Stigeoclonium tenue frequent. Lichens were also rarely recorded. The only abundant mosses were Fontinalis antipyretica and Brachythecium rutabulum. Both Eurhynchium riparioides and Leptodictyum riparium were consistently recorded, but never frequent. Angiosperms were by far the most abundant group, five out of the seven most abundant species being submerged species. Phalaris arundinacea was the most abundant species, but no other bank species were abundant. Seven submerged angiosperms were recorded from the river, and all but Ranunculus aquatilis agg. were abundant. "Sewage fungus" was frequent only in the 0.5 km length below the effluent discharge of Biggar.

8.42 Lyne Water

(i) In the Lyne, twice the number of algae were recorded than bryophytes, the next most recorded group. In percentage abundance, algae were equally dominant, with their total being higher than the aggregate of the other three groups. Although there were only two more bryophytes recorded than angiosperms, the former group was four times as dominant based on percentage abundances. Lichens, represented only by submerged Verrucaria spp. had a higher abundance total than submerged angiosperms.

(ii) Submerged Verrucaria spp., Eurhynchium riparioides, Fontinalis antipyretica, Cladophora glomerata, Ulothrix zonata, Hildenbrandia rivularis, Phalaris arundinacea, Grimmia alpicola, Hygroamblystegium fluviatile and Myriophyllum alterniflorum.

Three algae were abundant, Cladophora glomerata, Ulothrix zonata and Hildenbrandia rivularis. Heribaudiellia fluviatilis was often recorded, but was never frequent. Other less frequently recorded algae were: Chamaesiphon spp., Tolypothrix penicillatus, Lemanea fluviatilis, Didymosphenia geminata, Chaetophora pisiformis and Rhodoplax schinzii. Submerged Verrucaria spp. was the most abundant macrophyte, and with some of the algae mentioned above, was part of the encrusting community that was the dominant growth form in the river. Many bryophytes were recorded, and four were abundant. Angiosperms were not a common group, and Myriophyllum alterniflorum was the only abundant submerged species. Elodea canadensis, Potamogeton crispus and P. x olivaceus were present but rare; no Ranunculus species were recorded.

8.43 Yarrow Water

The survey of this tributary spanned 20 km of river. Since the vegetation showed little variation from the most upstream reaches to those in the lower reaches, the whole 20 km will be described as a whole.

(i) This tributary showed a very close relationship between the number of species of each group recorded, and their percentage abundances. Algae were dominant, and bryophytes sub-dominants, with the latter showing slightly higher values in the upper 10 km. Lichens were more important than angiosperms, both in numbers of species recorded and in percentage abundance.

(ii) Didymosphenia geminata, Fontinalis antipyretica, Ulothrix zonata, Chamaesiphon spp. = Diatoma spp., Eurhynchium riparioides, Oedogonium spp.,

Rhodoplax schinzii, Hygrohypnum luridum, Cinclidotus fontinaloides.
The 10 most abundant species were either algae or bryophytes. Encrusting algae were frequently recorded, with Chamaesiphon spp. and Rhodoplax schinzii abundant, and Hildenbrandia rivularis and Heribaudiella fluviatilis often frequent. Tolypothrix pencillatus and Chaetophora pisiformis were also present in the river. Lichens were well represented, with Collema fluviatile frequent in the lower stretches. Four mosses were abundant, and several other species were frequent, the most significant being Fontinalis antipyretica var. gracilis. No angiosperm was recorded more than abundance scale two for any 0.5 km length, and Myriophyllum alterniflorum was the only submerged species present.

8.44 Ettrick Water

There was a great difference between the plant communities of the Ettrick above and below Selkirk, and in particular, below the Burgh's sewage works. The 10 most abundant species of both sections of the river are thus listed separately (iia and iib).

(i) The upper stretches of the Ettrick and Yarrow had almost identical ratios of each group of macrophytes. It was only in these two tributaries that lichens were more abundant than submerged angiosperms.

Below Yarrow Foot, and particularly below Selkirk, the relative importance of the groups changed. The numbers of algae, lichens and bryophytes recorded decreased, while angiosperms increased six-fold. Based on abundance percentages, algae remained the most important group, but decreased by 10%. The lichen percentage dropped from 14 to four percent, but bryophytes remained almost the same. Angiosperms increased seven fold, to almost equal bryophytes in importance.

(iia) Above Selkirk. Chamaesiphon spp. Heribaudiella fluviatilis, submerged Verrucaria spp., Fontinalis antipyretica, Eurhynchium riparioides, *Lemanea fluviatile* = *Chaetophora* sp. *Rhodoplax schinzii*, *Nostoc rivularis* = *Hildenbrandia rivularis* = *Phalaris arundinacea*.

Algae were clearly the dominant group, with seven out of the 11 most abundant species. Encrusting forms were most abundant, and two *Nostoc* spp., *N. rivularis* and *N. parmelioides* frequent. Many lichen species were present, and in addition to submerged *Verrucaria* spp. being abundant, *Collema flaccidum*, *C. fluviatile*, *Dermatocarpon fluviatile* and *Verrucaria praetermissa* were frequent. Many bryophytes were recorded, but only *Fontinalis antipyretica* and *Eurhynchium riparioides* were abundant. One moss that was restricted to the Ettrick was *Fissidens rufulus*. Angiosperms were in general rare, with *Myriophyllum alterniflorum* being the only submerged higher plant recorded, and *Phalaris arundinacea* the only abundant bank species.

(iib) Below Selkirk. "sewage fungus", *Eurhynchium riparioides* = *Fontinalis antipyretica*, *Ranunculus pencillatus* var. *calcareus*, *Ulothrix zonata*, *Vaucheria* sp(p.), *Oedogonium* spp. = *Potamogeton crispus*, *Stigeoclonium tenue*, *Leptodictyum riparium*, *Phalaris arundinacea*.

All the algae that were abundant above Selkirk were either absent or rare below the town. There were four algae that were abundant in the lower stretches of the Ettrick, with *Oedogonium* spp., *Vaucheria* sp(p). and *Stigeoclonium tenue* confined to below the sewage outflow pipe. In complete contrast to the upper stretches, lichen species were rare. *Eurhynchium riparioides* and *Fontinalis antipyretica* were more abundant below Selkirk, and *Leptodictyum riparium* was restricted to the river below the sewage works thus showed a similar response in the Ettrick as it did in in the Tweed below the effluent discharge of Peebles. No other bryophytes were abundant. Five submerged angiosperms species were present, *Ranunculus penicillatus* var. *calcareus* and *Potamogeton crispus* being abundant. The other three species were *Elodea canadensis*, *Myriophyllum alterniflorum* and

Ranunculus aquatilis agg. The most abundant growth below Selkirk was "sewage fungus".

8.45 Jed Water

(i) This tributary had the lowest number of submerged macrophyte species recorded than any other river. The number of algal species recorded was slightly higher than bryophyte and angiosperm numbers. As percentage abundances, algae remained marginally the most important group, but bryophytes were more abundant than the same number of angiosperms.

(ii) Cladophora glomerata, Phalaris arundinaceae, Eurhynchium riparioides, Hygroamblystegium fluviatile, Myosotis scorpioides, Potamogeton crispus, Fontinalis antipyretica = Veronica beccabunga, Conocephalum conicum = Juncus acutiflorus.

Cladophora glomerata was the most abundant macrophyte in the Jed; it was also the only abundant alga. The only other algae that were at all well represented were the encrusting growths of Hildenbrandia rivularis and Heribaudiella fluviatilis. Four bryophytes were abundant, including the most frequently recorded liverwort, Conocephalum conicum. Potamogeton crispus was the only permanently submerged angiosperm to be abundant, although Myriophyllum spicatum and Potamogeton natans were also present. Bank angiosperms were as abundant as bryophytes. The Jed was the only river in which Chara vulgaris was recorded. The presence of Leptodictyum riparium was confined to below the town.

8.46 Eden Water

(i) The vegetation of the Eden showed a close relationship between the number of species recorded in each group, and their percentage abundance. The most abundant groups in descending order were; algae, angiosperms, bryophytes, and then lichens.

(ii) Enteromorpha sp(p)., Cladophora glomerata, Hildenbrandia rivularis, Verrucaria other spp., Ranunculus fluitans, Potamogeton crispus, Elodea canadensis, Gongrosira incrustans, Eurhynchium riparioides, Sparganium erectum.

Four algae were abundant, and the three most abundant macrophytes in the river were algal species. Gongrosira incrustans was the fourth algal species listed as abundant in the Eden. Submerged Verrucaria spp. was the only abundant lichen, and Eurhynchium riparioides was the only abundant bryophyte. Ranunculus fluitans x? was the only Ranunculus species in the river; it was also the most abundant angiosperm. Two other submerged higher plants were abundant, Elodea canadensis and Potamogeton crispus ; Zannichellia palustris was locally frequent. Sparganium erectum was the most abundant bank species, and many other bank angiosperms were frequent.

8.47 Leet Water

(i) Algae were the dominant group in the Leet, twice the number of species being recorded than for any other group. The abundance percentage of 65 was the highest for any taxonomic group in the whole of the Tweed Basin. Bryophytes were represented by two-thirds the number of species as angiosperms, but the total abundances of both groups was identical.

(ii) Cladophora glomerata, Enteromorpha sp(p)., Phormidium spp. Leptodictyum riparium, Rorippa nasturtium-aquaticum, Spirogyra spp., Vaucheria sp(p)., Veronica beccabunga, Myriophyllum spicatum, Phalaris arundinaceae.

The three most abundant species were all algae, and another two, Spirogyra spp. and Vaucheria sp(p). were among the 10 most abundant species. Other frequent algae were Hildenbrandia rivularis and Gongrosira incrustans; and the Leet was one of the few tributaries in which Botrydium granulatum was found. Leptodictyum riparium was the only abundant moss, and Fissidens crassipes was present in the lower stretches only. Myriophyllum spicatum was the only abundant submerged angiosperm, but Potamogeton crispus and P. pectinatus occurred at infrequent intervals. Zannichellia palustris and Ranunculus spp. were confined to the lowest stretches of the river where an inocula of the species were provided by a mill-lade from the Tweed. Rorippa nasturtium-aquaticum, a truely emergent species was abundant, and many bank species were frequent. Species more frequent here than in any other tributaries were: Carex riparia, C. rostrata, Iris pseudacorus, Juncus inflexus, Polygonum amphibium and Veronica beccabunga. Purple photosynthetic bacteria were present and often abundant in mid-river, and "sewage fungus" was abundant below the sewage pipe carrying the domestic sewage of Coldstream into the lowest 0.5 km of the river.

8.48 River Till

Although the survey represented a distance of 58.0 km, there was no sudden change in the vegetation from one 0.5 km length to another. The vegetation of the whole river is therefore described as a whole.

(i) Both algae and angiosperm species were recorded most from the lower half of the river, and the latter group had its peak number of submerged species recorded in the lowest 10 km. Throughout the river, angiosperms were the most abundant group, especially in the 10 km between -20.0 to -29.5, where a peak of 56% was reached. This was in the same stretch that lichens were totally absent, and the bryophyte percentage abundance the lowest of any tributary. In the upper half of the river, and in particular the uppermost 10 km, angiosperms decreased, and bryophytes increased in percentage abundance.

(ii) Ranunculus fluitans x ?, Vaucheria sp(p)., Cladophora glomerata, Myosotis scorpioides, Elodea canadensis, Veronica beccabunga, Sparganium erectum, Glyceria fluitans = Juncus effusus, Eurhynchium raparioides.

Vaucheria sp(p). and Cladophora glomerata were the only abundant algae in the Till. *Hildenbrandia rivularis*, *Lemanea fluviatilis* and *Heribaudiella fluviatilis* were frequent except in the middle reaches of the river. *Enteromorpha* sp(p). and *Cladophora aegagropila* were present in the lower 20 km only. Like the encrusting algae, *Verrucaria* spp. were absent in mid-river.

No bryophytes were abundant, the most recorded species being *Eurhynchium riparioides*, *Fontinalis antipyretica* and *Leptodictyum riparium*. The last species was the dominant moss in the lower 20 km of the river where it was present with *Fissidens crassipes*, a species confined to the lower stretches. Other bryophytes were more frequent further upstream.

Many angiosperms were frequent in the Till, with *Ranunculus fluitans* x ? the most abundant species in the whole of the river. *Elodea canadensis* was also abundant, and two other species, *Myriophylum spicatum* and *Zannichellia palustris* were frequent in all but the upper 10 km. *Potamogeton crispus* and *Ranunculus penicillatus* var. *calcareus* extended further upstream, but the latter species was absent where *R. fluitans* x ? was abundant. Other submerged species confined to the lower stretches were *Potamogeton x suecicus* which was frequent, and *P. pectinatus* and *P. perfoliatus*. Many bank species were recorded, and five species were abundant. One bank species which was confined to the Till was *Rumex hydrolapathum*.

8.49 Adder Waters

8.49a Blackadder

(i) In the 30 km of the Blackadder surveyed, the number of species recorded in each group, and their abundance percentages were well matched, and fairly uniform throughout the river. Angiosperms were the dominant group throughout, and algae sub-dominants. In the upper 10 km, the abundance of bryophytes was twice that in the lower 20 km, and a concomitant decrease in the other three groups was noted.

(ii) Enteromorpha sp(p)., Eurhynchium riparioides, Ranunculus fluitans x ? Sparganium erectum, Myriophyllum spicatum, Elodea canadensis, Potamogeton berchtoldii, Cladophora glomerata, Hildenbrandia rivularis, Phalaris arundinacea = Rorippa nasturtium-aquaticum.

Three macrophytic algae were abundant, and another three, Heribaudiella fluviatilis, Gongrosira incrustans and Tetraspora sp(p). were frequent. Eurhynchium riparioides was the only abundant bryophyte, but several others were locally frequent; Grimmia alpicola in the upper reaches, and Marchantia polymorpha and Leptodictyum riparium in the lowest reaches below Langton Burn Foot (km -24.0).

Submerged angiosperms were frequent, and four species were abundant. Many other species were frequent, however, they were usually only local. Ranunculus circinatus and R. penicillatus var. calcareus were frequent in the upper stretches, as was a hybrid of the two species. Seven Potamogeton species were present in various stretches of the river, and Myriophyllum alterniflorum was restricted to the upper stretches, and Zannichellia palustris to the lower stretches of the river. Emergent species Butomus umbellatus and Rorippa nasturtium-aquaticum were often frequent, and two bank species, Sparganium erectum and Phalaris arundinacea were abundant. Many other bank species were frequent, Iris pseudacorus being as frequent as in the Leet.

8.49b Whiteadder

Above Blackadder Foot, the vegetation of the Whiteadder was very different from that found below the confluence of the two rivers. The most abundant species above and below the confluence are thus listed separately (iia and iib).

(i) In the Whiteadder, algae and angiosperms were the most recorded groups, the former in the upper reaches, and the latter in the lower reaches.

Percentage abundances were closely related to the number of species recorded in each group, with angiosperms the most abundant group except in the upper 10 km, where algae were dominant. Bryophyte abundances never exceeded 20% of the total.

(iia) Above Blackadder Foot. *Potamogeton crispus*, *Myriophyllum alterniflorum*, *Verrucaria* other spp., *Potamogeton berchtoldii*, *Zannichellia palustris*, *Chamaesiphon* spp., *Heribaudiella fluviatilis* = *Ranunculus fluitans* x ?, *Eurhynchium riparioides*, *Enteromorpha* sp(p).

The most abundant algae were *Chamaesiphon* spp. and *Heribaudiella fluviatilis* which were particularly common in the upper stretches, and *Enteromorpha* sp(p). in the lower stretches. *Tolypothrix penicillatus*, *Didymosphenia geminata*, *Chaetophora pisiformis* and *Rhodoplax schinzii* were also frequent in the upper reaches surveyed, and *Tetraspora* sp(p). was almost as frequent as *Enteromorpha* sp(p). in the lower reaches. Submerged *Verrucaria* spp. were abundant, and was a member of the encrusting community that was abundant in the upper stretches of the river. *Eurhynchium riparioides* was the only abundant bryophyte, and *Fontinalis antipyretica* was rare.

Angiosperms were the dominant group, with five submerged species abundant. *Elodea canadensis* and *Ranunculus penicillatus* var. *calcareus* were also frequent. No bank species were abundant, however *Mentha aquatica*, *Myosotis scorpioides*, *Phalaris arundinacea* and *Rorippa nasturtium-aquaticum* were the most frequent species.

(iib) Below Blackadder Foot. *Enteromorpha* sp(p). *Ranunculus fluitans* x ? *Zannichellia palustris*, *Potamogeton crispus*, *Phalaris arundinacea*, *Cladophora glomerata* = *Sparganium erectum*, *Heribaudiella fluviatilis* = *Eurhynchium riparioides* = *Potamogeton berchtoldii*.

Three algae were abundant, with *Enteromorpha* being the most abundant species in the river. In the lowest 10 km, *Gongrosira incrustans* was often frequent . As in the upper reaches, bryophytes were not a common group, and only Eurynchium riparioides was abundant. Leptodictyum riparium was locally frequent. Angiosperms were by far the most dominant group, and four submerged species were abundant. Myriophyllum alterniflorum was frequent in the upper 10 km, but was replaced in the lower 10 km by M. spicatum, which occurred commonly among Potamogeton pectinatus and P. perfoliatus. Two bank species were abundant, and Butomus umbellatus, Mimulus guttatus, Myosotis scorpioides, Rorippa nasturtium-aquaticum and Scirpus lacustris were frequent.

8.5 Summary

Generally, the algal flora shows least variation from one river to another. In the Tweed and Teviot which were surveyed throughout their lengths, algae also showed least variation from uppermost to lowermost reaches. This was also true in the three lowest, most comprehensively partially surveyed tributaries, Till, Blackadder and Whiteadder. Algae were relatively more important in tributaries than in either the Tweed or Teviot, being the most abundant group in all except the Biggar and the three lowest and largest tributaries mentioned above. In all four tributaries where algae were not the most abundant group, they were second in abundance to angiosperms. In rivers where algae were the dominant group, bryophytes were always the sub-dominant group, except in the Eden.

Lichens were usually the least important group, reaching their highest percentage abundance in the middle reaches of the Tweed. Only in the Lyne, Yarrow and upper Ettrick were lichens more abundant than any other single group. In all these three tributaries, angiosperms were the least abundant group. Conversely, lichens were always least abundant where angiosperms were the dominant group, i.e. the Biggar, mid Till, Blackadder and lower Whiteadder. In the middle reaches of the Till they were completely absent.

In the Tweed and Teviot, bryophytes were the most abundant group in the upper stretches, but on passing downstream became less abundant, and gave way to angiosperm dominance. In the tributaries above Teviot Foot, in all but the Biggar, bryophytes were the second most abundant group after algae. In the tributaries below Teviot Foot, bryophytes were less abundant than both algae and angiosperms, except in the extreme upper 10 km of the Till.

Angiosperms were the dominant taxon in the lower two-thirds of the Tweed, and the lower half of the Teviot. In the tributaries, angiosperms were the dominant group in the three lowest tributaries surveyed, being the most abundant group in the Till, Blackadder and Whiteadder. They were also the most abundant group in the highest tributary surveyed, the Biggar.

Since the bryophyte and angiosperm proportion of the total abundance varied greatly, the ratio of one to the other from eighteen 10 km stretches of the main river and tributaries have been tabulated in Table 8.5a.

In the upper Tweed, upper Teviot, Lyne, Yarrow, upper Ettrick and upper Till, bryophytes were at least three times more abundant than angiosperms. In the upper stretches of the Teviot, Yarrow, and Ettrick, the fiqure was in the region of 10 : 1.

In the lower Tweed, lower Teviot, Biggar, mid and lower Till, Blackadder and lower Whiteadder, angiosperms were three times more abundant than bryophytes. The highest ratios occurred in the lower Tweed (14 : 1), mid Till and lower Whiteadder.

In mid Tweed, Jed, Eden, Leet and upper Whiteadder, the ratio of one to the other was much closer, never exceeding 2 :1 in favour of either taxonomic group. It is noteworthy that the rivers, or parts of rivers

river	region	number of species	abundance ratio
Tweed	km 0.0 to 9.5	8:2	5:1
	km 70.0 to 79.5	4:7	1:2
	km 140.0 to 149.5	4:13	1:14
Teviot	km -50.0 to -59.5	6:3	11:1
	km -0.0 to -9.5	4:13	1:3
Biggar	whole river	3:7	1:4
Lyne	whole river	7:5	4:1
Yarrow	whole river	8:1	8:1
Ettrick	upper	8.1	8.1
	lower	4:6	1:1
Jed	whole river	3:3	2:1
Eden	whole river	3:6	1:2
Leet	whole river	4:6	1:1
Till	km -50.0 to -59.5	3:3	3:1
	km -20.0 to -29.5	3:6	1:11
	km -0.0 to -9.5	4:11	1:4
Blackadder	whole river	3:12	1:5
Whiteadder	km -30.0 to -39.5	5:6	1:1
	km -0.0 to -9.5	3:13	1:9

Table 8.5a Comparison of the number and abundance ratios of submerged bryophytes and angiosperms within 10 km stretches of rivers within the Tweed Basin.

species	Yarrow	upper Ettrick	Lyne	lower Ettrick	Biggar	Jed	Till	upper Whiteadder	Leet	Blackadder	Eden	lower Whiteadder
Didymosphenia geminata	1											
Hygrohypnum luridum	9=											
Chamaesiphon spp. (*)	4	1						6				
Rhodoplax schinzii (*)	8	8										
Chaetophora pisiformis (*)	10	6										
Nostoc rivularis (*)		9										
Ulothrix zonata	3=		4=	5=								
Diatoma spp. (*)	4											
Lemanea fluviatilis		6										
Myriophyllum alterniflorum			8=		5=			2=				
Grimmia alpicola												
Juncus effusus							8					
Rorippa nasturtium-aquaticum									5	10		
Spirogyra spp.									6			
Fontinalis antipyretica	2	4	3	2	5	7						
Cinclidotus fontinaloides	10											
Hygroamblystegium fluviatile			8			4						
Conocephalum conicum						9						
Phormidium spp.					10				3			
Juncus acutiflorus						9						
Glyceria fluitans							8					
Veronica beccabunga						7	6		8			
Verrucaria (submerged spp.)		3	1					3			4	
Eurhynchium riparioides	6	5	1	2		3	10	9		2	9	8
Oedogonium spp.	7			7								
Stigeoclonium tenue				9								
Myosotis scorpioides						5	4					
Heribaudiella fluviatilis		2						7				
Potamogeton natans					4+							
sewage fungus				1								
Vaucheria sp(p).				6			2		7			
Hildenbrandia rivularis		9	4							9	3	
Phalaris arundinacea		9	7	9	1	2			10	10		5
Brachythecium rutabulum					8							
Ranunculus penic. var calcareus				4+	2+							
Sparganium erectum							7			4	10	6
Elodea canadensis					3+		5+			6+	7+	
Potamogeton crispus				7+	7+	6+		1+			6+	4+
Cladophora glomerata			4+		9+	1+	3+		1+	8+	2+	6+
Leptodictyum riparium				9+					4+			
Ranunculus fluitans x ?							1+	7+		3+	5+	2+
Zannichellia palustris								5+				3+
Myriophyllum spicatum									9+	5+		
Enteromorpha sp(p).								10+	2+	1+	1+	1+
Potamogeton berchtoldii (*)								4		7		8
Gongrosira incrustans (*)											8	

(*) species not present in the Tweed.

= species restricted to upper Tweed and Teviot (see Table 9.21b)

+ species restricted to lower Tweed and Teviot (see Table 9.21b)

Table 8.5b Ten most abundant species in tributaries which received only partial surveys.

where angiosperms were most abundant were described as predominately slow flowing where silt frequently accumulated. This was particularly obvious in the lower 40 km of the Tweed, mid reaches of the Till which flow over alluvium and interglacial peat, and the lower Whiteadder below Blackadder Foot (see 3.2).

The 10 most abundant species in the tributaries have been summarized in Table 8.5b. Species have been listed in the same order as in the "association table" of the Tweed (fig. 8.64a). Species marked with an '*' were not recorded in the Tweed as macrophytic growths, although Chamaesiphon spp., Rhodoplax schinzii, Chaetophora pisiformis and Diacoma spp. were noted as present (see 7.2). Tributaries have been ordered so that those with a species composition most akin to the upper Tweed are placed to the left, and those with a species composition most akin to the lower Tweed to the right.

8.64 Figures

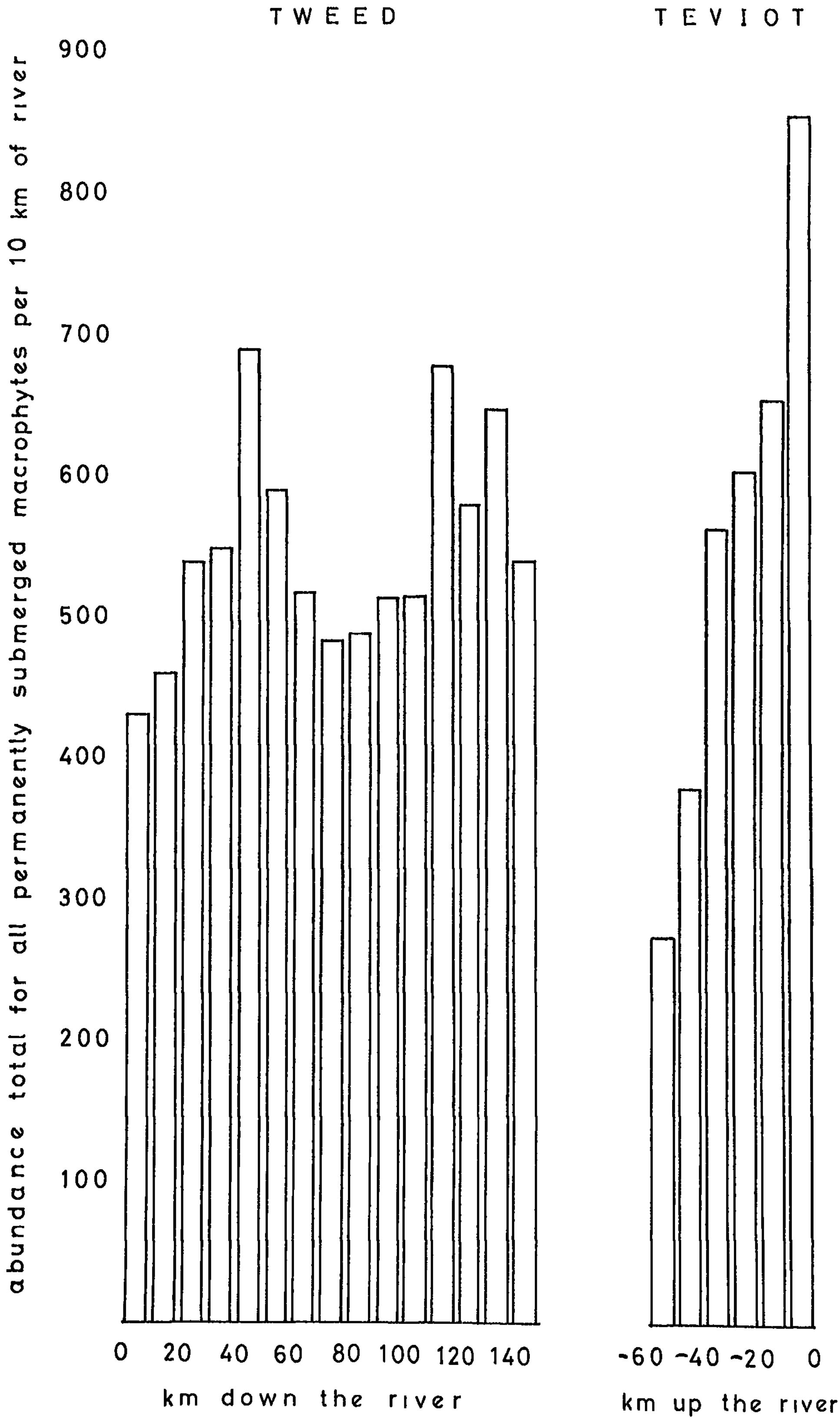


Fig. 8.61a Total abundance of all submerged macrophytes recorded from every 0.5 km length in 10 km stretches of the Tweed and Teviot.

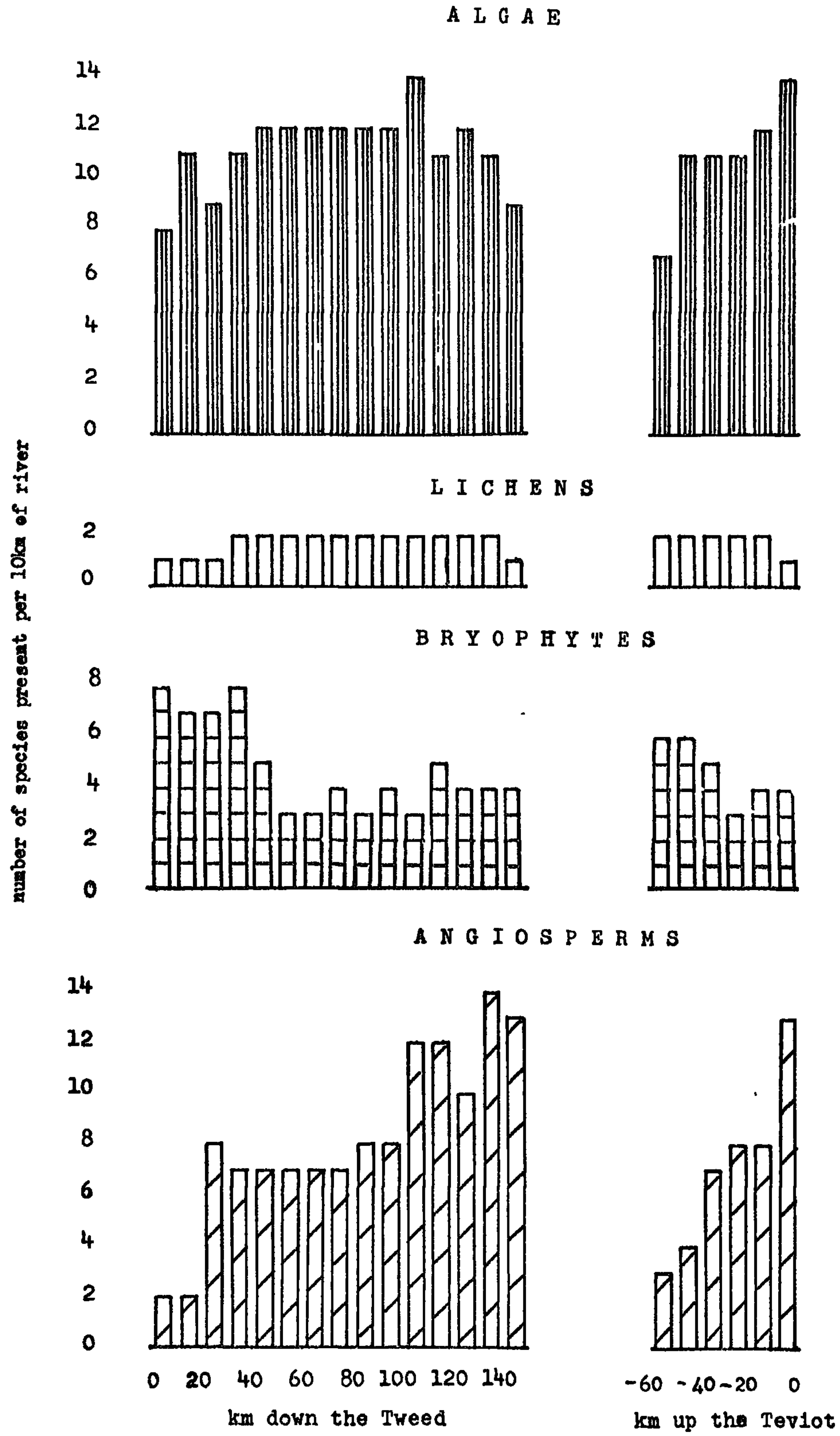


Fig. 8.62a Number of submerged algal, lichen, bryophyte and angiosperm species recorded from 10 km stretches of the Tweed and Teviot.

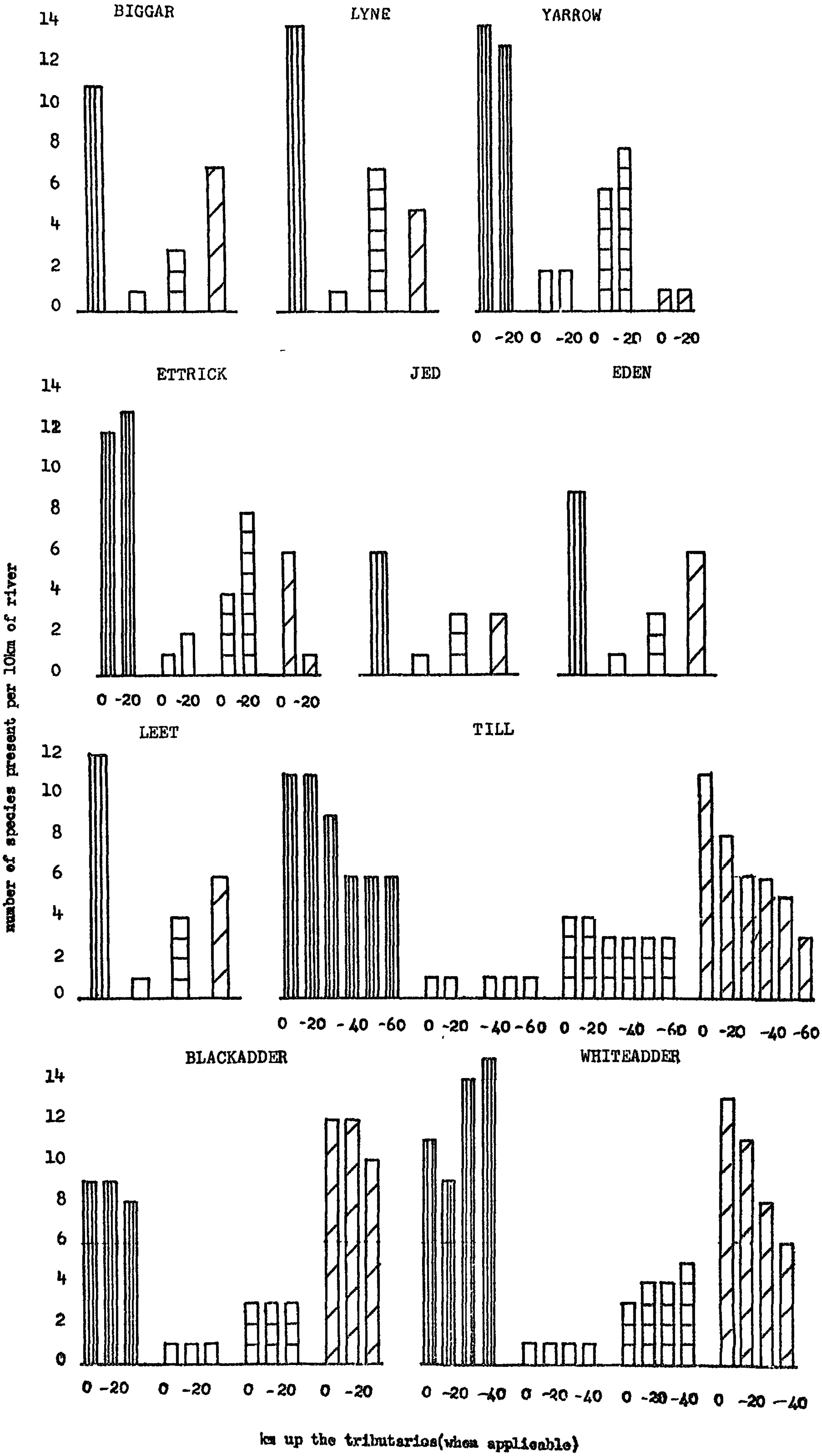


Fig. 8.62b Number of submerged algal, lichen, bryophyte and angiosperm species recorded from 10 km stretches of tributaries.

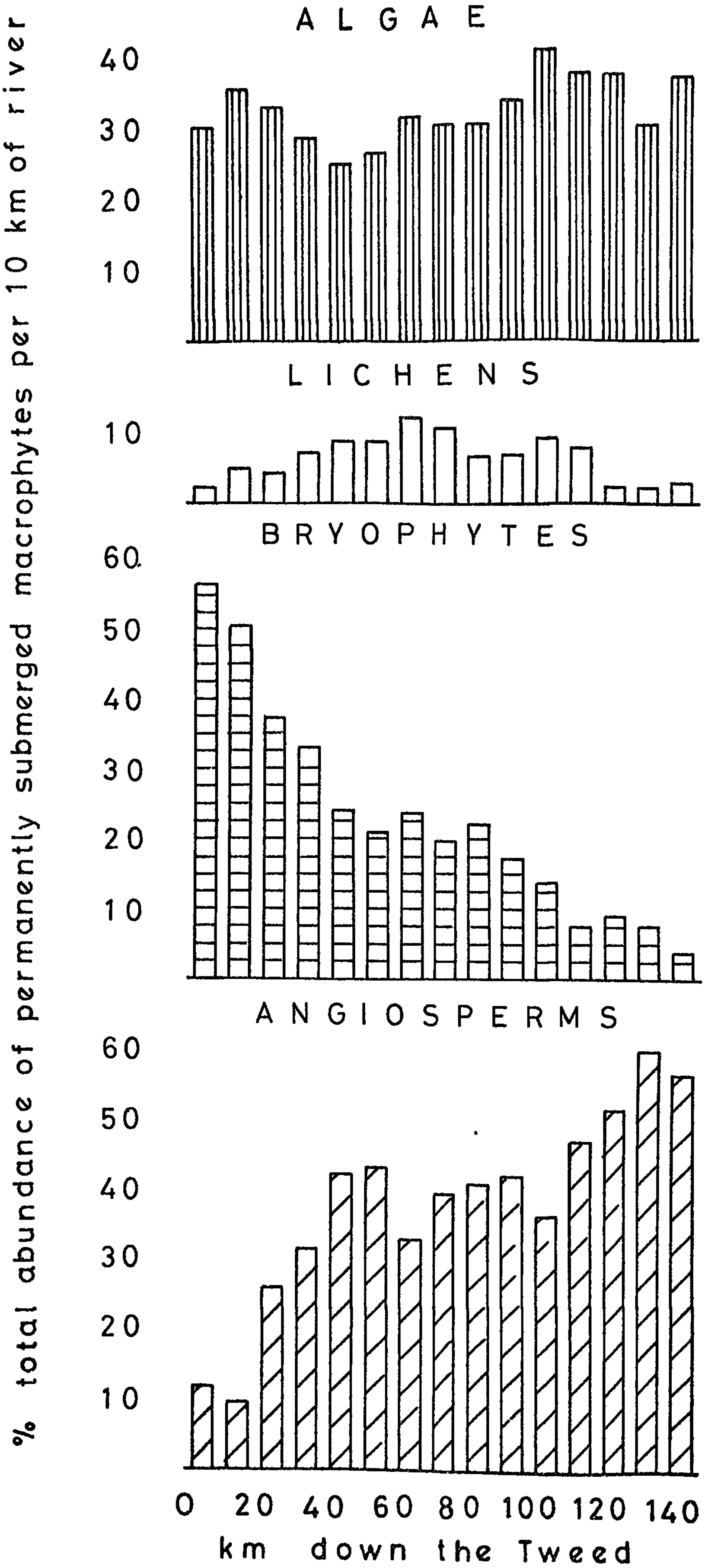


Fig. 8.63a Relative abundance of algae, lichens, bryophytes and angiosperms in 10 km stretches of the Tweed.

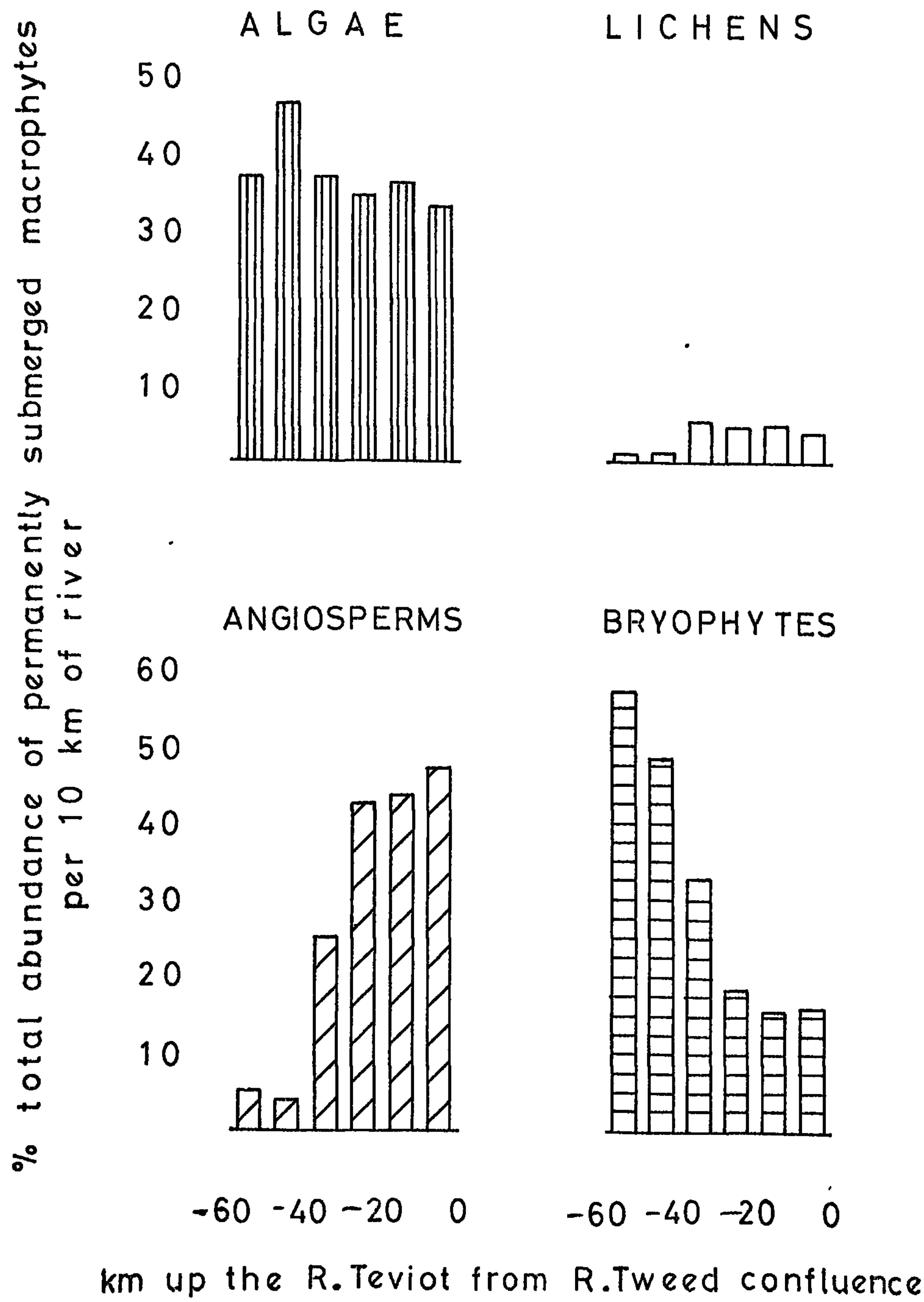


Fig. 8.63b Relative abundance of algae, lichens, bryophytes and angiosperms in 10 km stretches of the Teviot.

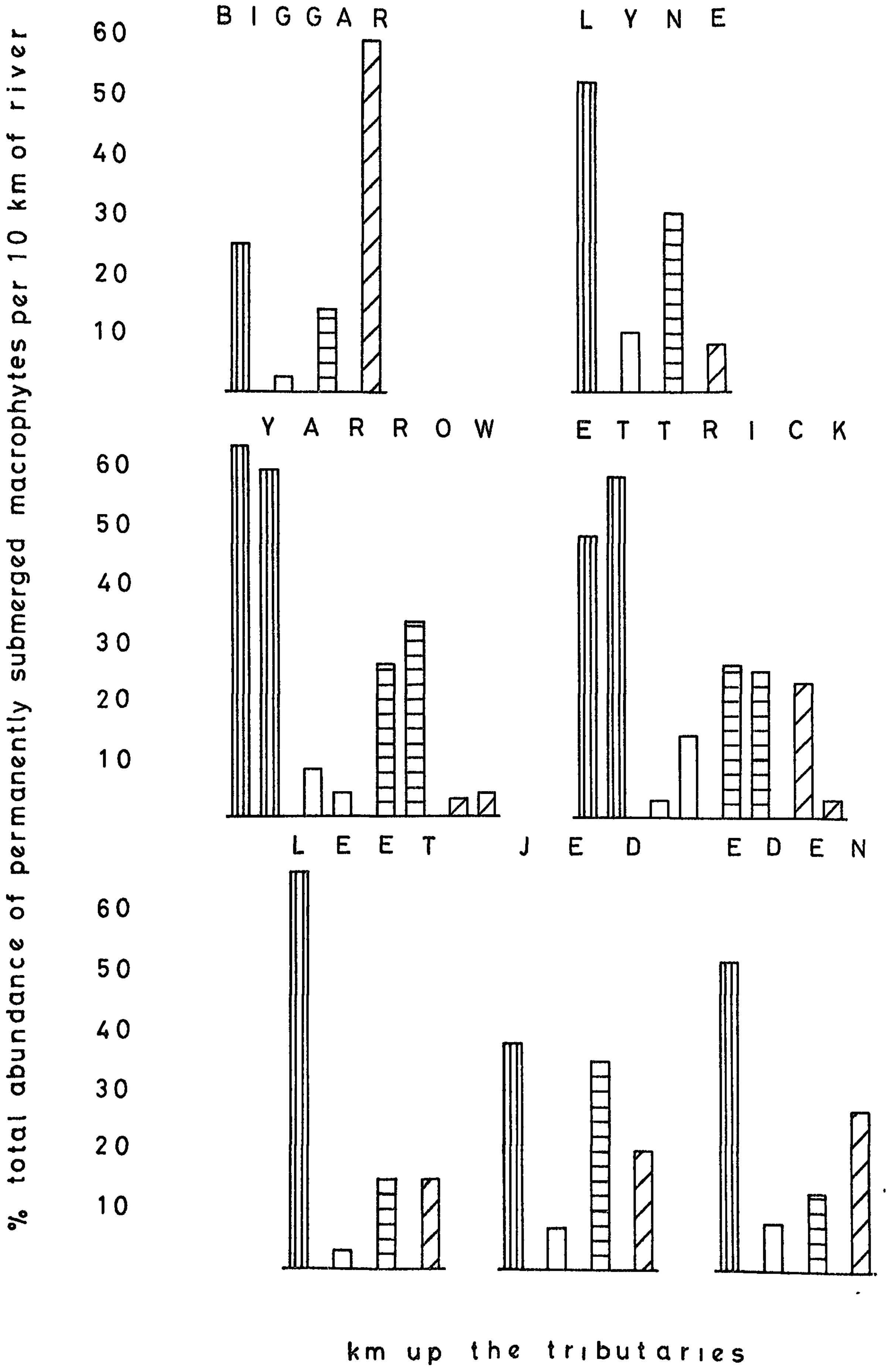


Fig. 8.63c Relative abundance of algae, lichens, bryophytes and angiosperms in 10 km stretches of partially surveyed tributaries.

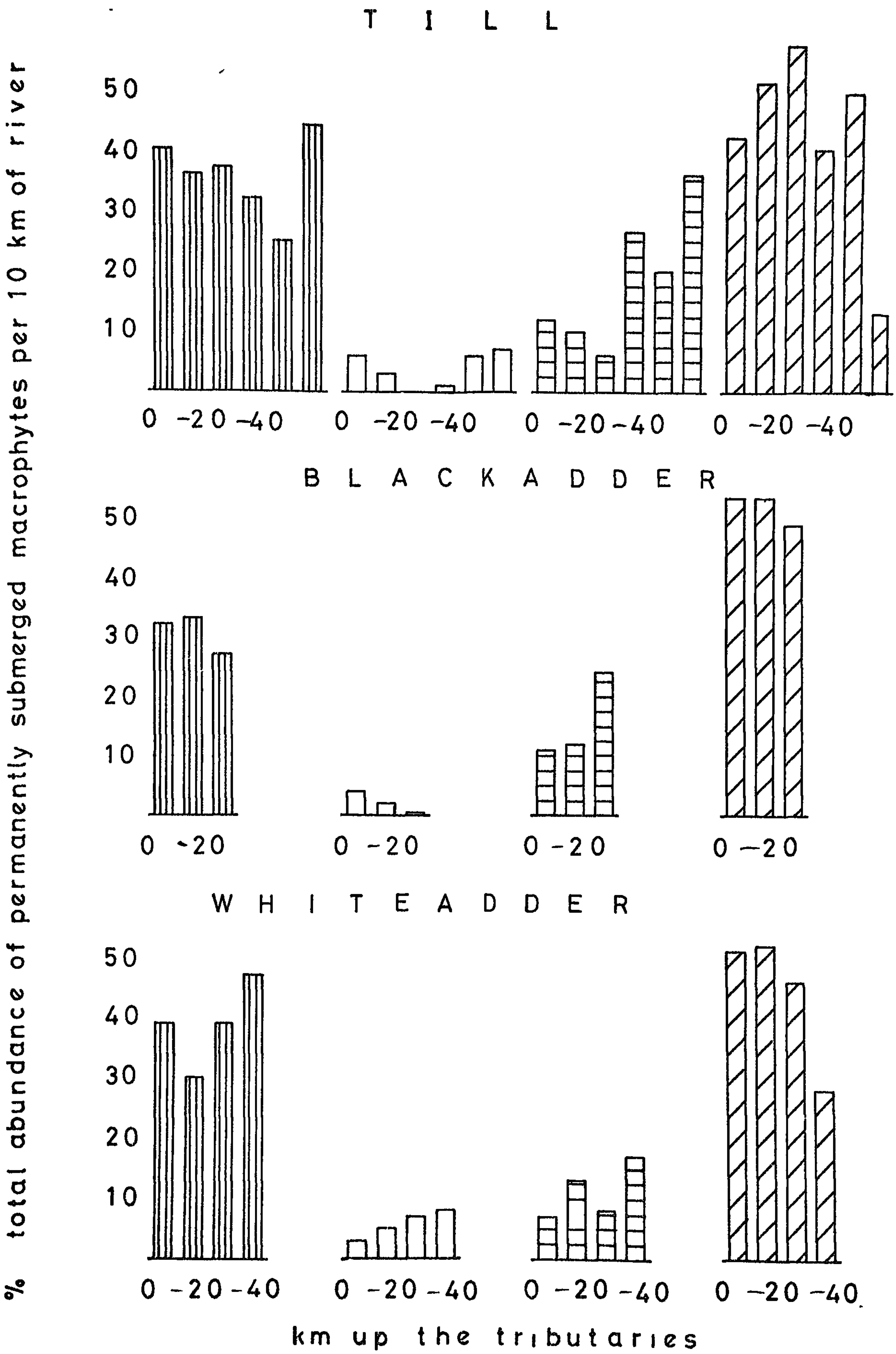


Fig. 8.63c continued.

species

km down the Tweed

species	0 – 10 – 20 – 30 – 40 – 50 – 60 – 70 – 80 – 90 – 100 – 110 – 120 – 130 – 140 – 150
Didymosphenia geminata	5 6 6 7 6 11 12 17 14 17
Hygrohypnum luridum	14 15 19 14 13 16 15 15 17 + + + + +
Brachythecium plumosum	18 13 14 19 21 12 13 9 7 + + + + + + . + . + +
Philonotis fontana	8 9 11 10 5 6 8 6 11 + + + . 5 + 6 + . +
Bryum pseudotriquetrum	9 12 8 9 11 6 9 7 7 6 + 5 + 5 + 5 + + + ... + ... +
Ranunculus flammula	+ + + + + + + + + +
Solenostoma triste	8 + 11 9 + + + + + + + + + + + . + 5 . +
Cochlearia alpina	+ + + + 5 5 5 + + +
Climacium dendroides	+ + + + + + + 5 + +
Amphidium mougeotii	+ + . + + + + . . . + . +
Hygrohypnum ochraceum	10 + + + + 8 + + 5 5 + . 5 + + +
Mnium punctatum	+ + + + + + + + + + + . . + . + ... +
Scapania undulata	+ + + + 5 . + . + . + 7 + . . +
Rhacomitrium aquaticum	+ + + + + + + ... +
Carex nigra	+ + + + 6 + + + + + + + + ... +
Rhacomitrium acicularis	+ + + ... + . . . + +
Haematococcus viride	+ + + + + . + + . + . + . + ... + ... +
Rhytidiadelphus squarrosus	+ . + + . + ... + +
Acrocladium cuspidatum	11 11 6 5 13 8 8 6 5 + . + +
Brachythecium rivulare	8 6 6 + + + 5 5 9 8 6 10 5 7 + 9 7 5 + 7 . + + + ... + + + + + . . . + + + . +
Dichodontium pellucidum	11 14 10 10 + 6 9 + 5 + 5 6 8 6 + 8 + ... +
Ulothrix zonata	+ + + 8 10 8 + 5 6 11 5 10 7 6 6 6 7 7 8 + 9 + + + + + + + + + + + + + + + + + . + . +
Prasiola crispa	+ + + + + + + + + + + + + + + . + + ... + . + . + + . + . + . + . . + + + +
Lemanea fluviatilis	+ . + + + + . + + + + . . +
Myriophyllum alterniflorum	9 7 10 7 9 + 7 7 12 7 8 12 12 11 12 13 14 15 11 17 16 8 12 9 11 10 10 8 10 9 5 8 7 7 6 + 6 9 9 7 7 10 7 + +
Grimmia alpicola	14 16 16 8 11 10 11 8 9 5 + 6 6 + . + + + + + + + . + + + + + . + + . +
Juncus effusus	+ 5 + 5 5 + 6 6 5 7 6 5 + 7 + + + + 5 + 8 + + + + + + + . . + + + + + . + + 5 . + + + + . + . + . + . . . + . . . +
Cratoneuron filicinum	+ + 5 + + + 7 8 5 7 5 6 11 9 7 10 6 + + + + + + + + . + . + . + . + + + . + . + + + . + . + + . + + +
Callitriche spp.	6 5 5 + + + 5 + + + + + 8 +
Filipendula ulmaria	+ + + + + 6 5 6 5 5 + 5 + + 5 6 6 5 6 + 5 + + + + + + + + + + + + + + + + + 5 5 + + + 6 + . + . + + . + + 5 + 5
Rorippa nasturtium-aquatic	+ + + + + + + + + + + + 5 5 + + + + + + + + . + + + + + + + + + + + + + 7 6 7 . 6 9 + + + + + + + + + + + + + + . +
Fontinalis ant. var gracilis	+ . + ... + ... + ... + ... +
Funaria hygrometrica	+ . + . + + + . + + + + + + . . . + . + . + + + + . + + . + . + . + . + . . + . . + ... +
Carex other sp(p).	+ + + + + + + + + 7 . + + + + . + + + . + + . + + + + ... + . + . . . + . + + + . + + . . + + +
Thamnium alopecurum	+ . + . + + . + + + + + + + + . + . + + + . + . + + . + + + + . . + . . + . . . +
Collema flaccidum	+ . . . . . . + ... + ...
Chiloscyphus polyanthos	+ + + . + + + + 5 5 5 + + + + + + + + + + + 5 6 + + + + . + + + + + + + + + + + + + . . . + . +
Fissidens adianthoides	+ + + + + . + . + 5 + + . + + + + + + + + . . . + + + + . + + + + + + + + + 6 +
Leskea polycarpa	+ 8 + + + + . +
Ranunculus aquatilis agg.	+ 5 + 8 7 6 + 6 8 16 19 17 7 6 9 8 5 + + + + + 5 + + + . + + +
Potam. X olivaceus	+ 6 5 + + 12 10 9 15 6 8 14 5 7 9 + + . + + . + + + . + + . . . + ... + . . +
Nostoc other sp(p).	+ . . . . + . + + + . + + . + + . + . + + + . . . + +
Dermatocarpon fluviatile	+ . + + + + + + . . + + + + + + + 5 + + + + + 5 + + + + +
Mentha aquatica	+ + + 5 6 + 6 5 + + + + + + + + 5 + + + ... + . + . + + ... + . . + + + + + + . . . + ... + . . . +
Spirogyra spp.	+ + + + + 6 + + + + + + . + . + . + . . + + + ... 6 5 + +
Carex rostrata	+ + + + + + + + + + 7 . + + + . + + + . + + . . + ... + + ... + . . + . + . . . + . . 9 10 6 +
Mnium longirostrum	+ + + 6 + + + + + + 6 + 5 + + + + + + + + + + + + + + + + +
Marchantia polymorpha	+ +
Verrucaria praetermissa	+ + + + . + + + . 5 + + + + + + 5 + + 5 5 5 5 5 + 5 + + 5 + + 7 + + 5 + 5 6 6 6 + + . + . + . + + + + + +
Fontinalis antipyretica	13 13 15 17 18 14 13 13 17 8 11 15 14 8 9 11 13 9 11 10 9 8 14 7 12 9 10 10 7 7 7 11 5 6 11 14 9 12 6 + + + 5 + + + + . + + + 5 + + + . + + +
Cinclidotus fontinaloides	16 15 9 + + 8 7 7 9 6 5 11 8 10 10 11 6 9 5 6 + + + 6 8 + + 8 + + + 6 + 8 10 8 9 10 + + + 9 10 5 5 + 11 + + + 5 + + + + + + . +
Hygroamblystegium fluviatile	11 12 10 12 15 12 10 14 12 8 9 14 13 14 9 12 13 16 12 8 9 6 5 6 7 5 + + 6 8 9 + 6 6 6 + + 5 + 6 6 6 5 + + + + . + + + + 6 + + + + + +
Pellia epiphylla	5 . + 8 +
Conocephalum conicum	7 8 8 8 + + . + + + + 5 7 6 9 + 8 8 6 + + 6 + + 5 5 6 5 5 + 6 + + + + + + 5 8 5 + + + + + + + . . . 5 . + + + + + +
Phormidium spp.	5 + + + + + . . . + + + 5 + + + + + + + + + + + + 5 5 6 6 7 + + + + + + + + + + + + + + ... + + + + + + + +
Juncus acutiflorus	+ + + + 5 5 5 6 5 6 5 6 + 6 + 5 + + 5 + 9 + + + + + + + + + + + 6 + + + + 5 5 6 + + + + + + + + + + + + + 5 6 + + + + + +
Glyceria fluitans	+ + + + + + + . + + . + + . + 7 + + 6 5 + 7 + + . + + + + . + + + + + + + + + + . + + + + 5 + + 6 + + + + + +
Veronica beccabunga	+ + + + + + + 5 + 5 + + + + + + + + 6 5 + + + ... + + + + + + + + + . + + + 5 + + + +
Verrucaria other spp.	+ + + 6 + 5 8 + 5 7 6 5 8 8 8 14 13 12 14 11 9 10 13 12 13 14 15 9 9 7 10 5 6 7 7 6 8 6 6 6 5 7 5 + 7 8 11 6 + + + + + + + + 5 + 5 +
Eurhynchium riparioides	6 8 7 5 8 6 9 9 14 10 13 14 15 20 17 16 18 19 15 13 13 10 15 17 14 12 19 16 11 6 7 11 11 14 13 13 11 15 10 7 6 9 10 11 + + + 6 6 5 5 6 5 + + + + + +
Mimulus guttatus	+ 6 7 5 7 7 6 6 + 5 6 6 5 5 8 9 7 10 10 + 8 5 7 5 + + + 6 + + + + + + 7 + + + 6 5 + + 5 + + + 5 + + + + + + + + + + + + + 5 +
Caltha palustris	+ 5 + + 5 + 5 + 5 + 5 + 5 5 + 5 5 + 5 + + + 5 + 5 5 5 + 5 + 5 5 + + 5 + + + + + + + + + + + 5 + + + + + + + + + + + + + + + 5 6
Oedogonium spp.	11 11 12 9 6 7 6 5 6 6 6 3 5 5 5 5 7 6 8 9 12 8 9 5 + + + ... + 10 . 5 6 7 11 10 9 8 11 16 15 21 17 20 13 12 17 10 16 13 7 7 17 20 7 10 +
Stigeoclonium tenue	+ + 6 7 7 6 6 6 6 6 6 5 5 + 5 + 6 6 6 6 + + 5 + + + 5 + + + 5 + + + + + + + 5 5 5 + + 8 11 14 + + 10 7 10 7 11 6 + + +
Myosotis scorpioides	+ + + + 5 5 5 5 5 5 6 6 5 6 7 9 7 10 10 6 9 8 7 5 + + 5 6 + + + 5 6 6 5 7 + 9 8 6 7 8 8 7 6 5 5 5 6 5 5 5 6 5 9 6 6 5 6 +
Heribaudiella fluviatilis	+ + + + + + + + + + + + 6 6 5 + 5 6 6 7 + 6 5 + 5 7 7 7 8 + 5 6 + + 5 7 5 5 + 6 + 6 7 8 5 + 6 7 6 + 9 + 6 7 7 5 + + 7 15
Orthotrichum rivulare	+ . + + + . + + + + + + + + . + . . . + . + + + + +
Pellia endiviifolia	+ . . . . . + + . + . . + . + + + . + . . + . . + + ... + ... + . . . + + + + + + +
Iris pseudacorus	+ . + . . . + . . + . . + . . + . . . + . + . + . + ... + . . + ... + . . + . +
Potamogeton natans	+ . + . . . + ... +
Scirpus sylvaticus	+ . . + . . + + + . + + . + + + + + + 5 + + 6 + 5 . . + + + + + . 5 . . . . . . + + . . . +
Collema fluviatile	7 + + + . + . + + + + + . + + + 5 + + + + 8 + + + + + + + + + 9 + 12 + 6 6 + 7 . + + + + +
Cladophora species 'A'	+ . + + . + + . + . + + + + + + + + + + + 5 + 6 + + 6 + + + + 7 + + 5 + + + + + + +
Sewage fungus (obvious)	+ + + . . + 6 . + . . + . . + . + . + + . . + ... + +
Nostoc parmelioides	+ . . + + + + + 6 + + 6 + 6 . + . + + + 6 7 8 + 8 . + + + 5 + + + + + +
Juncus inflexus	+ . . + + + + + ... + + + +
Monostroma bullosum	+ . + . + . + . + . . + . . +
Botrydium granulatum	+ + . + + + + + + + . +
Tetraspora sp(p).	+ + + + + + + + + + + + + + + 5 + + + + +
Fissidens crassipes	7 + + 5 + + + + + 6 6 + + + +
Vaucheria sp(p).	+ . . . . + + ... + . 5 + + + . + + + . + . . . + 6 + . + + + + + + 5 5 + 7 6 + . . + . + . + + + + + + + + + + 9
Equisetum fluviatile	+ + 5 + + + + + + . + + . + + + + 6 + + . + + + + + + + + + + + + + + + + + 5 + 6 + 5 + + . + + + + 5 + + + + + + . +
Tortula mutica	+ + + . + + + + + + 5 + + + + 6 6 6 6 6 5 6 + 5 + + + + + + + + + + + + + + + + + . + + . + + + + + +
Hildenbrandia rivularis	+ + + + + + 5 5 5 7 9 8 8 6 11 9 9 6 9 15 7 8 8 13 9 6 5 7 8 12 8 8 6 11 10 8 6 12 9 7 8 11 11 9 6 5 8 + 8 5 9 + + + 9 +
Phalaris arundinacea	+ + 5 6 + 6 8 7 6 8 11 11 12 12 14 11 13 12 13 8 10 10 10 10 10 11 12 10 11 12 8 11 9 10 9 8 9 9 8 7 7 7 6 7 7 6 5 6 9 8 6 6 6 6 10 10
Brachythecium rutabulum	+ . . . + . . + . + + + + 5 . + + + + 8 6 7 + 5 + + + + + + + + 5 8 5 7 8 6 8 5 7 6 7 5 + + + 5 5 + + + 5 + + + + + 8 +
Ranunculus penicillatus var. calcareus	+ + + 13 5 + 6 8 14 13 13 10 15 12 16 18 13 9 11 12 13 18 18 16 14 13 18 16 16 16 10 12 11 12 12 10 16 13 12 17 14 15 14 13 12 13 16 13 10 14 8 +
Eleocharis palustris	+ + + + . + + + + + + + + + 5 7 6 7 + + + + + + + 5 + 6 8 5 + + 8 5 7 7 + 5 11 8 6 12 9 5 6 + 5 + + 7 + 8 6 7 5 6 5
Sparganium erectum	+ + + + . + 12 6 + + 9 9 9 9 11 6 7 + + 6 8 7 + + 6 + + + + 5 + + + . + + + 12 6 7 + + 5 + + + + + 9 + 5 + + +
Polygonum amphibium	+ . + + . + + + + + + + + . . + . + + + + + + + + + 5 + + + + + + + 5 + 8 + 6 6 + 8 + 6 + + + + 9 5 + 5 + + + +
Elodea canadensis	+ + 10 5 + 9 12 15 14 16 17 16 21 17 12 10 11 8 10 13 11 12 12 15 11 13 13 9 13 13 17 10 14 9 13 11 10 9 7 8 6 6 9 10 8 12 10 19 16 12 +
Potamogeton crispus	5 6 + + + + + 5 + 5 + . + 6 + 8 7 + 9 6 + 7 8 + + + + + 5 7 6 + + + + 7 + + + 6 5 5 5 6 6 7 5 6 + 6 +
Cladophora glomerata	+ . . . . . + 5 + 6 6 6 7 + 5 5 7 6 7 5 + 5 6 5 7 5 7 5 7 + + 5 + 10 6 + 7 + 7 8 8 8 9 9 7 11 9 9 6 5 7 + 7 6 11 22
Rorippa amphibia	+ . . . . + . . + + + + + + . + + 5 . + 5 8 5 7 5 8 7 7 5 7 8 6 + 5 + + 6 5 5 5 6 6 7 5 6 + 6 +
Leptodictyum riparium	5 + + . + ... + + + ... + ... + + + + + + + + + + 5 + + + + + + +
Ranunculus fluitans	+ 13 19 17 19 17 12 7 7 10 12 16 10 13 15 14 15 11 12 15 15 16 13 16 17 9 5
Zannichellia palustris	+ 5 + + 5 + + + + + 5 + 6 + + +
Potamogeton X salicifolius	+ 14 16 13 + 13 13 + 8 10 14 6 5 . + 8 +
Potamogeton pectinatus	+ 15 15 17 13 12 16 8 16 12 12 13 10 11 5 6 9
Myriophyllum spicatum	5 8 12 9 6 9 8 10 8 11 12 13 8 8 8 14 8
Potamogeton pusillus	+ + + + + + + + + + + + + + + + +
Enteromorpha sp(p).	10 + 5 6 8 + 12 + 7 7 9 6 5 12 8 8 22
Potamogeton perfoliatus	+ . . + . . + . . 7 14 17 16 12 14 15 8
Potamogeton lucens	+ 6
Potamogeton X suecicus	+ + + + + . + +

km down the R.Teviot (from R.Tweed at Kelso)

species	60.0	57.5	55.0	52.5	50.0	47.5	45.0	42.5	40.0	37.5	35.0	32.5	30.0	27.5	25.0	22.5	20.0	17.5	15.0	12.5	10.0	7.5	5.0	2.5	0.0
Solenostoma triste	+	+	+																						
Rhacomitrium acicularis	+	+	+																						
Climacium dendroides	+	+	+																						
Rhytidiadelphus squarrossus	+	+	+	.	+																				
Rhacomitrium aquaticum	+	+	+	+	+																				
Carex ovalis	+	+	5	+	+	+																			
Ranunculus flammula	+	+	+	.	+	+																			
Scapania undulata		+	+	+																					
Carex hirta		+	.	.	+																				
Ranunculus aquatilis		+	+	.	+																				
Ulothrix zonata	6	9	13	8	8	13	+	+																	
Philonotis fontana	17	13	9	9	9	7	.	+	.	+															
Carex nigra	7	+	11	+	+	+	+	+	+																
Amphidium mougeotii	+	+	+	+	.	+	+	+																	
Carex rostrata	+	+	+	7	12	10	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+		
Cochlearia alpina	5	+	+	.	+	+	.	.	+	+															
Haematococcus viride	+	+	.	+	+	.	+	.	.	+															
Chamaesiphon (obvious)	5	6	+	6	+	6	5	5	+	+															
Brachythecium plumosum	5	12	+	7	11	5	7	8	+	+															
Mnium punctatum	+	+	+	+	+	+	.	+	+	+	+														
Hygrohypnum luridum	9	9	7	10	9	9	16	15	13	15	9	+	+												
Acrocladium cuspidatum	+	16	9	10	15	8	5	9	+	+	.	+	.	.	.	.	.	.	.	.	+				
Brachythecium rivulare	+	7	+	9	11	+	9	6	+	8	.	.	.	+	+	+	.	+	.	.	.	+			
Cratoneuron filicinum	13	10	5	8	11	5	10	10	6	8	+	+	+	.	+	+	+	.	+	.	.	+			
Bryum pseudotriquetrum	14	13	9	8	10	7	5	7	7	+	.	+	.	+	.	.	.	.	.	+	.	+	+	+	
Pellia epiphylla	5	6	+	5	5	+	+	+	+	+	.	.	.	.	+	.	.	.	+	+	.	+	+	+	+
Grimmia alpicola	9	14	8	9	12	8	11	10	8	+	+	+	+	.	+	+	7	+	+	+	+	.	.	+	
Phormidium spp.	+	6	9	10	7	9	10	+	+	+	.	.	+	+	+	.	+	+	.	.	.	.	+	+	+
Mentha aquatica	5	5	6	+	8	9	+	+	+	+	+	+	+	+	+	.	.	.	+	+	.	.	+	+	+
Juncus effusus	7	9	7	7	5	+	+	+	.	.	+	.	.	+	.	+	+	.	+	+	.	.	+	+	+
Juncus acutiflorus	17	8	15	10	11	8	+	5	7	+	+	.	+	6	+	+	+	.	+	+	.	+	+	.	+
Mnium longirostrum	6	+	5	+	7	+	+	6	+	+	+	+	+	.	.	+	.	+	+	+	+	+	+	+	
Verrucaria praetermissa	+	8	6	+	+	6	8	5	+	+	+	+	+	.	+	.	+	.	+	+	.	+	+	+	+
Lemanea fluviatilis	+	.	.	+	+	+	+	+	7	+	+	+	.	.	.	.	+	.	.	.	.	+	+	+	+
Callitriche other sp(p).	+	.	.	+	+	.	.	.	+	.	.	+	.	.	.	.	+	.	.	+					
Funaria hygrometrica	+	.	+	.	+	.	+	+	+	+	+	.	.	.	+	+	.	.	+						
Fissidens adianthoides		+	.	+	+	.	+	+	+	+	+	+	+	.	+	+	.	+							
Vaucheria sp(p).		+	+	.	.	.	.	.	+	.	+	7	.	+	8	.	5	+	.	.	.	+	.	+	
Orthotrichum rivulare			+	.	+	+	+	.	+	.	+	+	.	.	+	+	+	.	+	.	.	+	.	.	+
Carex acutiflorus			+	+	6	+	+	5	+	+															
Myriophyllum alterniflorum				+	.	+	.	+	7	12	7	.	+	+	+										
Hygrohypnum ochraceum							+	+	+																
Chara sp.					+	.	.	.	+	+															
Sewage fungus (obvious)									+	.	.	+													
Leskea polycarpa									+	.	+	+	+	+	+	+	+								
Collema fluviatile									+	+	+	.	+	.	.	.	+	+	+	+	.	.	+		
Stigeoclonium tenue												+	+	.	.	.	.	.	.	.	.	.	+		
Dermatocarpon fluviatile													+	.	+	+									
Pellia endiviifolia								+	+	+	+	.	.	.	.	+	.	.	+	+	+	+	.	+	
Tortula mutica											+	+	+	+	+	6	7	+	+	+	.	.	+	.	+
Collema flaccidum															+	.	.	+	.	.	+				
Phragmites communis																		+	+						
Leptodictyum riparium										+	.	.	.	.	.	.	+	+	+	+	.	+	6		
Prasiola crispa							+	+	.	.	.	5	+	.	.	+	+	+	.	.	+	+	5	6	+
Iris pseudacorus				+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	+	8	+
Thamnium alopecurum								+	8	7	.	+	.	.	.	.	.	.	.	.	.	+	+	+	+
Fissidens crassipes								+	.	.	+	+	+	.	.	.	.	+	.	.	.	+	5	+	5
Potamogeton natans										+	.	.	.	.	.	.	.	+	.	.	.	+	.	.	+
Equisetum fluviatile	8	5	+	5	5	+	6	6	5	+	+	+	+	+	+	.	+	+	+	+	.	.	+	.	+
Glyceria fluitans	6	9	13	6	+	10	9	+	+	5	5	+	+	+	+	+	+	.	+	+	+	.	+	+	+
Conocephalum conicum	5	12	5	5	7	5	+	5	7	9	+	+	5	+	+	+	+	+	+	+	+	+	+	.	+
Dichodontium pellucidum	7	6	6	6	7	8	6	8	8	6	5	+	+	+	+	+	+	+	+	+	+	+	5	.	+
Filipendula ulmaria	6	6	5	8	9	10	12	5	6	+	+	+	+	+	+	+	.	6	+	+	5	+	+	+	+
Hygroamblystegium fluviatile	+	+	+	+	+	+	5	+	+	10	5	12	9	6	7	5	10	8	6	5	+	5	+	.	+
Myosotis scorpioides	5	5	+	5	5	5	5	+	6	6	5	5	5	6	6	7	7	5	7	5	6	6	6	7	6
Mimulus guttatus	9	8	+	6	7	5	+	6	+	+	5	+	+	7	6	8	7	6	9	5	6	5	5	8	6
Eurhynchium riparioides	14	22	17	12	18	19	18	21	23	17	16	18	22	13	10	8	11	10	16	12	7	14	18	17	22
Fontinalis antipyretica	9	10	5	7	10	7	5	8	10	13	6	10	16	11	6	10	14	9	12	7	5	17	7	6	8
Veronica beccabunga	6	+	.	+	6	.	.	+	+	+	.	+	.	+	6	+	5	+	+	5	+	5	+	+	+
Caltha palustris	+	+	.	+	+	+	+	+	5	+	+	+	+	+	5	.	+	+	+	5	.	+	+	5	6
Eleocharis palustris	+	+	+	+	+	+	+	+	6	.	.	.	+	9	9	+	+	7	6	6	+	6	10	10	11
Cinclidotus fontinaloides		+	+	+	.	+	12	17	17	15	7	7	8	+	+	+	7	5	+	+	.	.	+	7	7
Rorippa nasturtium-aquaticum		+	+	+	+	+	+	+	+	.	+	+	+	+	7	+	+	+	.	.	+	+	.	+	+
Rorippa amphibia			+	+	+	+	+	.	+	+	+	+	.	.	.	.	+	+	+	+	5	+	+	.	+
Gongrosira incrustans		5	5	+	5	6	7	10	11	6	12	8	7	7	12	8	8	9	10	6	8	+	7	12	13
Heribaudiella fluviatilis		+	+	+	+	+	+	+	5	7	9	7	9	5	6	5	5	+	+	+	6	+	9	+	7
Hildenbrandia rivularis		+	.	+	.	.	+	+	6	7	7	11	9	5	6	9	6	7	10	8	7	9	15	11	15
Verrucaria other spp.		+	.	+	.	.	.	+	+	+	+	8	11	7	7	7	5	7	10	5	6	7	8	8	7
Brachythecium rutabulum				+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	+	+	5	+	+	+	+
Phalaris arundinacea				+	6	+	+	+	+	5	5	7	7	7	9	5	6	7	10	8	8	6	6	7	6
Oedogonium spp.						+	+	8	6	8	5	8	5	9	6	+	+	6	6	14	+	+	5	5	+
Spirogyra spp.							+	6	7	9	+	+	.	+	8	7	5	+	+	5	+	+	+	+	+
Cladophora glomerata							+	6	+	+	12	14	15	10	16	16	10	5	15	7	16	9	5	5	9
Melosira varians							+	5	5	+	+	+	.	+	+	+	+	+	8	10	+	+	11	9	+
Polygonum amphibium							+	.	+	+	+	+	+	+	+	+	7	+	+	6	.	6	6	7	6
Sparganium erectum		+	.	.	.	.	.	.	+	+	+	+	+	+	+	+	.	9	10	+	8	9	14	19	18
Potamogeton crispus										6	8	17	15	11	8	6	5	8	8	9	+	10	5	5	8
Elodea canadensis									+	7	9	9	11	11	11	8	12	14	13	8	6	7	10	6	10
Ranunculus penicillatus var.calcareus									+	+	+	.	+	17	19	21	20	20	24	19	14	17	22	22	20
Myriophyllum spicatum											5	7	12	10	8	9	17	20	16	15	17	16	16	16	18
Zannichellia palustris											+	+	+	11	13	13	15	15	17	15	15	12	10	10	11
Marchantia polymorpha										+	+	+	+	+	+	.	+	+	+	+	+	+	+	.	5
Juncus inflexus														5	+	+	+	.	.	+	.	.	+	+	6
Potamogeton pusillus															+	+	+	+	+	+	+	+	.	.	+
Nostoc parmelioides																	+	.	.	+	.	.	.	.	+
Enteromorpha sp(p).																	+	7	12	12	12	12	12	10	13
Tetraspora sp(p).																			+	+	+	+	11	11	6
Scirpus sylvaticus																				+	+	+	5	5	+
Monostroma bullosum																					+	.	+	+	+
Callitriche hermaphroditica																						+			
Potamogeton lucens																						+	.	.	+
Potamogeton perfoliatus																						+	+	+	+
Potamogeton pectinatus																						+	9	15	13
Potamogeton X salicifolius																						+	8	14	18
Ranunculus fluitans																							9	14	21
Lemna minor																								+	6

9. SUMMARY AND DISCUSSION

9.1 Introduction

The primary aim of this research was to obtain a comprehensive picture of the distribution of macrophytes in a single river basin, and relate this to environmental parameters. The Tweed and 10 tributaries were surveyed, and the species composition of each river compared. This data will be compared in 9.3 with that found by other workers for other rivers in the British Isles and mainland Europe. Literature which specifically referred to individual species has been included in Chapter 6.

The factors governing the distribution of species in rivers have been outlined in 1.3, but it may be useful at this point to summarize those regarded as most important. The initial step must be the dispersal of a species to the river. In this respect the presence of a species is often more significant than its absence, for its absence may not be in any way related to the environment, but due to failure in dispersal (Haslam, 1971). Once present at a site, a macrophyte must be able to withstand all environmental parameters, in addition to competition with other species with similar habitat preferences. The most important parameters known to effect the distribution of a species are the flow regime of the river (see 1.3), substratum, including geology, water chemistry, and to a much less well documented or known degree, any historical influences. This includes pollution and all biotic effects.

The influence of these factors on the distribution of macrophytes in rivers has been discussed by many authors (see 1.2), however the complexity of the field situation is often oversimplified. To ascertain if a single parameter is the main causal factor governing a species distribution is often almost impossible to determine. It is rare that a situation occurs where all but one parameter remain the same, whilst the single variable changes.

In order to determine the distribution of macrophytes in the rivers within the Tweed Basin, the method of Whitton and Buckmaster (1970), as modified by Holmes et al. (1972) was used. The method involved plotting macrophyte species presence or absence, together with a subjective evaluation of their abundance in 0.5 km lengths of river. A standard distance of 0.5 km was chosen for the reasons outlined below. In terms of delimination of an area for study in relation to actual landmarks, and those found on the maps used, the length chosen was probably accurate to ± 50 m. If larger, a loss of accuracy in the actual description of the vegetation would have resulted because of the reduction in the possibility of relating changes in the vegetation, to changes in the environment. On the other hand, smaller areas might have been more accurate in their description of the river's vegetation, but if the size was reduced to 100 m, there would have been data from 1,500 reaches for the Tweed itself. The time involved in the collection of such data would have been exhaustive.

It is useful to have a river delimited into sections from source to mouth, or vice versa, so that every point on the river has a reference in relation to its position. By dividing the river into continuous 0.5 km lengths, the river became almost equivalent to a 'transect' (see 2.2). Two possible methods of study could then be applied for macrophyte surveys; either all 'quadrats' (0.5 km lengths) could be surveyed, or only some preselected, or random ones.

Although it was desirable that all the rivers should have been surveyed throughout their entire lengths, this was unpracticable however. During the summer months when surveys were carried out (see 3.2), flow levels usually limited work to one day in two, and on average, five to six 0.5 km lengths could be surveyed thoroughly in a single day. The major river and its largest tributary were completely surveyed from source to mouth; and others partially surveyed. Data were collected in similar ways so that the results from either complete or partial surveys could be compared.

It is important that problems in collection of such data are fully realised when evaluating the results. When wading, the river was frequently traversed in each 0.5 km length in an attempt to cover most of the area of river and its banks. It was however impossible to cover "every inch", and some species that occurred only rarely in some 0.5 km lengths will have inevitably been occasionally overlooked. Other stretches that were too deep to wade were usually surveyed by boat, again however, the same problem applied. Regrettably a few stretches (rarely greater than 20 m) could not be surveyed at any time at all. This only applied where the river was so deep, and the current so swift, that neither wading nor boating was possible. It was noted in 7.2 that during an exceptionally low flow period, one site (km 114.0) was just wadable, revealing an almost 100% cover over an area 5 m^2 of a Hildenbrandia rivularis monoculture. This was not seen elsewhere in the river system.

Another problem is the yearly, seasonal, and even daily changes in vegetation that occur in a river (see 1.5). This may be related to individual species behaviour e.g. most Potamogeton species die back in the winter; and also to environmental effects, probably the most obvious and sudden effects being caused by scouring floods. The data given for the Tweed and its tributaries thus refer to the vegetation at the season and year of survey e.g. the Tweed for summer and early autumn 1971 (see 2.2).

Once surveys have been completed, the presentation of the data is of paramount importance. It is imperative that all the primary data are included as an all time record of the vegetation at the time of survey so that it can be compared with old records, or surveys made at a future date. When relating the distribution of species to environmental parameters, the main consideration is usually the amount of background imformation which is available.

The role of classification of water plant communities is still far from clear, especially those in flowing waters. Attempts have however been made by Braun-Blanquet and Tüxen (1943), Braun-Blanquet (1921, 1964) and Hartog and Segal (1964) to characterise communities on the basis of floristic composition and dominant growth forms (see 1.4). To what extent the communities found in the Tweed Basin can be 'classified' according to such criteria will be discussed in 9.5.

9.2 The distribution of species in relation to environmental parameters

9.21 Physical characteristics

In this section an attempt is made to show that the distribution of some species, and to a less well known degree some taxa, are clearly related to physical parameters. In a river such as the Tweed which rises as a small, rapidly flowing stream in mountains, and falls to become a large, deep, slow flowing river, vast differences in habitat characteristics can be expected. Ignoring changes in such factors as water chemistry, which will be dealt with later, some species can be shown to be associated with either the conditions that prevail in upland reaches, or those of lowland reaches (see Tables 9.21a, b).

Most species showed a geographical distribution that is difficult to quantify in precise terms. The nature of the correlations made for the Tweed are only general, since macrophyte data were not collected with a precise knowledge of the physical characteristics of each 0.5 km length surveyed. Such features as stream size, i.e. mean width and depth, as well as mean daily flows were noted (see 3.6); features regarded as important in affecting macrophyte colonization including water velocity and

and depth, frequency and extent of floods, and the predominate nature of the stream bed were also noted (see 3.2).

Table 9.21a lists the number of species that occurred only at one extreme of the Tweed and Teviot (complete river surveys). The Table shows the number of species that occurred either in the upper or lower reaches, but not both. In addition, the Table indicates how many species of each community were also present in the middle stretches of each river. The data has been taken from the following 10 km stretches of river.

river	upper reach	middle reach	lower reach
Tweed	0.0 to 9.5	65.0 to 74.5	130.0 to 139.5
Teviot	-50.0 to -59.5	-25.0 to -34.5	-0.0 to -9.5

The lowest 10 km of the Tweed surveyed (km 140.0 to 149.5) has not been used since at high tide the lowest stretches are brackish (see 3.2).

Of the 25 species present in the upper Tweed, but not lower Tweed, and 26 species present in the upper Teviot but not lower Teviot, 18 species (72%) were the same. These are listed on the left of Table 9.21b. Of the 36 species present in lower Tweed but not upper Tweed, and 35 species in lower Teviot but not upper Teviot, 24 species (68%) were the same. These are listed to the right of Table 9.21b.

Table 9.21c summarizes the number of species from Table 9.21b that were present in the partially surveyed tributaries. It also includes a ratio of the number of species from the upper reaches compared to the number of species from the lower reaches. More than half the species restricted to the upper reaches of the Tweed and Teviot were recorded in the Yarrow, upper Ettrick, Lyne and upper Whiteadder. Conversely, of the 24 species restricted to the lower Tweed and Teviot, more than half were recorded from the lower Till, lower Whiteadder, Blackadder, Eden,

	no. of species present in upper 10 km but absent in lower 10 km stretch of river	no. of species present in upper 10 km but absent from mid and lower 10 km stretches of river	no. of species present in upper and mid 10 km but absent from lower 10 km stretch of river
TWEED TOTAL	25	16	9
no. of SB	3	4	1
no. of SA	1	0	1
TEVIOT TOTAL	26	20	6
no. of SB	3	2	1
no. of SA	3	2	1

	no. of species present in lower 10 km but absent from upper 10 km stretch of river	no. of species present in lower 10 km but absent from mid and upper 10 km stretches of river	no. of species present in lower and mid 10 km, but absent from upper 10 km stretch of river
TWEED TOTAL	36	15	21
no. of SB	1	1	0
no. of SA	15	10	5
TEVIOT TOTAL	35	12	23
no. of SB	1	0	1
no. of SA	12	5	7

SB = submerged bryophyte   SA = submerged angiosperm

Table 9.21a Indication of the number of species that are confined to either the upper or lower stretches of the Tweed and Teviot.

(a) 18 species present in the upper 10 km, but absent from the lower 10 km of the Tweed and Teviot	(b) 24 species present in the lower 10 km, but absent from the upper 10 km of the Tweed and Teviot
Haematococcus lacustris	Nostoc parmelioides
Ulothrix zonata	Cladophora glomerata
Amphidium mougeotii	Enteromorpha sp(p).
Brachythecium plumosum	Monostroma bullosum
Climacium dendroides	Tetraspora sp(p).
Funaria hygrometrica	Collema fluviatile
Hygrohypnum luridum (SB)	Fissidens crassipes (SB)
Mnium punctatum	Leptodictyum riparium
Philonotis fontana	Tortula mutica
Rhacomitrium aciculare	Elodea canadensis (SA)
R. aquaticum	Juncus inflexus
Rhytidiadelphus squarrosus	Myriophyllum spicatum (SA)
Scapania undulata (SB)	Polygonum amphibium
Solenostoma triste (SB)	Potamogeton crispus (SA)
Carex nigra	P. lucens (SA)
Cochlearia alpina	P. natans (SA)
Myriophyllum alterniflorum (SA)	P. pectinatus (SA)
Ranunculus flammula	P. perfoliatus (SA)
	P. pusillus (SA)
	P. x salicifolius (SA)
	Ranunculus fluitans x ? (SA)
	R. penicillatus var. calcareus (SA)
	Scirpus sylvaticus
	Zannichellia palustris (SA)

SB = submerged bryophyte

SA = submerged angiosperm

Table 9.21b List of species that were confined to the upper stretches of both the Tweed and Teviot (a), and those species that were confined to the lower stretches of the Tweed and Teviot (b).

	upper Tweed and Teviot	lower Tweed and Teviot	ratio
Biggar	7	7	1:1
Lyne	13	5	3:1
Yarrow	17	2	8:1
upper Ettrick	14	3	5:1
lower Ettrick	5	5	1:1
Jed	1	9	1:9
Eden	0	15	0:15
Leet	1	14	1:14
upper half Till	4	10	1:2
lower half Till	3	19	1:6
Blackadder	2	18	1:9
upper Whiteadder	10	13	1:1
lower Whiteadder	1	19	1:19

Table 9.21c Number of species listed in Table 9.21b that were present in partially surveyed tributaries.

(a) No of recorded species ratio		(b) Abundance ratio	
Yarrow	8:1	upper Teviot	11:1
upper Ettrick	8:1	Yarrow	8:1
upper Tweed	4:1	upper Ettrick	8:1
upper Teviot	2:1	upper Tweed	5:1
mid Till	1:2	Lyne	4:1
Eden	1:2	upper Till	3:1
Biggar	1:2	lower Teviot	1:3
lower Till	1:3	Biggar	1:4
lower Teviot	1:3	lower Till	1:4
lower Tweed	1:3	Blackadder	1:5
Blackadder	1:4	lower Whiteadder	1:9
lower Whiteadder	1:4	mid Till	1:11
		lower Tweed	1:14

Table 9.21d Tributaries where the ratio of the number of submerged bryophytes and angiosperm species recorded exceeded 2:1 or 1:2(a), and abundance ratios exceeded 3:1 or 1:3(b).

(a)

Chamaesiphon spp.
Tolypothrix penicillatus
Didymosphenia geminata
Chaetophora pisiformis
Rhodoplax schinzii
Amphidium mougeotii
Brachythecium plumosum
Climacium dendrioides
Drepanocladus uncinatus
Hygrohypnum luridum (SB)
H. ochraceum (SB)
Mnium punctatum
Philonotis fontana
Scapania undulata (SB)
Solenostoma triste (SB)
Rhacomitrium aciculare
R. aquaticum
Rhytidiadelphus squarrosus
Carex nigra
Cochlearia alpina
Ranunculus flammula

(b)

Lemanea fluviatilis
Ulothrix zonata
Acrocladium cuspidatum
Dichodontium pellucidum
Grimmia alpicola
Myriophyllum alterniflorum (SA)

(c)

Heribaudiella fluviatilis
Verrucaria spp.
Conocephalum conicum
Cratoneuron filicinum

(c) continued

Eurhynchium riparioides (SB)
Fontinalis antipyretica (SB)
Hygroamblystegium fluviatile (SB)
Filipendula ulmaria
Glyceria fluitans
Juncus acutiflorus
Myosotis scorpioides
Rorippa nasturtium-aquaticum

(d)

Hildenbrandia rivularis
Cladophora glomerata
Leptodictyum riparium
Tortula latifolia
Eleocharis palustris
Elodea canadensis (SA)
Phalaris arundinacea
Polygonum amphibium
Potamogeton crispus (SA)
Ranunculus penicillatus var. calcareus (SA)
Scirpus lacustris
Sparganium erectum

(e)

Enteromorpha spp.
Tetraspora sp(p).
Fissidens crassipes (SB)
Myriophyllum spicatum (SA)
Potamogeton lucens (SA)
P. pectinatus (SA)
P. perfoliatus (SA)
P. pusillus (SA)
P. x salicifolius (SA)
P. x suecicus (SA)
Ranunculus fluitans x ? (SA)
Zannichellia palustris

(SB) = submerged bryophyte species
(SA) = submerged angiosperm species

Table 9.21e Macrophyte species which are characteristic of particular stretches of the Tweed basin. (a) restricted to upper reaches with fast currents and rocky substrata, (b) abundant in upper stretches but less frequent or absent further downstream, (c) present throughout whole river system, (d) present in all but uppermost stretches, (e) Restricted to localities at low altitudes.

Leet and upper Whiteadder.

Tables 9.21a,b clearly illustrate that in both rivers surveyed throughout their entire lengths, the ratios of submerged bryophytes to submerged angiosperms were very different. In the list of species from the upper reaches, the ratio was 3 : 1, but in the lower reaches it was 1 : 12. In the former, the dominant taxonomic group were bank bryophytes (nine species); in the latter, submerged angiosperms were by far the dominant taxa, with seven Potamogeton species present.

The gradual replacement of bryophyte dominance by angiosperm dominance on passing downstream has been clearly illustrated for both the Tweed and Teviot in 8.62 and 8.63. The former shows this in relation to the number of species recorded ; the latter more clearly, using the relative abundance totals of the two groups. The abundance ratio was 5 : 1 for the Tweed and 11 : 1 for the Teviot in the upper stretches, and 1 : 14 and 1 : 3 in the lower stretches.

It was noted in 3.2 that the uppermost 10 km of the Tweed had the greatest vertical drop per 10 km of the whole catchment area. The upper stretches of the Teviot also have a steep vertical drop. In these stretches, the rate of flow is swift and the substratum rocky, with silt deposition at a minimum. The bed of the former river was stable and consolidated, but the latter's was unstable. Conversely, in the lower stretches of both rivers vertical drops were minimal, resulting in stretches of deep slow flowing water, with few rock surfaces and abundant silt.

Tributaries noted for their rocky nature, rapid currents and lack of appreciable silt were the Lyne, Yarrow, upper Ettrick, Eden, upper Till and upper Whiteadder. In all but the more lowland Eden and upper Whiteadder, all had submerged bryophyte abundance totals more than three times that of submerged angiosperms (see 9.21d). Highest ratios occurred in the Yarrow and upper Ettrick which were the most rapid flowing and rocky.

Those tributaries noted in 3.2 for slow flow rates, few rock surfaces, and abundant silt, were the Biggar, Leet, mid and lower Till, Blackadder and lower Whiteadder. In all except the Leet, more than double the number of submerged angiosperms were recorded than submerged bryophytes, and the ratio of abundance always exceeded 1 : 3. The ratio was highest in mid Till (1 : 11) and lower Tweed (1 : 14). In the former, the substratum is alluvium and interglacial peat (see Fig. 3.2g), and in the latter, predominately soft mud. Fig. 3.2c shows that these two stretches had small vertical drops, indicating slow current velocity.

Table 8.5b summarized the 10 most abundant species in each of the partially surveyed tributaries. In the Biggar, upper Whiteadder, Leet, Blackadder, Eden and lower Whiteadder, four or five of the 10 most abundant species were listed as characteristic of lowland stretches of the Tweed and Teviot (Table 9.21b). Apart from single records in the Biggar and upper Whiteadder, no species listed in the same Table as characteristic of upland reaches were abundant. Although the Eden and upper Whiteadder were described as rapidly flowing and rocky, because they were lowland streams they still had species growing abundantly in them that were listed in Table 9.21b as indicative of lowland, slow flowing conditions. The Biggar on the other hand, was the most upland stream surveyed, but it had canal like characteristics (see Fig. 3.2e). Five species characteristic of lowland, rather than upland Tweed and Teviot were abundant, but they were those species which spread furthest upstream. No species that were most characteristic of the lowlands, i.e. species restricted to below 110 m (see Tables 9.7b) were even present in the river.

Only in the Yarrow and Lyne were two species listed as characteristic of uplands (Table 9.21b) abundant, and in upper Ettrick one species was abundant (see Table 8.5b).

In summary, it can be stated that on the evidence furnished from these surveys, many common species have distribution patterns that can be correlated with physical parameters. Table 9.21e lists species that occurred frequently, (or were present in at least three rivers) in the particular habitat described.

The species listed as present only in extreme upper reaches, (a), where current speed is high and the substratum rocky, four submerged bryophyte species and no angiosperm species were recorded. The list of species from extreme lowland reaches (e), characterised by deep, slow flowing water and muddy substrata, included nine submerged angiosperms and only one bryophyte.

Data given throughout this section and also in previous chapters have shown a striking dominance of bryophytes in stretches with greatest current velocity. Similarly, submerged angiosperms dominate the slowest reaches. Whether the main causal factor in influencing this distribution is actual flow rate, or the indirect effect brought about by the nature of the substratum is unknown; both factors are strongly correlated. One possible conclusion is that in rocky torrent conditions, the stronger attachment and tougher nature of bryophytes is probably more suitable than that of submerged angiosperms. Ability to withstand the scouring effects of floods would also be greater. On passing downstream, many bryophytes still remain frequent (listed in (c) Table 9.21e) in rocky conditions, but in more slow flowing reaches where silt begins to accumulate, submerged angiosperms begin to become established (d). In the slowest sections of such stretches, Elodea canadensis and Potamogeton crispus grow, and in faster areas, Ranunculus penicillatus var. calcareus and bryophytes are found. In the most lowland stretches which are predominately slow flowing, deep and silted (e), submerged angiosperms dominate. Their vegetative form makes them less resistant to the fastest currents and scouring effects, while their more extensive rooting system provides anchorage in the soft substratum.

9.22 Water chemistry

A detailed analytical programme to show the water chemistry of rivers within the Tweed Basin during a variety of seasons or flow regimes was not carried out. Instead, five surveys were undertaken, and the four collected during low flow conditions (see Fig. 5.1a) have been used to compare one river with another. Where more than one site was sampled, different stretches of the same river could be compared.

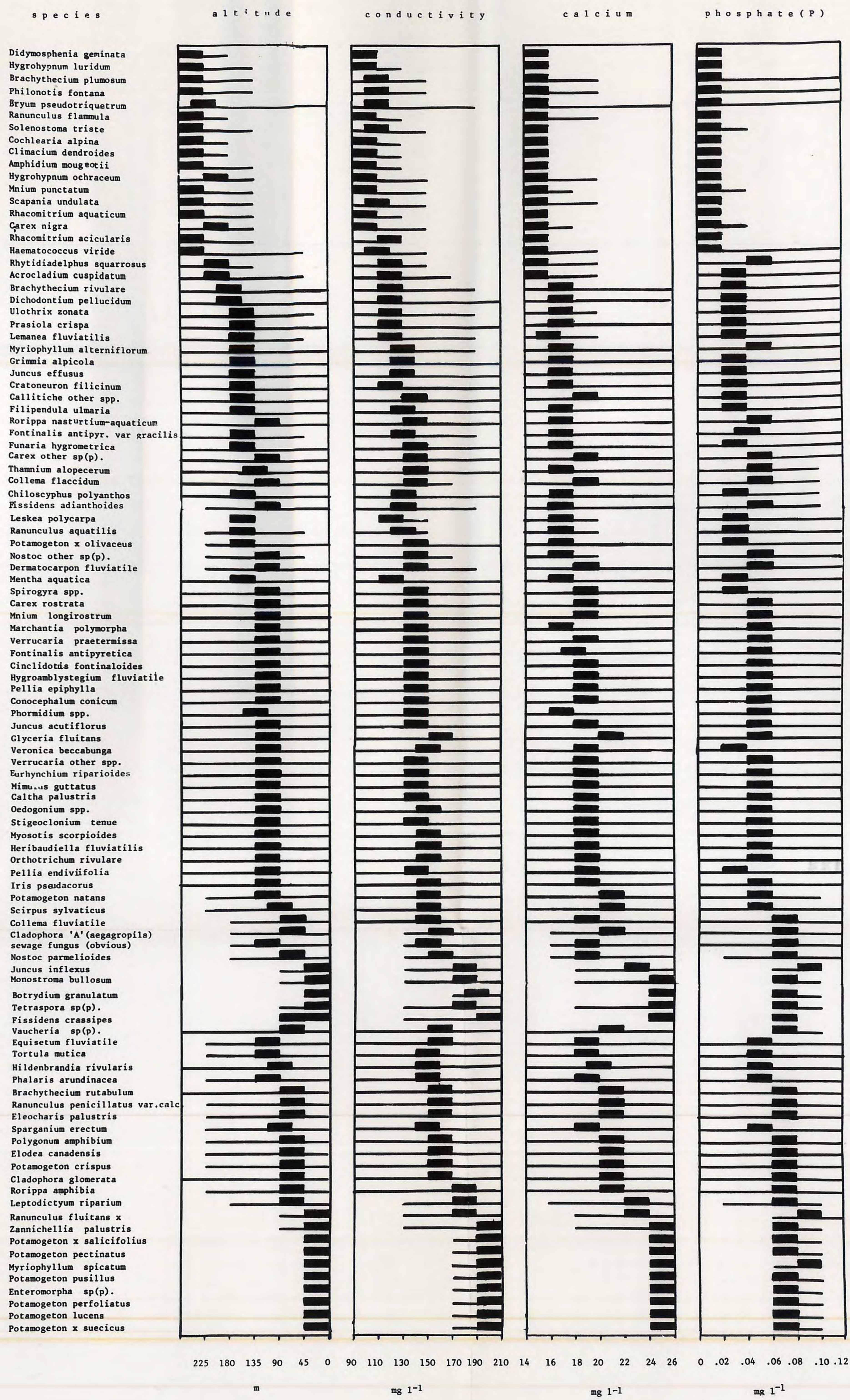
The influence excerted by the chemistry of the water on the distribution of macrophytes will be briefly considered here. As discussed in 1.3 and 9.1, the individual factors (elements) cannot be seen in isolation, for in the field situation many factors change together. Broad generalisations are made, the statistical validity of certain of which are tested using two nonparametric methods.

As more chemical samples were collected from the Tweed than any other river surveyed for macrophytes, a detailed comparison of species response to changes in water chemistry have been made for that river. Table 2.12a indicates which sampling sites have been used to represent the chemistry of all 0.5 km lengths surveyed in the river. All species listed as present in the Tweed (6.21) have been related to 13 chemical parameters, as well as altitude. By using the mean values for the four lowest flows (taken from 5.22) the mean value of each element for each species has been calculated by adding every single record at each chemical level, and then dividing by the total number of records to get the mean. Data are tabulated in 9.7, p. 464 with species being listed in the same order as in the "association table" of 8.64a, p. 405.

Fig. 9.22a summarizes the data in pictorial form for three chemical parameters. It relates the position at which the species were present in the river (altitude), with an indication of the overall solute state (conductivity), hardness (Ca), and nutrient status (PO_4-P). Again species are listed in the same order as in the "association table". The maximum and minimum range of each species are indicate by the length of each line, and the means are indicated by the shaded raised boxes.

Since a much wider variation of water chemistry was evident when the whole river basin was considered, water chemistry data from the tributaries have been included in Fig. 9.22b. It summarizes for five species, the maximum and minimum values for eight parameters. The five species are selected as examples from the five categories of distribution based on physical parameters in Fig. 9.21e. The Mg + Ca / Na + K ratio (Seddon, 1972, modified from Pearsall, 1922) is included since a single figure incorporates data from four analyses. This is referred to by Seddon as the "hardness ratio", with low figues indicating soft water. However, it produces conflicting results to what might have been expected, i.e. some soft water sites have high "hardness ratios", while some hard waters have low "hardness ratios". This might often be affected by sewage effluent, which can be best illustrated by referring to data from the Teviot at Hawick, and also the Jed (5.22). The Mg + Ca totals were 46.6 and 63.6 mg l^{-1} respectively, and Na + K were 7.12 and 25.23 mg l^{-1}. The Seddon hardness ratios are thus 6.5 and 2.5 respectively. The results are included for future reference, for it may be that other workers will also find that this ratio can only be applied to lake waters.

Reference to Figs 9.22a,b shows that species listed in Table 9.21e



species
altitude
conductivity
calcium
phosphate(P)
Didymosphenia geminata
Hygrohypnum luridum
Brachythecium plumosum
Philonotis fontana
Bryum pseudotriquetrum
Ranunculus flammula
Solenostoma triste
Cochlearia alpina
Climacium dendroides
Amphidium mougeotii
Hygrohypnum ochraceum
Mnium punctatum
Scapania undulata
Rhacomitrium aquaticum
Carex nigra
Rhacomitrium acicularis
Haematococcus viride
Rhytidiadelphus squarrosus
Acrocladium cuspidatum
Brachythecium rivulare
Dichodontium pellucidum
Ulothrix zonata
Prasiola crispa
Lemanea fluviatilis
Myriophyllum alterniflorum
Grimmia alpicola
Juncus effusus
Cratoneuron filicinum
Callitiche other spp.
Filipendula ulmaria
Rorippa nasturtium-aquaticum
Fontinalis antipyr. var gracilis
Funaria hygrometrica
Carex other sp(p).
Thamnium alopecerum
Collema flaccidum
Chiloscyphus polyanthos
Fissidens adianthoides
Leskea polycarpa
Ranunculus aquatilis
Potamogeton x olivaceus
Nostoc other sp(p).
Dermatocarpon fluviatile
Mentha aquatica
Spirogyra spp.
Carex rostrata
Mnium longirostrum
Marchantia polymorpha
Verrucaria praetermissa
Fontinalis antipyretica
Cinclidotus fontinaloides
Hygroamblystegium fluviatile
Pellia epiphylla
Conocephalum conicum
Phormidium spp.
Juncus acutiflorus
Glyceria fluitans
Veronica beccabunga
Verrucaria other spp.
Eurhynchium riparioides
Mimulus guttatus
Caltha palustris
Oedogonium spp.
Stigeoclonium tenue
Myosotis scorpioides
Heribaudiella fluviatilis
Orthotrichum rivulare
Pellia endiviifolia
Iris pseudacorus
Potamogeton natans
Scirpus sylvaticus
Collema fluviatile
Cladophora 'A'(aegagropila)
sewage fungus (obvious)
Nostoc parmelioides
Juncus inflexus
Monostroma bullosum
Botrydium granulatum
Tetraspora sp(p).
Fissidens crassipes
Vaucheria sp(p).
Equisetum fluviatile
Tortula mutica
Hildenbrandia rivularis
Phalaris arundinacea
Brachythecium rutabulum
Ranunculus penicillatus var.calc.
Eleocharis palustris
Sparganium erectum
Polygonum amphibium
Elodea canadensis
Potamogeton crispus
Cladophora glomerata
Rorippa amphibia
Leptodictyum riparium
Ranunculus fluitans x
Zannichellia palustris
Potamogeton x salicifolius
Potamogeton pectinatus
Myriophyllum spicatum
Potamogeton pusillus
Enteromorpha sp(p).
Potamogeton perfoliatus
Potamogeton lucens
Potamogeton x suecicus
225 180 135 90 45 0
m
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mg l-1

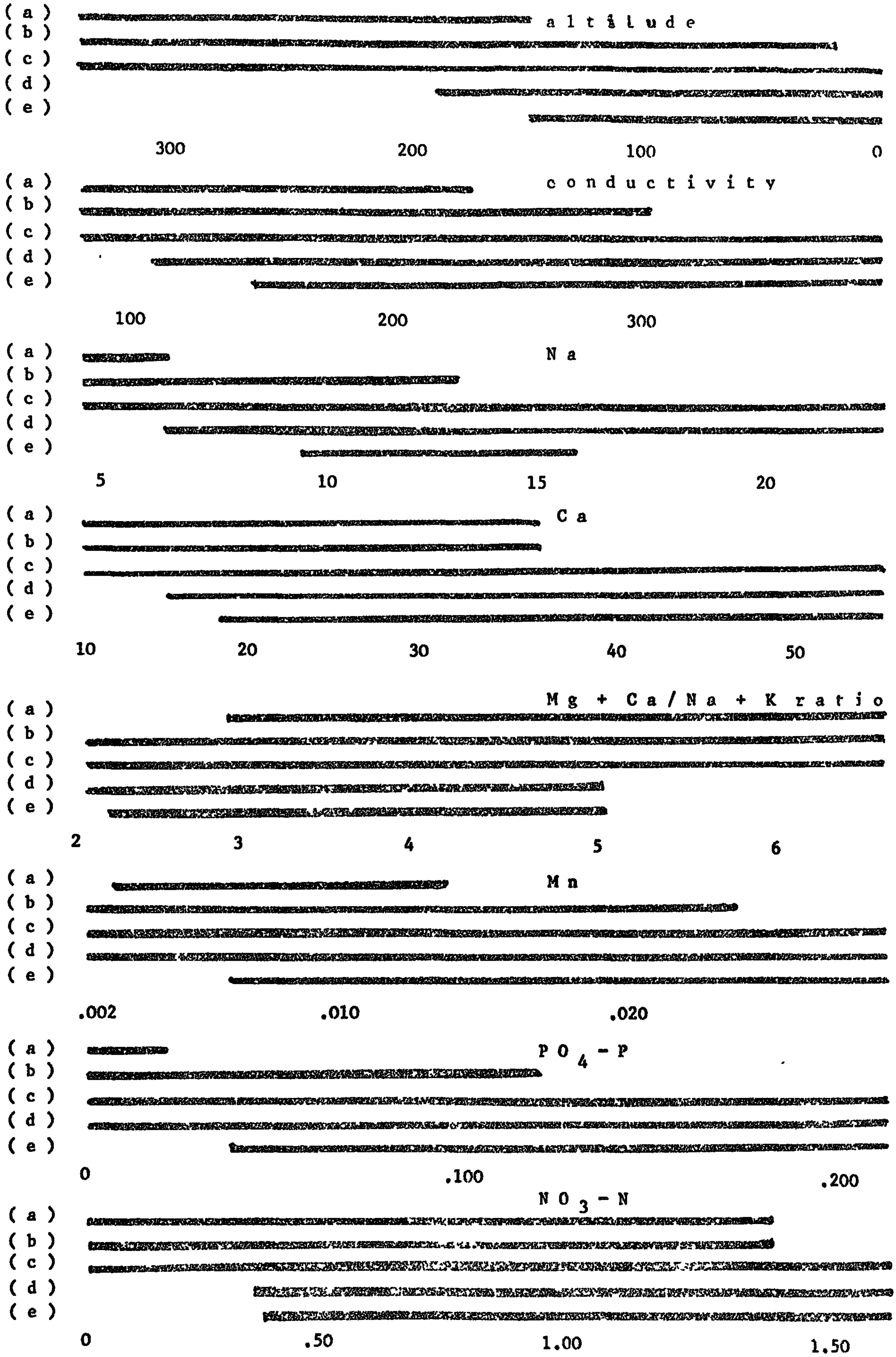

Fig. 9.22b Water chemistry maxima and minima for five macrophytes : (a) Scapania undulata , (b) Myriophyllum alterniflorum , (c) Eurhynchium riparioides , (d) Elodea canadensis , (e) Zannichellia palustris .

as restricted to upland reaches (a), were all present at the minimum levels of each chemical parameter, rarely present at medium levels, and totally absent in waters with maximum levels. Species which tended to be most abundant in upper reaches, and become progressively less abundant on passing downstream (b), have mean element values below medium, but like the former group, they are totally absent in waters with maximum element values. Species present throughout the river (c), must by definition, be able to withstand all types of chemistry. Species absent at high altitudes (d), and those restricted to very low altitudes (e), were never present in waters with low element values, and mean levels were always above average.

In order to ascertain if there was any statistical validity to such generalisations, certain species have been selected and looked at more critically. Species which showed wide ranges of distribution patterns were chosen for comparison. Since the Tweed Basin has many Potamogeton and Ranunculus species present within its rivers, and because there is so much historical data concerning these groups, especially the former, their distribution in relation to external parameters have been critically examined. Other macrophyte species have been selected because certain features of their distribution suggested that they might be correlated with a single parameter (e.g. Gongrosira incrustans). Those blue-green algae, which, by possession of heterocysts might suggest the ability to fix atmospheric nitrogen (Fogg, 1974), have all been tested to see if their distribution was in any way related to nitrogen levels in the water.

Simple non-parametric statistics were employed. They were used because of their ease of computation, and because they are distribution free i.e. they do not assume any population distribution beforehand. A further advantage is that they are useful when the sample size is small. The first tests employed the ranking method of Spearman (1955).

With reference to mean chemistry data of 5.22 and 5.24, the maximum and minimum levels of conductivity, Ca, PO_4-P and NO_3-N throughout the basin were found. The differences between the minimum and maximum levels of each parameter were then divided into six, even gradations. This was also done for altitude. Each of the 570 0.5 km lengths surveyed were then placed into one of the six ranked catagories for each parameter, and the total number of lengths in each group listed at the top of each of the Tables in 9.7.

The number of times each species was recorded as present in each of the six categories was then ascertained from the primary data in Chapter 6. As the number of 0.5 km lengths in each category was not constant, the number of records for each species in each category, had, for comparative purposes to be expressed as a percentage of the number of records possible. Table 9.7b gives the actual number of records for each species in each catagory, and also the percentage occurrence.

Both sets of data are ranked by replacing actual values by single figures, which are then arranged in order from lowest to highest. In the case of the data under discussion, the lowest value for each parameter was 1, and for the highest value, 6 i.e. n = 6. The percentage number of records for each species were also ranked, and the rank correlation coefficient (r_s) calculated as outlined in the example below. The r_s calculation is based on the sum of the squares of differences between paired ranks (Σdn^2) - see Segal (1956); Jones (1973).

e.g. conductivity and Cladophora glomerata

conductivity rank value	occurrence of Cladophora as a percentage of the maximum possible	rank of distribution	d^1	d^2
1	22	1	0	0
2	83	2	0	0
3	98	5	2	4
4	97	4	0	0
5	96	3	2	4
6	100	6	0	0

r_s is calculated: $$r_s = 1 - \frac{6\Sigma dn^2}{n^3 - n} = 1 - \frac{6 \times 8}{6^3 - 6} = .77$$

The null hypothesis (H_o) states that there is no correlation between the two variants. If r_s values are greater than 0.83, the H_o can be rejected at the 95% confidence level, and a positive correlation shown. If r_s values are lower than 0.83, but higher than 0.70, the H_o can still be rejected, but only at the 90% confidence level. If r_s results are preceeded by a minus sign, the same figures (i.e. -0.70 and -0.83) also reject the H_o, but in this instance there is a negative correlation to either 90 or 95% confidence levels. Figures between those given above do not reject the H_o.

Table 9.22a shows the r_s values for 32 species in the Tweed Basin in relation to ranked altitude, conductivity, Ca, PO_4-P and NO_3-N, taken from Tables in 9.7. Table 9.22b clarifies the data pictorially. It lists in order, the species with the most negative correlations, to the species with the most positive correlations. In the middle are placed the species that showed no correlations with any parameters. Only one species, Heribaudiella fluviatilis, was positively correlated with one parameter, and negatively correlated with another.

Of the four species tested from list (a) in Table 9.21b, all showed negative correlations with at least three parameters, and none showed any positive correlations. Although Fontinalis antipyretica was present throughout the whole river system, it was negatively correlated with three parameters. Of the 15 species tested from list (b) in Table 9.21b, every single one was positively correlated with at least one parameter, four were correlated with all five parameters, and there were no negative correlations.

With reference to the data in 9.6 and Tables 9.22a,b, the best correlations using this method were shown where there was a gradual increase or decrease in percentage occurrence associated with each parameter. Poor correlations were shown when species were restricted to either the lowest, or

species	altitude	conductivity	Ca	PO_4-P	NO_3-N
Heribaudialla fluviatilis	0.83	0.00	-0.89	-0.25	0.60
Cladophora glomerata	1.00	0.77	0.81	0.94	0.83
Enteromorpha sp(p).	0.94	0.93	0.90	0.83	0.94
Gongrosira incrustans	0.93	0.87	0.77	0.77	0.64
Eurhynchium riparioides	-0.14	-0.26	0.16	0.37	-0.23
Fontinalis antipyretica	-0.83	-0.77	-0.52	-0.54	-0.80
Hygrohypnum luridum	-0.96	-0.83	-0.59	-0.91	-0.91
Leptodictyum riparium	0.93	0.43	0.43	0.83	0.83
Scapania undulata	-0.93	-0.77	-0.77	-0.58	-0.61
Solenostoma triste	-0.94	-0.83	-0.83	-0.58	-0.71
Elodea canadensis	0.99	-0.03	0.03	0.03	0.49
Myriophyllum alterniflorum	-1.00	-0.71	-0.71	-0.57	-0.66
M. spicatum	0.94	0.76	0.93	0.94	0.94
Potamogeton berchtoldii	0.89	0.77	0.84	-0.09	0.46
P. crispus	0.87	0.89	0.71	0.77	0.77
P. lucens	0.71	0.80	0.24	0.31	0.46
P. natans	0.59	0.73	0.03	-0.29	-0.29
P. x olivaceus	0.41	-0.09	-0.11	-0.34	0.01
P. pectinatus	0.72	0.41	0.29	0.64	0.46
P. perfoliatus	0.86	0.59	0.20	0.03	0.89
P. pusillus	0.86	0.54	0.59	0.07	0.77
P. x salicifolius	0.71	0.12	0.25	0.25	0.51
P. x suecicus	0.71	0.51	0.37	0.23	0.46
Ranunculus aquatilis agg.	0.26	10.85	-0.66	-0.56	0.49
R. circinatus + hybrid	0.54	0.54	0.54	0.11	0.34
R. penicillatus var. calcareus	0.99	-0.37	-0.043	0.20	0.43
R. fluitans x ?	0.94	0.71	0.37	0.01	0.77
Zannichellia palustris	0.94	0.77	0.77	0.40	0.80

>0.83 = positive correlation to 95 % confidence level

0.70 to 0.82 = positive correlation , but not to 95 % confidence level

0.69 to -0.69 = no correlation shown

-0.70 to -0.82 = negative correlation, but not to 95 % confidence level

>-0.83 = negative correlation to 95 % confidence level

Table 9.22a Spearman rank (r_s) values for correlation of the distribution of species with altitude and four water chemistry parameters.

species	altitude	conductivity	Ca	PO_4-P	NO_3-N	χ^2 altitude	χ^2 Ca	χ^2 NO_3-N
Hygrohypnum luridum	--	--		--	--			
Solenostoma triste	--	--	--		-			
Scapania undulata	--	-	-					
Fontinalis antipyretica	--	-			-	-34.0		
Myriophyllum alterniflorum	--	-	-					
Ranunculus aquatilis agg		--						
Ranunculus circinatus + hybrid								
Potamogeton x olivaceus								
Eurhynchium riparioides						-49.1		
Heribaudiella fluviatilis	++		--					
Potamogeton x suecicus	+					24.9		
P. x salicifolius	+					128.5		
P. pectinatus	+					211.0		63.1
P. natans			+			93.3		186.4
Ranunculus penicillatus var. calcareus	++					78.1		
Potamogeton lucens	+	+				12.1		
Elodea canadensis	++							
Potamogeton pusillus	++				+	56.8		51.7
Ranunculus fluitans x ?	++	+			+	93.4		
Potamogeton perfoliatus	++				++	42.0		30.3
P. berchtoldii	+	+	++			12.2		
Zannichellia palustris	++	+	+		+	156.0		
Leptodictyum riparium	++			++	++			
Gongrosira incrustans	++	++	+	+			491.3	
Potamogeton crispus	++	++	+	+	+			
Cladophora glomerata	++	+	+	++	++			
Myriophyllum spicatum	++	+	++	++	++	75.5		
Enteromorpha sp(p).	++	++	++	++	++	62.3		125.6

-- = negative correlation to 95 % confidence level - = negative correlation
++ = positive correlation to 95 % confidence level + = positive correlation
figures indicate χ^2 values where more than three ranks were tied (see text)

Table 9.22b Illustration of correlation data given in Table 9.22a, and χ^2 data for tied ranks.

highest ranked series. For example, Potamogeton pectinatus in relation to altitude, where the percentage occurrence was 0 in the lowest ranks 1 - 5, but 48 at rank 6. Using Spearman's rank, this species was only correlated to the 90% confidence level with decreasing altitude. Conversely, in the case of altitude and Eurhynchium riparioides, there were five tied values due to the presence of the species in all 0.5 km lengths above 55 m. This method did not show either positive or negative correlations with respect to altitude.

Where three or more tied values at either extreme of the rankings occurred, whether due to absence or 100% presence, a simple χ^2 test has been used to test the statistical probability of this occurring by chance (see Siegal, 1956). These are listed on the right of Table 9.22b. As before, the method presumes that the distribution is not predetermined and the H_o is rejected at the 95% confidence level when a figure larger than 10.28 is obtained. In general, the higher the figure, the stronger the correlation. For the most part, the results are self explanatory, but a few points are noteworthy. (i) Using the χ^2 method, Eurhynchium riparioides was more negatively correlated with a decrease in altitude than Fontinalis antipyretica. (ii) Ranunculus fluitans was correlated more strongly with a downstream distribution than Ranunculus penicillatus var. calcareus. (iii) Potamogeton pectinatus was the species most correlated with a lowland distribution in the Tweed Basin. (iv) The strongest correlation of any species to a single parameter was Gongrosira incrustans. The species was significantly correlated with presence only in waters with an excess of 32.5 mg l^{-1} Ca. (v) The distribution of heterocystous blue-green algae using both statistical methods showed no correlation with total nitrogen levels in the water.

In future, these data, together with additional data from surveys from other rivers will be used as part of a large computer programme using multivariate analysis to determine the relationship of the distribution of species to environmental parameters, especially changes in water chemistry.

9.3 Comparison with macrophyte surveys of other rivers

As stated in 1.2 , the vegetation of most rivers in the British Isles still remains inadequately, or totally undescribed. However, considerable detail is known about the vegetation of several rivers. Over the past 200 years, many interested local botanists have collected valuable data about the vegetation of the countryside, including rivers. On a more organised basis, many naturalist clubs have done the same, but neither have tackled the job systematically. Unfortunately, the data are usually scanty, perhaps often unreliable, and not easily available for reference.

The first well documented surveys were carried out by Butcher in the 1920's. His paper of 1933 summarized findings from seven rivers which he classified according to water hardness characteristics, flow regimes, and substratum. More recently, more systematic macrophyte surveys have been done on rivers in the N-E. by Whitton and Buckmaster (1970) for the Wear, Proctor (1971) for the Wheel of the Tees, and by Holmes et al. (1972) for the North Tyne and Tyne. Butcher (1933) pointed out that due to natural features of topography in Britain, the characteristics of rivers in one geographical area often have features in common with one another. He states that in northern England and Wales, rivers are most commonly swift, with natural cascades in their upper reaches, and high frequencies of heavy floods. They rise in highlands where rainfall is high and frequent. Southern English rivers in contrast, are rarely rapidly flowing, do not rise in highlands, and serious flooding rarely result from exceptionally high rainfall (see 9.32). Both in geographical position and characteristics, the Tweed most resembles rivers in N-E. England.

In 9.31 the vegetation of four rivers in N-E. England will be briefly summarized and compared with that of the Tweed. Most of the information discussed is from the references quoted above, but since the author has been present in the N-E. for several years, additional information is included from personal surveys. Also, notes made in local journals reporting the presence of rare species within rivers in the area are included. In 9.32 and 9.33 the dominant macrophytic vegetation of the rivers in the rest of England and mainland Europe are briefly discussed. Reference is made only to papers that are of a survey nature. Throughout the present text, little mention is made of bank species since a comprehensive appraisal of such literature has not been carried out.

9.31 Rivers in N-E. England

The number of macrophytic species listed for the Tweed Basin (4.2) shows that the Tweed is strikingly rich in species in comparison with records from the Tyne, Wear, Tees and Wharfe. This may in part be due to the less intensive and thorough approach to the investigations. This is illustrated for the N. Tyne by Holmes _et al._ (1972) using an identical survey method as that used for the surveys of the Tweed. In the twenty 0.5 km lengths surveyed, no less than 32 bryophyte species were recorded, 10 of which were submerged species. For the whole of the Wear, only nine bryophyte species were recorded by Whitton and Buckmaster (1970), but the authors, and personal observations made during the past three years show this to be a marked underestimation of the taxons importance. The observations made by Butcher (1933) for the Wharfe were only concerned with obvious characteristic species of the river. The work of Butcher _et al._ (1937) was intended to give a complete floristic account of the vegetation in the Tees, however, many bryophytes were not described.

In Table 9.31a the submerged angiosperm flora of the Tweed is compared with that of the four largest rivers in N-E. England. Only submerged angiosperms are considered because other taxa have not been recorded consistently, and many species appear to have been overlooked. There were 21 submerged angiosperm species in rivers within the Tweed Basin, all but four of these being recorded from the Tweed itself. In comparison with the N. Tyne (8), Tyne (8), Wear (10), Tees (11) and Wharfe (7), the Tweed is obviously very species rich.

In the N. Tyne and Tyne, a large number of bryophytes were present, including 10 submerged species in the lower 10 km stretch of the N. Tyne. In no stretch of the Tweed or its tributaries were so many submerged members of this taxon recorded. In the same river eight submerged angiosperms were reported to be present in the river (plus Potamogeton berchtoldii by G. A. Swan, verified by J. E. Dandy, 1972). In this 10 km stretch of river there were at least four members of each of the five groups of species listed in Table 9.21e as characteristic of certain stretches of the Tweed and its tributaries. In some instances, species listed in the Table as characteristic of upland reaches (a), e.g. Hygrohypnum luridum and Solenostoma triste, were present in the same 0.5 km lengths as species listed in (e), i.e. characteristic of the lowland stretches, e.g. Tetraspora spp. and Zannichellia palustris.

Three Potamogeton species, although not recorded from the Tyne at the time of survey by Holmes et al., have been recorded from the river at various times: (i) P. perfoliatus, which has been reported from many lowland sites by Heslop-Harrison (1942), and as recently as 1971 by Whitton (personal communication), and the author in 1973 (unpublished). (ii) P. alpinus and

species	Tweed (a)	N. Tyne (b)	Tyne (c)	Wear (d)	Tees (e)	Wharfe (f)
Callitriche sp(p)	+	+	+	+	+	
Elodea canadensis	+	+	+	+	+	+
Myriophyllum alterniflorum	+	+	+		+	
M. spicatum	+			+	+	
P. crispus	+	+	+	+	+	
P. densus						+
P. lucens	+					
P. natans	+	+	+	+	+	
P. x nitens			+			
P. x olivaceus	+					
P. pectinatus	+			+	+	+
P. perfoliatus	+		+	+	+	+
P. pusillus	+	+	+		+	
P. x salicifolius	+					
P. x suecicus	+					
Ranunculus aquatilis	+				+	
R. penicillatus var. calcareus	+	+	+	+		
R. fluitans or hybrid	+			+	+	+
Sium erectum						+
Sparganium emersum						+
Zannichellia palustris	+	+		+		
TOTAL NUMBER OF SPECIES	17	8	8	10	11	7

Data from: (a) present study, (b,c) Holmes et al. (1972), (d) Whitton and Buckmaster (1970), (e,f) Butcher (1933).

Note Record for R. penicillatus is included for the Wear although not reported at time of survey by Whitton and Buckmaster (see p.435)

Table 9.31a. Comparison of the submerged angiosperm floras of the Tweed and rivers in N-E. England.

(iii) P. sparganifolius, two most unlikely records for a lowland river reported by Heslop-Harrison (1942). P. alpinus was present only in upland, slightly acid pools and streams in the Tweed Basin, and P. sparganifolius was absent, but present in the upper reaches of the nearby Clyde. A fourth species, P. x nitens, was rare at the time the Tyne was surveyed, and was absent from the Tweed Basin.

Species notable for their absence in the Tyne system were Myriophyllum spicatum, Potamogeton pectinatus and Ranunculus fluitans, and the algae Heribaudiella fluviatilis and Enteromorpha flexuosa. Three other species which were often frequent in the Tweed, Nostoc parmelioides, Cladophora aegagropila and Collema fluviatilis were absent from the Tyne and other rivers in N-E. England.

Whitton and Buckmaster (1970) surveyed the Wear 0.5 km by 0.5 km, but only species presence or absence were noted, and no subjective judgement of each species abundance were made. The results were represented graphically in a manner identical to that for the Tweed in 6.41. The respective histograms clearly show the difference in the behaviour of Eurhynchium riparioides and Fontinalis antipyretica in the two rivers. The former species was present, and often frequent in all 0.5 km lengths in the upper stretches of the river, but it gradually became less frequently recorded, and was absent from the lower most 10 km. Fontinalis on the other hand, was very rare in the upper reaches, but increased markedly on passing downstream, and was the most recorded species in the lower half of the river.

Submerged angiosperms common to both rivers, usually had different distribution patterns in the Wear and Tweed. For instance, Potamogeton crispus had a confined distribution to the middle of the Wear, as did Elodea canadensis. In 1966, the year of survey, Elodea was a rare species. Recently, the present author has observed it to be frequent in the lower reaches of the Wear. *Potamogeton natans* was more frequent than in the Tweed, and both *Potamogeton perfoliatus* and *P. pectinatus* were frequent in the lower reaches only. Prior to 1959, the Wear was apparently devoid of *Ranunculus* species. In that year, (as discussed by Whitton and Buckmaster, 1970) the river bailiff transplanted a few plants of *R. fluitans* from the Tees into the Wear. The present author has observed that in more than a decade, the species had spread only slightly further, but *Ranunculus penicillatus* var. *calcareus* had invaded the river from an unknown source, and become the most common species in fast flowing, lowland stretches.

Another interesting addition to the flora of the R. Wear in recent years is the spread of *Hildenbrandia rivularis*, but as yet, not *Heribaudiella fluviatilis*. The spread of such incrusting species may be predicted as likely to continue in the Wear as the reduction in coal washings continue, for the washings used to stick to, and smother rock surfaces so that black crusts formed upon them.

Data are available concerning the vegetation of the Tees during the first half of this century. The river is most unusual in both physical character and vegetation. Prior to damming, the Wheel of the Tees was an almost unique stretch of water at high altitude (see 1.2). The influence of the Skerne still has a great effect on the chemistry and flora of the river in the lower stretches (see 1.2)

The vegetation of the Wheel was described by Butcher in 1933 and 1937, and prior to its drowning, Proctor (1971) resurveyed the whole area in detail. He reported the absence of bryophytes, and the presence of *Callitriche* spp., *Myriophyllum alterniflorum*, *Potamogeton alpinus*, *P. natans*, *Ranunculus aquatilis* and *Sparganium emersum*. The area was thus an ideal 'control', being an upland site but having the physical characteristics of a lowland site. The absence of mosses is as might be predicted from the discussion in 9.2. The presence of *Ranunculus aquatilis* in such a habitat is complementary to findings in the Tweed and Teviot, where the species occurred in upstream sites in quiet alcoves at the sides of the river; only in the Tweed did it spread to become common in the lower stretches of the upper half of the river.

The rest of the Tees above the entry of the Skerne was, and still is, dominated by bryophytes, the list of species given by Butcher being a very marked underestimation of their numbers. There are few records for the presence of submerged angiosperms in any part of the Tees above the Skerne, apart from those from the Wheel. However, in 1973 the author found small plants of *Potamogeton crispus* in the river a short way upstream from the Skerne. The same species, and *Ranunculus penicillatus* var. *calcareus* have also been found in tributaries of the river, which provide inocula above the Skerne. As reservoirs in the upper reaches reduce the scouring effects of heavy floods, perhaps angiosperms will spread further upstream.

The entry of the Skerne adds hardness and organic matter to the river, and no real change in physical parameters are evident, except for a slight increase in boulder clay which helps stabalise the substratum. Butcher *et al.* (1937) described two sites of similar physical characteristics, one above, and one below the entry of the Skerne. In the one below the tributary, *Ranunculus fluitans* was the dominant species, with *Potamogeton pectinatus* sub-dominant. Also present were *P. crispus*, *P. perfoliatus*, *P. pusillus* and *Myriophyllum spicatum*. In the one above, none of those species were present. The influence of a single inflow on the macrophytic vegetation of the Tees was even more dramatic than that for the Tweed and the Teviot. The Skerne, like the Teviot, not only altered the chemistry of the recipient river, but also provided an inoculum of new species.

Both above and below the entry of the Skerne, Hildenbrandia rivularis and Heribaudiella fluviatilis were present, and often quite frequent, although not recorded as present in the river by Butcher. A species not likely to have been overlooked by Butcher if present, was Enteromorpha. In 1963-1965, Whitton and Dalpra (1968) carried out a re-investigation of the algal flora of the river. One point noted, was the apparent invasion by Enteromorpha of the river since Butcher's surveys.

The Wharfe is less well documented, and the author has not surveyed any of the river to verify if the vegetation described by Butcher in 1933 still applies today. At that time, the river was dominated by bryophytes in the upper, rocky, and fast flowing stretches, but in the lower reaches, they were replaced by submerged angiosperms in the slower, silted reaches. The dominant species, as in the lower Tees was Ranunculus fluitans, with Potamogeton perfoliatus dominant in the slowest reaches. Three species not present in the Tweed, were present in the Wharfe; Potamogeton densus, Sium erectum , Sparganium emersum. Neither Potamogeton crispus nor P. pectinatus were recorded.

Due to the lack of critical observations made concerning bryophyte floras, only the distribution of submerged angiosperm species in N-E. rivers could be summarized and compared with the Tweed (see Fig 9.31a). Elodea canadensis grew in all rivers in N-E. England, but it was never as widespread, or abundant as in the Tweed. Only in the Tees did both Myriophylum species occur, M. alterniflorum as in the Tweed was present in the softer watered upper stretches (Wheel), and M. spicatum in the lower, harder reaches below the Skerne. Again, both species were far less widespread or abundant as in the Tweed. In the Tweed, nine Potamogeton species were present in the main river, in other rivers in N-E. England the maximum was five recent records for the Tees. P. lucens was the only non hybrid species present in the Tweed that was absent from all other N-E. rivers. More critical surveys should be made to check whether the normally most wide-spread species, P. crispus is absent from the Wharfe, and also if P. pectinatus is absent from the lower Tyne and Wharfe. Ranunculus fluitans and R. penicillatus var. calcareus only occurred together in the Wear, where the former was introduced into the river by man in 1959, and the latter, (naturally ?), more recently. Zannichellia palustris has been reported only from the N. Tyne and Wear, apart from the Tweed.

9.32 Other rivers in England

Butcher published data on macrophyte surveys of the Itchen (1927), Lark (1931), and a comparative account of seven rivers (1933). Few macrophyte surveys have since been carried out on other rivers in Britain. However, more recently the chalk streams of southern England have been studied by Ladle and Casey (1971), Haslam (1973) and Westlake (1968, 1968a, 1970, 1973) at great length, and some reference will be made to their findings.

Although data from the Lark were included in Butcher (1933), since in the original paper (Butcher et al., 1931) reference is made to associations of species, this is briefly summarized and discussed here. The authors recognised three associations in the river, the dominant species and others found in the associations are listed in Table 9.32a.

Of the 19 species listed in Table 9.32a, seven species (*) were not present within the Tweed Basin. Of the other 12, only two, Vaucheria sp. and Callitriche stagnalis were not characteristic of lowland, rather than upland reaches (see 9.21b). Butcher concluded that the distribution of plants in the river was primarily dependent on the nature of the river bed, which was itself governed by current speed. The more rapid the current, and more stony the substratum the more dominant was Ranunculus fluitans. As depth, and silt, increased, and flow rate decreased, the more dominant Potamogeton lucens became.

Table 9.32b summarizes data from Butcher (1933) taken from his classification of rivers based on flow, substratum and hardness characteristics.

Although no rivers surveyed from the Tweed Basin were comparable with the non-calcareous, acid, slow flowing rivers of the New Forest, two species, Potamogeton alpinus and P. polygonifolius were present in both areas. The former was found in the upper reaches of the Tweed, above the uppermost point of survey. It was also present in many other upland sites on moorlands, where in a few localities, P. alpinus was also recorded (J. E. Dandy, personal communication). These sites were of similar water chemistry to the New Forest streams, but they were at high altitudes.

The Tees and Wharfe have already been discussed, but the results are included in the Table for reference. They represent respectively, slightly, and moderately calcareous streams that rise in mountainous districts. They are thus most like the Tweed in both physical and water hardness characteristics. The Tern (Shropshire) had a similar water chemistry, but rises from lowlands.

There was a distinct lack of bryophyte records from the whole of the Tern , and angiosperms such as Elodea canadensis, Potamogeton crispus, P. perfoliatus and P. pectinatus only grew in stretches which had moderate currents and fine gravel beds. Where current velocity was slowest, and fine muds formed the substratum, the vegetation became dominated by species that in the Tweed Basin were most commonly only bank species. These included Sparganium erectum and Scirpus lacustris. The latter species was confined to the lowest stretches of the Tweed Basin, and was most abundant in slow flowing stretches of the Blackadder, which had similar

(a)	(b)	(c)
Ranunculus fluitans	Potamogeton lucens	Sparganium emersum (*)
Potamogeton densus (*)	Cladophora glomerata	Cladophora glomerata
Oenanthe fluviatile (*)	Vaucheria spp.	Callitriche sp.
Callitriche stagnalis	Ceratophyllum demersum (*)	Nuphar lutea (*)
Elodea canadensis	Nuphar lutea (*)	Potamogeton crispus
Rorippa nasturtium -aquaticum	Potamogeton crispus	P. lucens
Sium erectum (*)	P. pectinatus	P. pectinatus
Sparganium emersum (*)	P. perfoliatus	P. perfoliatus
	P. pusillus	Saggitaria sagittifolia (*)
	Saggitaria sagittifolia (*)	
	Sparganium emersum (*)	
	Zannichellia palustris	

(a) Ranunculus fluitans association of fast flowing water
(b) Potamogeton lucens association of slow silted stretches
(c) Sparganium emersum association, also of slow silted stretches
(*) indicates species not present within the Tweed Basin

Table 9.32a Species of three assocaitions described by Butcher et al. (1931) for the River Lark.

stream	No. of species absent from the Tweed Basin	No. of species which were also recorded in Tweed Basin
New Forest streams	7	9
Tees	1	19
Wharfe	4	10
Tern	3	14
Dove	5	11
Itchen	9	12
Lark	11	15

Table 9.32c Relative number of species recorded by Butcher (see Table 9.32b) which were either present or absent from the Tweed Basin.

hardness characteristics	non-calcareous acid waters			slightly calcareous		moderately calcareous									highly calcareous									
Ca mg l^{-1}	< 10			5 - 50		40 - 100									> 80									
conductivity (approx.)	< 60			40 - 300		250 - 500									> 400									
river	New Forest streams			upper Tees		lower Tees				Wharfe			Tern			Dove				Itchen			Lark		
Butcher's description of physical characteristics of each stretch	stony, rapid	slow flowing	silted	rocky, rapid	gravel, slow	rocks, swift	stones, medium	gravel, medium	silt, slow	rocks, swift	stones, swift	gravel, slow	course gravel, fast	fine gravel, medium	mud, slow	rocks, fast	stones, fast	gravel, medium	mud, slow	stony, fast	gravel, medium	gravel, slow	stones, fast	gravel, slow	mud, very slow
species																									
Batrachaspermum sp. (*)											5														
Lemanea fluviatile				3		5					4														
Vaucheria sp.																						6			
Cladophora glomerata						5														6					
Chara vulgaris												6													
Nitella opaca								6	6																
Cinclidotus fontinaloides		5		5						6	5					5									
Eurhynchium riparioides				3		4	6			4	[illegible]					4									
Fontinalis antipyretica				3	6	4	4			4	4					4				3			6		
Grimmia alpicola				6		6				–			–												
Hygroamblystegium fluviatile				5		6				6						6									
Alisma plantago (*)				5											5										4
Apium sp.		6															6			2	6		6		
Butomus umbellatus															4										
Callitriche intermedia	4		6		5																				
Callitriche stagnalis			3						5			6		4					3		4	2		5	5
Elodea canadensis								6	4			6		5					4		4	1		4	
Equisetum fluviatile					5																				
Glyceria maxima (*)																									1
Hippuris vulgaris (*)																					2	3			
Juncus bulbosus (*)			5																						
Lemna trisulca (*)																									5
Mimulus guttatus																		5		6	6				
Montia verna (*)		5																							
Myosotis scorpioides														[illegible]	4										
Myosotis secunda (*)		5																							
Myriophyllum alterniflorum	4	4																							
M. spicatum								6					2				6								
Nuphar lutea (*)			5																						4
Oenanthe fluviatilis																				6	3	4	4		
Phalaris arundinacea																									4
Polygonum amphibium														4											
Potamogeton alpinus	5	4	5		4																				
P. crispus								4	4					5				6			6	6		4	4
P. densus (*)											4						5	6		3	4	5	4		
P. lucens																									1
P. natans																									4
P. pectinatus							2	2						5											2
P. perfoliatus								6				1		5				4						4	
P. polygonifolius		4	1																						
P. praelongus (*)																								6	
P. pusillus	6							6														4		6	
Ranunculus fluitans							1	1			1	4	2				1	3			6	6	1		
R. penicillatus	1																			1	6				
R. lenormandi (*)			4																						
Rorippa nasturtium-aquaticum															5					3					
Sagittaria sagittifolia														4	4									2	
Scirpus fluitans			4																						
S. lacustris														4	2						3				4
Sium erectum (*)											5						3			2	6		6		
Sparganium erectum															1										1
S. emersum (*)		5			4							4		1				3			2	3	6	1	3
Typha latifolia															5						6				4
Veronica anagallis-aquatica (*)																	5			4					
Zannichellia palustris																									5

(*) species absent from Tweed 1 = dominant 2 = co-dominant 3 = abundant
4 = frequent 5 = occasional 6 = rare

Table 9.32b Summary of the distribution of macrophytes in relation to characteristics of rivers surveyed by Butcher (1933).

hardness characteristics as the Tern.

Of the three highly calcareous rivers surveyed, the Dove (Derbyshire) rose from mountains. Despite the differences in hardness characteristics, the vegetation of both upper Dove and Tweed were dominated by bryophytes. These species disappeared downstream, where in fast flowing stretches Ranunculus fluitans dominated; the same species remained abundant alongside Sparganium emersum in gravelly stretches of moderate current. In the slowest, muddy reaches, Callitriche stagnalis and Elodea canadensis dominated.

The Itchen (Hampshire), is another highly calcareous stream that rises in hills. In the fast, rocky upper stretches, the only bryophyte to be found was Fontinalis antipyretica. In the same area, Ranunculus penicillatus was the dominant species, with Apium nodiflorum and Sium erectum sub-dominants. Lower downstream in gravelly reaches of moderate current, three of the four most abundant species were absent from the Tweed Basin. In the slowest, muddiest reaches, as in the Dove, Callitriche stagnalis and Elodea canadensis were the dominant species, but in the Itchen, Hippuris vulgaris and Sparganium emersum were also abundant.

The vegetation of the Lark (Suffolk), has already been described. It is included here as an example of a highly calcareous stream rising in lowlands.

In Table 9.32c, the relative number of 'Tweed' or 'non-Tweed' species are listed for the seven rivers surveyed by Butcher. It clearly illustrates that of the species that were absent from the Tweed Basin, but recorded in the surveys of Butcher, most occurred either in slightly acid streams, or the most highly calcareous streams. The Itchen and Lark, both classified as highly calcareous had the highest number of "non-Tweed" species, the latter which rises from lowlands having the most. The Tees, which has physical characteristics similar to the Tweed except for short stretches in its upper reaches, and also very similar water hardness characteristics, had the flora that was most like that of the Tweed.

The chalk stream vegetation probably shows more seasonal change than that of softer, northern streams (Butcher, 1933; Butcher *et al.*, 1937; Westlake, 1968, 1970, 1974) and require more management. Westlake (1968, 1970), Westlake *et al.* (1970) and Ladle and Casey (1971) report that in spring and early summer, the headwaters are usually dominated by *Apium nodiflorum* and *Rorippa nasturtium-aquaticum*; further downstream, *Ranunculus penicillatus* var. *calcareus*; and in slower, deeper stretches, *Potamogeton pectinatus*, *P. lucens*, *Nuphar lutea* and *Sparganium erectum*. *Ranunculus* is the dominant genus , growing rapidly in spring and early summer to cover large areas of river. By growing at such speed, and spreading so far, the plants collect abundant silt, and frequently the river water is diverted into small channels, and almost negligible flow rates occur around the plants. Under natural conditions, the river levels rise, and the *Ranunculus* plants die back to be replaced and overgrown by *Rorippa nasturtium-aquaticum* in July and August (Ladle and Casey, 1971). The latter then dies back in the autumn, leaving the area open for colonization by *Ranunculus* again. There is thus a natural succession in these chalk streams, but the river management problem is that if the *Ranunculus* is not cut, serious flooding often occurs. On the other hand, cutting in spring and early summer stimulates growth, and the natural succession to *Rorippa* does not occur, and further cutting is required later in the season.

In fast flowing northern streams this is a less serious problem, but populations of species change, and individual plants move position in a river (Butcher, 1937). Cutting is only occasionally practiced in the main rivers. *Potamogeton pectinatus* has only reguired cutting once in the lower Wear. In the Tweed Basin, the main problems are *Ranunculus* species in shallow reaches in the lower half of the river. It is occasionally cut, but there is no organised programme supervised by either the Purification Board or the Tweed Commissioners. The weed is rarely removed from the river, but just cut and left to drift downstream. In the Teviot, *Sparganium erectum* is usually cut, and left to float downstream in late summer. The Biggar, Leet, Till and Whiteadder all have stretches that are periodically dredged. Both weed cutting and dredging must have very important consequences when considering the vegetation of a river, especially short term changes.

9.33 Rivers of mainland Europe

A brief description of macrophyte surveys carried out on rivers from mainland Europe will be given here. Some species which were recorded from both the Tweed and European rivers have been referred to in Chapter 7.

Perhaps the most surveyed river in Europe is the Danube. An account of the macrophytes of the upper reaches was given by Backhaus (1967), and a complete list of all species present in the whole river by Szemes (1967). The last author reported the presence of 28 bryophytes and 121 angiosperms. As in the Tweed, the number of angiosperm species increased on passing down stream. In the headwaters, 14 species were recorded, with 55 in the upper, 88 in the middle, 84 in the lower, and 107 in the delta region. Many macrophytic algae were also recorded, but neither *Hildenbrandia rivularis* nor *Heribaudiella fluviatilis* were. Species present in both the Danube and the Tweed have been mentioned breifly in Chapter 7.

A more detailed description of species distribution was given by Backhaus (1967) for the two main headwaters of the river. In the upper reaches of the Breg, many bryophytes were frequent, but so too were such species as *Nitella flexilis*, *Carex riparia* and *Potamogeton natans*. In the lower reaches, *Fontinalis antipyretica* was still frequent, but *Ranunculus fluitans* was the dominant species. In the Brigach, the number of species increased greatly on passing downstream. Backhaus related the increase in the number of species to higher pH and Ca content, plus a general increase in nutrient status.

As in the Tweed, Ranunculus aquatilis had a middle of the river distribution (see 6.41), being most abundant where the nutrient levels were high. Ranunculus fluitans was only present in the lower reaches where it was the dominant species. Many species of lowland Tweed (see 9.21e) were only present immediately below the confluence of the Breg and Brigach. This included Myriophyllum spicatum which in the Tweed was correlated with increases in Ca levels (see 9.23).

Several rivers in Germany have been surveyed, including the Rhine (Krause, 1971), Moosach (Kohler et al. 1971, 1973); Aller (Weber-Oldecop, 1970, 1971, 1973) and several smaller rivers. Almost all the surveys have used Braun Blanquet phytosociological methods (see 1.4) and described the vegetation within 'aufnahme'. Not only the abundance of each species were considered, but also their sociability. Much of the data have been classified into water plant communities (see 1.4 and 9.5).

Krause studied the macrophytes in the water courses of the southern plain of the upper Rhine Valley. During the past 150 years the building of the Grand Canal d'Alsace has caused great landscape changes and a wide variety of river conditions.

In the deep, clear, non-polluted waters, Hildenbrandia rivularis, Cladophora glomerata and Sium erectum were the dominant species. In the polluted stretches the vegetation was luxuriant, with Ceratophyllum demersum, Agrostis alba, Phalaris arundinacea and Impatiens roylei, dominant. In the deep stretches after the two types have joined, Potamogeton lucens, P. pectinatus, Callitriche obtusangula and Cladophora crispata were dominant. Callitriche obtusangula was the species that Kohler et al. (see later) most associated with increases in pollution in the Moosach.

Krause compared his recent data with that collected 150 years ago by Lauterborn (1910), and stated that little change in the vegetation has taken place, despite the alterations in the landscape.

Kohler et al. described the vegetation in the Moosach river system. The water is calcareous, which in the upper reaches is oligotrophic, and in the lower reaches, polluted. The distribution of all aquatic macrophytes were charted, and the frequency of each estimated.

Many of the macrophytes found in the Moosach were also found in the Tweed. Of "non - Tweed" species, most were present as at least abundant in the chalk streams described by Butcher (see 9.32). Two types of distribution could be distinguished in the river. (i) Those occurring in the whole river system regardless of the state of eutrophication; Sium erectum, Callitriche obtusangula, Ranunculus fluitans, R. trichophyllus, P. fluitans x trichophyllus, Fontinalis antipyretica, Zannichellia palustris, Potamogeton pectinatus, Ranunculus circinatus, Elodea canadensis, Potamogeton crispus and Myriophyllum verticillatum. (ii) Those occurring only at the oligotrophic source, which were fewer in numbers, a typical species being Potamogeton coloratus.

The presence of Ranunculus fluitans, R. trichophyllus and the hybrid of these two, growing together in this river is indicative of in situ hybridization. In the Tweed, a R. fluitans cross exists in the absence of possibly both parent species (see 7.24).

Kohler et al. described the phytosociology of each species, three associations being distinguished. The same method as used in the "association tables" of the Tweed were used. Species distribution were also correlated with chemical and bacterial properties of the water. The most distinct correlations were shown with phosphate and ammonia.

Weber-Oldecop studied the many rivers of the Aller river system (tributary of the Weser). Twelve plant communities were recognised from the rivers, brooks and ox-bow lakes investigated. The plant communities were described and classified on the basis of the principles of Braun-Blanquet (1964). Important ecological factors including the chemical composition of the water, current velocity, water pollution, temperature, climate and fluctuations in water level were considered. These environmental parameters were correlated with the distribution of the associations discussed. The findings are too lengthy to summarize.

Weber-Oldecop (1974) also briefly described the crytogamic vegetation of brooks in the Harz Mountains. Again, the data were expressed in the form of plant communities, two communities being recognised. Both were stated to require cool and fast flowing water, which was poor in electrolytes and rich in oxygen. The species present included Chamaesiphon sp., Lemanea fluviatilis and Scapania undulata, species that were either confined to, or most frequent in the upper reaches of the Tweed in similar conditions. Also present however, were Hildenbrandia rivularis, Cladophora glomerata and Leptodictyum riparium. The latter two species in the Tweed were most strongly correlated with a decrease in altitude and increase in nutrient status (see 9.23).

The same author (Weber, 1967) classified into plant communities the vegetation of a headwater stream in a Bavarian wood. The species list contained many species that were associated with upland or mid stretches of the Tweed. The dominant plant community was Callitricho-Myriophylletum Steusloff 1939. As in the Aller system (see above), Myriophyllum alterniflorum was characteristic of slightly acid, oligotrophic water, and absent from highly calcareous waters.

Siedlecka-Binder (1967), Turala (1970), and Wølek (1971) have carried out surveys on Polish rivers. Siedlecka-Binder studied the vegetation of a stream with torrent characteristics. The species present were described, and their distribution throughout the year noted, showing when each species is most evident, and when they die back. Turala's survey of the Nysa, showed that *Ranunculus penicillatus* grew in the upper reaches of one of the river's major tributaries. In the lower stretches it grew among *R. fluitans*, and in the main river was replaced by the latter species. This compliments findings in the Tweed Basin; with *R. penicillatus* extending much further upstream than *R. fluitans*. Only in the Till did the latter replace the former in more downstream stretches.

Wølek made a study of the distribution of submerged aquatic angiosperms in the Dunajec. Of the 13 species which had their distribution accurately mapped, 10 were present within the Tweed Basin. The most abundant species were *Callitriche hamulata*, *Myriophyllum spicatum*, *Potamogeton crispus*, *P. pusillus* and *Ranunculus circinatus*. Wølek concluded that the distribution of species in the river was most dependent on the depth of water and type of river bed, and not greatly correlated with current velocity.

9.4 Comparison with literature on environmental parameters

9.41 Physical factors

Current velocity is likely to be one of the most important factors affecting macrophytic vegetation in rivers. Whether the main influence is exerted directly through control of establishment, physical damage or effects on metabolic rates is still unresolved (Butcher, 1933; Sirjola, 1969; Westlake, 1973, 1975). Flow velocity also influences the nature of the substratum, which in turn greatly influences macrophyte distribution, (see 1.3). The types of substratum normally associated with various flow regimes have been described by many authors, including; Minnikin (1920), Butcher (1933), Haslam (1971), Hawkes (1975).

As stated in 9.32, Butcher (1933) related the distribution of many species to the flow regimes found in seven rivers. More accurate correlations of species distribution to current speed have been made since that date. These include: Roll (1938), Ackenheil (1944), Hillebrand (1950), Ruess (1954), Gessner (summary, 1955), Sirjola (1969), Hynes (1970), Haslam (1971). Thienemann (1912) studied the Sussaa River, Denmark, and classified species distribution into three rheo (stream flow) categories: rheobionte, rheophile and rheoxene, in order of decreasing velocities. This terminology has been used by Roll (1938), Ackenheil (1944), and Gessner (1955).

The findings of Butcher (1927) for the Itchen, S. England, and Roll (1938) for rivers in Holstein, Germany, have been summarized by Gessner (1955, pp. 259-296). The study of Roll involved the investigation of 'aufnahme', and all data were expressed in terms of associations based on the Zürich-Montpellier School (Braun-Blanquet, 1921, 1964). Plant associations were related to both flow rates and substratum characteristics. If only those species that were recorded from the Tweed and by Butcher and Roll are considered, the species typical of various flow regimes can be compared. Below are listed characteristic species of three broadly based categories of flow regime.

slow - silted	moderate - partly silted	fast - silt free
Vaucheria spp.	Callitriche stagnalis	Cladophora sp.
Callitriche stagnalis	Elodea canadensis	Fontinalis antipyretica
Elodea canadensis	Potamogeton crispus	Ranunculus penicillatus
Potamogeton crispus	Ranunculus fluitans	Rorippa nasturtium-aquaticum
P. pusillus	R. penicillatus	
Ranunculus fluitans	Scirpus lacustris	
	Typha latifolia	

from; Butcher (1933 for the Itchen)

rheoxene (0.12 m s^{-1})	rheophile (0.13 - 0.70 m s^{-1})	rheobionten (0.70 - 1.20 m s^{-1})
Caltha palustris	Elodea canadensis	Hildenbrandia rivularis
Filipendula ulmaria	Phalaris arundinacea	Hydrurus foetidus
Phragmites communis	Potamogeton crispus	Cladophora glomerata
	P. lucens	Eurhynchium riparioides
	P. perfoliatus	Hygroamblystegium fluviatile
	Sparganium erectum	Glyceria fluitans
		Butomus umbellatus

from; Roll (1938, for rivers in Holstein)

In general, the above agree with the comments made in Chapter 7 for the response shown by each species to flow characteristics. Butcher found that Ranunculus was the dominant genus in the Itchen, and could grow at all flow velocities measured, although preferring the fastest currents. This was also true in the Tweed Basin. Butcher reported that Elodea candensis could not grow at velocities greater than 0.75 m s^{-1}, and Callitriche stagnalis, not above 0.50 m s^{-1}. Roll recorded only bank species from stretches with "immeasurably" slow flow rates. As in the Tweed, Elodea canadensis and Potamogeton species were most abundant in slow flow reaches, particularly P. lucens in the deepest stretches. In the faster stretches, Roll found bryophytes frequent, and also Hydrurus foetidus. This chrysophyte was not recorded in the macrophyte surveys of the Tweed, however it was present in mountain flushes during late winter and early spring.

The finding of Ackenheil (1944) will be considered alongside those of Sirjola (1969), for the last author compared his results with those of the former. In the Teuronjoki, studied by Sirjola, the nutrient status of the river increased only minimally on passing downstream; it was thus discounted by the author as having any causal effect on the changing flora of the river. However, very obvious changes in vegetation occurred as water velocity changed.

A few algae were present in the river, five bryophytes, and 25 submerged angiosperms. To show the current tolerance of each species, Sirjola investigated at which flow rate each species was dominant, where they were most frequently recorded, and the limits of each species. As examples, Potamogeton perfoliatus was only dominant in waters where the flow rate was below 0.6 m s^{-1}, and it was positively correlated with decreases in flow rate; conversely, Fontinalis antipyretica and Myriophyllum alterniflorum were positively correlated with increases in current velocity.

Sirjola then compared his results for various species with those of Ackenheil. In general, the findings of both authors complemented each other, and also the observations made for species in the Tweed (Chapter 7). Only the alga Lemanea fluviatilis, and the bryophytes Fontinalis antipyretica, Hygroamblystegium fluviatile and Hygrohypnum ochraceum could withstand the highest velocities; they were also absent from low velocities. Species such as Eleocharis palustris, Iris pseudacorus, Nuphar lutea and Potamogeton natans were confined to the slowest reaches. Many submerged species including Callitriche sp., Elodea canadensis, Glyceria fluitans, Myriophyllum alterniflorum and Potamogeton perfoliatus grew at both low and moderate water velocities. Callitriche sp. and Myriophyllum alterniflorum were present at the highest water velocities, in exact agreement with findings in the Tweed (see 9.22).

The dominance of mosses and liverworts in stretches of the Tweed Basin with the highest flow rates was striking, and has been demonstrated quantitatively in 9.22. The authors quoted in this section found similar results, as did Watson (1919), Backhaus (1967), Szemes (1967), Glime (1968, 1970), Westlake (1973) and Dawson (1973). In reviewing the literature on macrophytes in rivers, Westlake (1973) stated that *Ranunculus* spp. and *Myriophyllum* spp. are typical of fast flowing stretches with stony, gravelly substrata, and *Potamogeton* spp. and *Elodea canadensis* are usually abundant in slow flowing waters. Although these were broad generalisations, they agree most closely with distribution patterns found in the Tweed Basin.

9.42 Water chemistry

Correlations of aquatic floras with either calcareous or non-calcareous waters, and also with eutrophic, oligotrophic or dystrophic conditions, are frequent. However it is infrequently shown that there are species with absolute requirements (Westlake, 1973). In lakes, the situation is probably less complicated, and several correlations have been made (Pearsall, 1920, 1922; Spence, 1964, 1967; Seddon, 1972). For example, Spence (1967) for Scottish lochs, suggests that the water chemistry of a given loch often determines whether or not a species will grow. Seddon (1972) for Welsh lakes has also shown correlations between a species distribution, and conductivity and hardness ratios (see 9.23). However, the problems of such correlations are the same as that for river systems, i.e. many of the environmental parameters such as pH, alkalinity, conductivity, Ca, etc. are often correlated themselves, (Spence, 1967; Seddon, 1972; Westlake 1975), and the isolation of the causal factor is difficult.

An integral part of the classification of rivers by Butcher (1933) was a consideration of the degree of hardness. Below are listed species that he found were confined to acid, non calcareous rivers, or neutral, slightly calcareous ones (a), and those confine to alkaline, highly calcareous rivers (b).

(a)	(b)
Callitriche intermedia	Apium nodiflorum
Equisetum fluviatile	Glyceria maxima
Juncus bulbosus	Hippuris vulgaris
Montia verna	Lemna trisulca
Myosotis secunda	Mimulus guttatus
Myriophyllum alterniflorum	Oenanthe fluviatilis
Potamogeton alpinus	Phalaris arundinacea
P. polygonifolius	Potamogeton lucens
Ranunculus lenormandi	P. natans
Scirpus fluitans	P. praelongus
	Zannichellia palustris

Three of the species present in the non calcareous rivers of Butcher were present in the Tweed Basin. Potamogeton alpinus and P. polygonifolius were confined to slightly acid, soft waters that drained high lying moorland. Of the other species, Myriophyllum alterniflorum will be discussed at the end of this section. Of the species confined to Butcher's highly calcareous rivers, five species were also present in the Tweed: Mimulus guttatus and Phalaris arundinacea were frequent and widespread, and not confined to calcareous waters; Potamogeton natans had a wide distribution, was rarely frequent, but was weakly correlated with increased Ca levels (see Table 9.23b); Potamogeton lucens and Zannichellia palustris were present only in the lower half of the catchment area, the latter being frequent, and weakly correlated with increased Ca.

Many submerged lake macrophytes listed by Spence (1967) and Seddon (1972) were also present in the Tweed. In the Scottish lochs, Cinclidotus fontinaloides, Myriophllum spicatum and Potamogeton lucens were confined to 'rich waters'; Potamogeton pectinatus was confined to 'moderately rich water'; and Fontinalis antipyretica, Myriophyllum alterniflorum and Potamogeton *perfoliatus* were ubiquitous. Seddon discovered that in Welsh lakes *Potamogeton pectinatus* and *Myriophyllum spicatum* were the species most correlated with high conductivity and hardness ratios, and *Myriophyllum alterniflorum* was the species least correlated with these factors. All three species were frequent in the Tweed.

Iverson (1929) classified 50 stretches of river into acid, neutral or changeable (Wechselnd sauer-alkalische), and alkaline. Submerged species that were frequently recorded for both the Tweed and by Iverson show a lot in common. *Myriophyllum alterniflorum* had the widest distribution, extending through the range: weak acid, neutral to alkaline. *Myriophyllum spicatum*, *Potamogeton pectinatus* and *Ranunculus circinatus* were species confined to alkaline waters.

It has not been possible to compare the findings of various authors for hardness and related parameters for every species found in the Tweed. However, reference has been made to specific points when discussing individual species in Chapter 7. Since two members of the genus *Myriophyllum* were present in the Tweed Basin, and both were frequent yet rarely present in the same localities, their distribution in relation to environmental parameters will be summarized.

In the Tweed, *M. alterniflorum* was negatively correlated with conductivity and Ca, and decreasing altitude, *M. spicatum* was positively correlated with the same parameters (see 9.23). Butcher (1933) found *M. alterniflorum* only in low lying, non-calcareous rivers, and *M. spicatum* in moderately and highly calcareous rivers. The findings of Iverson (1927), Spence (1967), and Seddon (1972) have already been described. The findings of Lohammar (1938) and Iverson and Ohlson (1943) are almost identical to that for the Tweed. Using pH, both showed that *M. alterniflorum* grew between pH 6 - 8.5, with maximum frequency between 7 - 7.5. On the other hand, *M. spicatum* did not grow at pH levels below 7, and reached maximum frequency between 7.5 - 8.5.

The distribution of the two species in the Tweed Basin reflects the findings of most authors. The mean altitude for the distribution of M. alterniflorum was 140 m, compared with 15 m for M. spicatum. This supports the greater tolerance of the former to high water velocities, reported by Sirjola (1969). Evidence for M. alterniflorum showing preference for more soft water is also evident in the Tweed. The mean Ca level for the distribution of M. alterniflorum was 17.1 mg l^{-1}, and for M. spicatum 26.3 mg l^{-1}. The mean values for PO_4-P were 0.042 and 0.076 mg l^{-1} respectively, and for NO_3-N 0.74 and 1.02 mg l^{-1}. This is in agreement with the findings of Iverson and Ohlsen (1943), Weber (1967), Seddon (1972)and Weber-Oldecop (1974) who reported that M. alterniflorum is the most oligotrophic of the two species. The mean values for the Tweed have been taken from 9.7.

A complete appraisal of the literature relating species distribution to nutrient levels has not been undertaken. Instead, a very general, short account will be given of some salient findings.

Carbon, nitrogen, phosphorus and potassium are regarded as the elements most likely to be limiting in rivers (Westlake, 1973). Fogg (1973), and Lee (1973) concluded that phosphorus is the key element that controls the growth of plants in aquatic environments. However, in most streams the annual throughput of nutrients in the water alone, (thus ignoring that obtained from the sediment), is ample to produce the plant biomasses found in them (Norman, 1967; Stake, 1967, 1968; Westlake, 1968; Peltier and Welch, 1969; Ladle and Casey, 1971; Ahl, 1972). Westlake (1975) when reviewing the literature reported that in a wide variety of rivers and streams, the annual throughput was over five times, and often over 40 times the annual plant demand. However,the availability at critical growth periods was not considered. The same author stated that phosphorus, occasionally nitrogen, and possibly potassium may be insufficient for optimum growth in oligotrophic, upper stretches of rivers, such as those that rise in mountainous country, but most lowland waters are likely to have an excess of these nutrients.

Kohler et al. (1973) found that it was possible to relate the distribution of macrophytes in the Moosach to water chemistry parameters, Only ammonia and phosphate were regarded as good indicators. However, this may have been because other parameters showed little change on passing downstream. This highlights the problem of stating whether a parameter is an indicator, or merely being able to state that certain species distribution can be correlated, but not necessarily related to a certain parameter. Mulligan and Baranowski (1969) experimented with Elodea canadensis, Myriophyllum spicatum and Potamogeton crispus. They reported that in general, 0.02 mg l^{-1} P, and 0.1 mg l^{-1} N were sufficient to support optimum growth. However, in the Tweed Basin, the latter two species could be correlated with increases in both elements. Peltier and Welch (1969) found that increasing the levels of N and P above 0.44 and 0.03 mg l^{-1} respectively, had no significant effect on Potamogeton pectinatus growth. The above shows that great caution should be used when using the term 'correlated', when attempting to show if a relationship exists between a species distribution, and chemical parameters.

Cladophora glomerata is one species where there is, however, strong support for the belief that there is a causal relationship between high phosphorus, and the amount of this alga's presence. (Blum, 1956; Fitzgerald, 1970; Whitton, 1970; Pitcairn and Hawkes, 1973; Bolas and Lund, 1974). In the Tweed, the species was correlated to the 95% confidence level with increases in this parameter (see Table 9.23b). In 3.59 the advent of serious Cladophora growths on the Tweed in the late 50's has been described. This too, was attributed by many to increases in phosphorus. Recently, such growths have not occurred in the river (Currie, personal communication), perhaps due to an 85% decrease in mean total phosphate levels (see Table 3.49a).

9.43 Other parameters

The possibility of light being a limiting factor is one external parameter not previously discussed in this thesis. Berrie (1972) and Mann et al. (1972) took cross sections across the Thames to show the effects of shading and turbulance on the distribution of plants. Edwards and Owen (1962), Westlake (1966, 1975), Peltier and Welch (1969), and Hannan and Dorris (1970) have shown that in rivers, communities increase their productivity with increases in light levels. The effects have also been studied for lake macrophytes by Spence (1972) and Spence and Crystal (1971, 1971a) who showed that as an adaption to low light intensities, some species developed shade morphology. Westlake (1975) suggests that similar occurrences are likely in rivers.

Owens and Wood (1961) have shown that a fairly normal river flora is found at sites where shading by trees reduces incident irradiation by between 35 - 95%. Dawson and Westlake (1975) report that where tree cover reduces irradiation by 95%, only mosses and liverworts remain, but Sirjola (1969) found no macrophytes at all. In the Tweed Basin, some algae and bryophytes reached their maximum abundance in heavily shaded areas. The encrusting algae, Hildenbrandia rivularis and Heribaudiella fluviatilis were most abundant under the heaviest summer tree cover, and also under permanent cover, e.g under bridges or under large boulders that could only rarely be turned over (see 7.2). In Lake Bodensee, Zimmermann (1927) found Hildenbrandia under permanently shaded ledges at the lake side, and Oberdorfer (1928) reports its presence at depths between 10 - 30 m in the same lake. Bryophytes that could be correlated with heavy shading in the Tweed were Chiloscyphus polyanthos and Tortula latifolia (= T. mutica). Cook (1966) noted that high light intensities were required for Ranunculus species. In the Tweed where heavy tree cover occupied both sides of the river, Ranunculus species were often more frequent on the north bank of the river, suggesting confirmation of Cook's finding. In chalk streams, Owens and Edwards (1961) found that R. calcareous was replaced by Callitriche spp. and Berula erecta in shaded reaches.

Temperature has a major effect on the distribution of plants on a world wide scale (Sculthorpe, 1967). Westlake (1973) points out that despite differences in temperature shown by upper and lower stretches of a river, in Britain, longitudinal distribution patterns can rarely be attributed to this parameter.

The vegetation of a river may often be dependent on mans activities, i.e. the biotic factor. This may result from pollution, river management, or indirectly through grazing of domestic animals. The dominance of Ranunculus penicillatus var. calcareous in the chalk streams of southern England reported in 9.22, is, in the view of Westlake (1973) almost certainly due to regular cutting that has been practiced for hundreds of years.

9.5 Classification of plant communities

The re-arrangement of data from the Tweed and the Teviot into "association tables" (8.64) has shown that phytosociological techniques can be used to show the existance of distinct plant communities in a river system. The ultimate step is to be able to classify these communities. The classification of water plant communities has been discussed in 1.5, and since Hartog and Segal (1964) synthesized the Zürich-Montpellier system of Braun-Blanquet and Tüxen with specific modification for classifying communities found in water, data from the Tweed will be related to their system.

Hartog and Segal recognised nine classes of water plant communities, and listed 'faithful taxa' to be found in each, using data from sites in the Netherlands. The system has limitations when considering data from the Tweed, for it only considers submerged angiosperms. In the class POTAMOTEA, there are three orders which have faithful taxa that were present in the Tweed. The class is characterised by communities of elodeids, myriophyllids, batrachiids and nuphaeids, found in fresh or slightly brackish waters. Faithful taxa are Myriophyllum spicatum, Potamogeton natans and P. pectinatus. The order Magnopotametalia is characterised by large Potamogeton species and other elodeids and numphaeids, which are present in deep, eutrophic to meso-eutrophic water: faithful taxa are Potamogeton lucens and P. perfoliatus. The order Parvopotametalia is characterised by small eledeids, myriophyllids and batrachiids present in shallow, meso-eutrophic and oligotrophic waters: faithful taxa are Elodea canadensis, Potamogeton berchtoldi, P. crispus, P. pusillus and Zannichellia palustris. The order Luronio-potametalia includes elodeids and small nuphaeids present in shallow, oligo-meso-dystrophic waters: faithful taxa include Myriophyllum alterniflorum.

Reference to Fig. 8.64a shows that there are four communities in the Tweed that contain at least two submerged angiosperm species. The lowermost community i.e. restricted to the deepest and slowest stretches of the river could be classified as Magnopotametalia, for it contains the faithful taxa Potamogeton lucens and P. perfoliatus, and also other large Potamogeton species. It also contains two species of Parvopotametalia: Potamogeton pusillus and Zannichellia palustris. The community of species that extends to all except the upper reaches of the river fits well into Parvopotametalia. The order contains a sub-alliance Ranunculion fluitantis i.e. communities of fast flowing waters dominated by Ranunculus species. The community contains two Ranunculus species, Elodea canadensis and Potamogeton crispus. The communities in the uppermost reaches which are absent from the deep, slow, lower stretches, contain Callitriche spp., Myriophyllum alterniflorum and Ranunculus aquatilis, and are a combination of an alliance in Parvopotametalia; Callitricho - batrachium, and the order Luronio-potametalia. The former is characteristic of small rivulets and rivers, with faithful taxa Ranunculus aquatilis and Callitriche spp. and the latter, also characteristic of shallow waters has Myriophyllum alterniflorum as a faithful taxon.

The above shows that although plant communities can be classified, often species of different classes or orders are present within the same communities. It must be stressed, however, that the data were not collected with a primary aim of classifying communities, and the delimination of communities was not based on rigid phytosociological techniques. Despite this, with the limited data available it was possible to show that large Potamogeton species of the order Magnopotametalia, which is characteristic of deep, eutrophic waters, only occurred in the slow flowing, lowland stretches of the Tweed. Conversely, Myriophyllum alterniflorum which is the most faithful taxon in Luronio-potametalia and is characteristic of shallow non-eutrophic water, was the only abundant submerged angiosperm in the upper 30 km, and was absent from the lowermost stretches where Magnopotametalia was the dominant community. The community Parvopotametalia includes species which usually occur in habitats that are intermediate between the two extremes mentioned above. In the Tweed this is well illustrated, for faithful taxa within the order (Elodea canadensis, Potamogeton crispus, and Ranunculus species) have an intermediate distribution between that of Myriophyllum alterniflorum and the larger Potamogeton species.

Reference to 8.64b shows that the same distribution of the three orders was also evident in the Teviot. Two other faithful taxa in Parvopotametalia, Potamogeton pusillus and Zanichellia palustris extended further up the Teviot than they did in the Tweed, thus showing a more typical distribution than they did in the Tweed.

9.6 Concluding remarks

A descriptive account has been given of the distribution of macrophytes in the Tweed Basin. The account can be regarded as a record of the flora of the river system during the months and years when surveys were carried out. Any future surveys will be able to compare the flora of the river at that time, with the present flora. If obvious changes do take place, it may be possible to identify the influences which bring them about.

There are past data available from a wide variety of sources, but they are generally applicable to a few individual species. The most accurate records are herbarium specimens. Lack of previous intensive surveys make critical comparison of the present flora with the flora in former years difficult. This has been discussed in Chapter 7 for individual species, where for example, it was suggested that the distribution of *Potamogeton x salicifolius* has changed little over the past 150 years, whereas another member of the same genus, *P. x olivaceus* has probably become much more widespread. Knowledge of the history of a river can be valuable in interpretation of data. For example, *Cladophora glomerata* became a problem during the late 1950's and early 1960's, but more recently it has declined in abundance. It is possible to tentatively suggest that the increase in *Cladophora* may have been due to increased phosphorus levels in the river due to the high level of this element in synthetic detergents which were used in the textile industry. The mills have recently reverted back to using natural soaps, and there has been a six fold decrease in total phosphate (see pp. 67-69), and a concomitant decrease in *Cladophora*.

It is felt that if an attempt is to be made to correlate the distribution of individual species in a river with changes in environmental parameters, it is imperative that the river system is surveyed in its entirety. This can be illustrated by reference to the present study, and the interpretation of changes that take place in the Tweed immediately below Teviot Foot.

The macrophyte survey showed that Enteromorpha sp(p)., Myriophyllum spicatum and four species of Potamogeton had their most upstream occurrence in the 0.5 km length immediately below Teviot Foot (p. 159). The water chemistry survey indicated that the Teviot had a great effect on the chemistry of the Tweed, especially with regard to hardness parameters (p. 119). It would therefore have been easy to correlate the appearance of these six macrophytes with the changing water chemistry. Subsequent surveys indicated that the above six species were present in the lower reaches of the Teviot. Further examples of species occurring in rivers only below an affluent which carries an inoculum of the species are: P. x suecicus in the Tweed below Till Foot, P. x olivaceus and P. pusillus in the Whiteadder below Blackadder Foot.

The presence of some submerged angiosperm species only in recipient rivers below the point of entry of a donor river has been illustrated above. The possible causes of such a distribution pattern could be interpreted in a variety of ways, the two most probable explainations being; (a) the donor tributary causes changes in the receiving river which changes an otherwise unsuitable habitat to a suitable one, (b) the donor tributary provides the original inoculum, or continues to supply an inoculum, and upstream migration of macrophytes in rivers is a rarer occurrence than is generally reported. In the Tweed, only Zannichellia palustris has appeared to have migrated upstream (p. 367). Changes that take place in the recipient river, and the presence of an inoculum of a species are probably both important factors, but which is the overiding influence could only be shown be controlled experimental studies.

It has been suggested in this account and also by various workers in the Nature Conservancy (see p. 15) that the Tweed is particularly rich in macrophyte species. Due to the nature of surveys carried out on other rivers, accurate comparisons of floras has been limited to a discussion of submerged angiosperm species. Such a comparison was made with the four largest rivers in N-E. England (p. 431), which showed that there were 17 submerged angiosperm species in the Tweed, 8 in the Tyne, 10 in the Wear, 11 in the Tees and 7 in the Wharfe. The Wear, which was studied from source to mouth by Whitton and Buckmaster (1970) is brackish at km 96.5. The authors therefore surveyed 193 0.5 km lengths, from which a total of 10 submerged angiosperms were recorded. At a comparable point from the source of the Tweed (i.e. 10 km above Teviot Foot), only 9 species had been recorded. The rich angiosperm flora of the Tweed may therefore not be due to any historical influence or its meso-eutrophic water chemistry, but merely due to its large size, and the large number of variable tributaries which provide inocula to the main river.

The full significance of many of the points raised in this thesis may only become apparent when similar detailed surveys have been carried out on other rivers in S-E. Scotland and N-E. England. A computer analysis of the floristic composition of these rivers, together with data concerning their physical and water chemical characteristics might go a long way to substantiating some of the generalisations.

species	no. of records	altitude	conductivity	pH	Na	K	Mg	Ca	[illegible]	Cl	Si	PO_4-P	NH_4-N	NO_2-N	NO_3-N
Didymosphenia geminata	46	245	100	7.3	5.0	0.47	4.04	14.2	0.004	9.6	1.65	0.002	0.130	0.002	0.20
Hygrohypnum luridum	53	240	105	7.3	5.2	0.50	4.13	14.3	0.005	9.9	1.71	0.002	0.149	0.002	0.23
Brachythecium plumosum	59	235	110	7.3	5.6	0.59	4.41	15.3	0.006	10.9	1.71	0.007	0.166	0.003	0.37
Philonotis fontana	56	230	110	7.3	5.5	0.58	4.33	14.9	0.006	10.6	1.84	0.007	0.161	0.003	0.36
Bryum pseudotriquetrum	72	225	110	7.4	5.7	0.63	4.40	15.4	0.006	11.0	1.72	0.010	0.170	0.004	0.41
Ranunculus flammula	16	245	100	7.3	5.0	0.46	4.03	14.1	0.004	9.5	1.65	0.003	0.143	0.002	0.20
Solenostoma triste	45	230	110	7.4	5.8	0.60	4.38	14.8	0.006	10.5	1.89	0.005	0.158	0.003	0.42
Cochlearia alpina	34	245	100	7.3	5.2	0.48	4.06	14.2	0.006	9.5	1.64	0.003	0.142	0.002	0.20
Climacium dendroides	22	255	105	7.3	5.0	0.47	4.14	14.2	0.006	9.6	1.67	0.002	0.142	0.002	0.20
Amphidium mougeotii	15	255	1 5	7.3	5.2	0.52	4.25	14.5	0.006	10.1	1.70	0.003	0.155	0.002	0.28
Hygrohypnum ochraceum	36	230	105	7.3	5.4	0.52	4.22	14.7	0.005	10.4	1.83	0.006	0.171	0.003	0.30
Mnium punctatum	25	245	105	7.3	5.2	0.51	4.07	14.8	0.006	10.0	1.74	0.004	0.153	0.002	0.26
Scapania undulata	26	235	110	7.3	5.6	0.60	4.38	15.0	0.005	10.9	1.89	0.005	0.169	0.003	0.39
Rhacomitrium aquaticum	11	245	100	7.3	5.1	0.49	4.10	14.3	0.005	9.8	1.68	0.003	0.146	0.002	0.25
Carex nigra	34	225	100	7.3	5.1	0.50	4.02	14.4	0.004	9.9	1.68	0.005	0.153	0.003	0.27
Rhacomitrium acicularis	10	235	115	7.4	5.7	0.58	4.56	14.7	0.007	10.4	1.72	0.002	0.155	0.002	0.33
Haematococcus lacustris	17	235	110	7.3	5.5	0.57	4.34	14.9	0.007	10.6	1.75	0.010	0.16[illegible]	0.004	0.34
Rhytidiadelphus squarrosus	6	205	115	7.3	6.1	0.79	4.[illegible]	15.6	0.005	11.2	1.87	0.043	0.211	0.007	0.48
Acrocladium cuspidatum	99	185	120	7.4	6.2	0.72	4.62	15.5	0.007	12.3	1.9[illegible]	0.023	0.[illegible]68	0.006	0.49
Brachythecium rivulare	102	180	125	7.4	6.4	0.76	4.76	16.6	0.007	12.4	1.89	0.025	0.186	0.006	0.64
Dichodontium pellucidum	102	180	12[illegible]	7.4	6.4	0.75	4.67	16.4	0.007	12.4	1.91	0.023	0.180	0.006	0.58
Ulothrix zonata	125	165	125	7.4	6.7	0.81	4.72	16.6	0.008	13.0	2.06	0.025	0.177	0.007	0.67
Prasiola crispa	44	175	120	7.4	6.4	0.77	4.75	16.2	0.007	12.6	1.81	0.030	0.138	0.008	0.53
Lemanea fluviatilis	58	165	125	7.4	6.7	0.83	4.77	16.0	0.008	13.1	1.99	0.033	0.187	0.008	0.64
Myriophyllum alterniflorum	208	140	130	7.5	7.3	0.88	4.97	17.1	0.009	14.0	1.90	0.042	0.191	0.009	0.74
Grimmia alpicola	134	165	130	7.4	6.7	0.83	5.03	17.2	0.008	13.1	1.83	0.032	0.191	0.008	0.61
Juncus effusus	119	165	130	7.4	6.8	0.79	4.89	16.8	0.008	12.9	1.82	0.032	0.192	0.008	0.62
Cratoneurom filicinum	103	165	125	7.5	6.6	0.76	4.91	16.8	0.008	12.7	1.94	0.032	0.192	0.007	0.61
Callitriche spp.	110	150	135	7.5	7.0	0.90	5.33	18.2	0.009	13.4	1.79	0.035	0.211	0.008	0.66
Filipendula ulmaria	143	140	130	7.5	7.2	0.91	5.14	17.6	0.009	13.9	1.80	0.039	0.202	0.009	0.76
Rorippa nasturtium-aquaticum	119	125	140	7.5	7.6	0.93	5.40	17.9	0.010	14.3	1.61	0.046	0.214	0.010	0.80
Fontinalis antipyretica var. grac.	7	170	130	7.4	7.1	0.89	5.09	17.[illegible]	0.010	13.6	2.00	0.040	0.194	0.009	0.67
Funaria hygrometrica	32	150	140	7.4	6.9	0.83	4.97	17.1	0.010	13.4	1.82	0.034	0.185	0.009	0.66
Carex spp.	29	120	145	7.6	7.7	0.99	5.82	19.4	0.010	14.2	1.49	0.051	0.232	0.011	0.74
Thamnium alopecurum	18	135	140	7.5	7.5	0.89	5.15	17.5	0.011	14.0	1.74	0.041	0.201	0.009	0.64
Collema flaccidum	5	120	140	7.6	7.5	0.97	5.48	18.7	0.010	14.8	1.97	0.045	0.201	0.010	0.92
Chiloscyphus polyanthos	88	140	130	7.4	7.1	0.90	4.99	17.4	0.008	14.2	2.05	0.034	0.189	0.008	0.76
Fissidens adianthoides	40	100	130	7.5	7.9	0.94	5.24	17.8	0.009	14.9	1.80	0.050	0.199	0.011	0.83
Leskea polycarpa	15	165	125	7.4	6.8	0.92	4.73	16.7	0.010	13.3	2.28	0.023	0.210	0.006	0.84
Ranunculus aquatilis agg.	97	140	130	7.5	7.1	0.92	4.88	17.2	0.005	14.1	2.23	0.035	0.187	0.008	0.31
Potamogeton x olivaceus	74	140	135	7.5	7.3	0.96	5.09	17.6	0.009	14.2	2.26	0.037	0.204	0.009	0.36
Nostoc other sp.	15	120	140	7.5	7.5	0.99	5.11	17.8	0.009	14.8	2.08	0.051	0.212	0.011	0.87
Dermatocarpon fluviatile	55	100	140	7.5	8.6	1.01	5.48	18.5	0.010	15.5	1.81	0.053	0.201	0.012	0.89
Mentha aquatica	75	145	125	7.4	7.1	0.84	4.98	17.2	0.008	13.4	1.97	0.035	0.205	0.008	0.72
Spirogyra spp.	69	120	140	7.5	7.4	0.94	5.44	18.5	0.0[illegible]	14.2	1.74	0.039	0.209	0.010	0.73
Carex rostrata	61	110	145	7.6	7.5	1.01	5.81	19.6	0.011	14.5	1.73	0.041	0.230	0.010	0.76
Mnium longirostrum	93	120	140	7.5	7.5	0.95	5.59	18.9	0.010	14.6	1.83	0.046	0.221	0.010	0.76
Marchantia polymorpha	102	120	140	7.5	7.6	0.96	5.62	19.0	0.010	14.6	18.2	0.047	0.223	0.010	0.76
Verrucaria praetermissa	136	110	140	7.6	7.9	0.98	5.38	18.3	0.011	15.2	1.82	0.052	0.211	0.011	0.84
Fontinalis antipyretica	238	130	135	7.5	7.4	0.91	5.29	18.0	0.010	13.9	1.60	0.043	0.204	0.010	0.75
Cinclidotus fontinaloides	201	125	140	7.5	7.5	0.95	5.51	18.7	0.010	1 44	1.73	0.046	0.209	0.010	0.77
Hygroamblystegium fluviatile	225	125	135	7.5	7.4	0.92	5.39	18.4	0.010	14.1	1.66	0.044	0.206	0.010	0.75
Pellia epiphylla	94	130	135	7.5	7.4	0.92	5.29	18.2	0.010	14.0	18.5	0.042	0.204	0.010	0.75
Conocephalum conicum	175	120	140	7.5	7.5	0.94	5.46	18.6	0.010	14.3	1.72	0.045	0.207	0.010	0.75
Phormidium spp.	105	135	140	7.5	7.3	0.90	5.11	17.7	0.010	13.7	1.89	0.041	0.197	0.011	0.74
Juncus acutiflorus	189	115	140	7.5	7.6	0.99	5.23	19.0	0.010	14.6	1.66	0.046	0.210	0.010	0.77

Table 9.7a Mean values of 14 parameters for each species present in the Tweed (see 9.23 for explaination).

species	no. of records	altitude	conductivity	pH	Na	K	Mg	Ca	Mn	Cl	Si	PO_4-P	NH_3-N	NO_3-N	NO_2-N
Glyceria fluitans	103	100	155	7.7	8.0	1.12	6.12	20.6	0.011	15.2	1.76	0.054	0.241	0.012	0.88
Veronica beccabunga	107	130	150	7.6	7.3	0.96	5.63	19.1	0.010	13.9	1.74	0.039	0 224	0.009	0.73
Verrucaria spp.	240	110	145	7.6	7.7	1.00	5.67	18.9	0.010	14.8	1.76	0.050	0.216	0.011	0.82
Euhynchium riparioides	267	120	140	7.5	7.5	0.86	5.54	18.7	0.010	14.3	1.63	0.048	0 215	0.011	0 78
Mimulus guttatus	224	120	140	7.5	7.6	0.98	5.62	19.0	0.010	14.5	1.82	0.046	0.219	0.010	0.78
Caltha palustris	190	115	140	7.5	7.6	0.98	5.50	18 6	0.010	14.6	1.79	0.046	0.210	0.010	0.77
Oedogonium spp	249	110	150	7.6	7.6	0.99	5.97	19.8	0 010	14.5	1.63	0.050	0.228	0.011	0.81
Stigeoclonium tenue	213	110	145	7.5	7.6	0.98	5.67	19.2	0.010	14.4	1.76	0.046	0.215	0.010	0.81
Myosotis scorpioides	275	100	150	7.6	7.5	1.00	5.83	19.7	0.010	14.9	1.66	0.052	0.228	0.011	0.82
Heribaudialla fluviatilis	228	105	150	7.6	7.6	0 99	5.73	19.6	0.010	14.9	1.66	0.052	0.225	0 011	0.82
Orthotrichum rivulare	45	110	150	7.6	7.6	0.98	5.56	19.5	0.010	14.9	1.65	0.042	0 225	0.011	0.82
Pellia endivifolia	24	130	145	7.6	7.3	1.00	5.79	19 6	0.011	14 0	1.79	0.039	0.228	0.009	0.77
Iris pseudacorus	21	95	150	7.6	8.2	1.11	5.79	19.5	0 010	15.4	1.73	0.059	0.253	0 012	0.82
Potamogeton natans	4	100	150	7.7	7.6	1.03	6.10	20.2	0.009	14.4	1.53	0.043	0 268	0.010	0.67
Scirpus sylvaticus	58	90	150	7.6	8.0	1.09	5.68	20.2	0.011	15.8	1.76	0.058	0 261	0.013	0.87
Collema fluviatile	75	85	150	7.6	8.6	1.09	5.90	14.7	0.012	15.1	17.4	0.064	0.217	0.014	0.93
Cladophora aegagropila	64	65	155	7.7	8 8	1.15	6.20	20.3	0.013	16 5	1.43	0.075	0.241	0.015	0.97
sewage fungus	22	100	150	7 6	8.2	1.16	5.81	19.6	0.012	15.5	1.43	0.075	0.241	0.015	0.94
Nostoc parmelioides	62	70	155	7.7	8.7	1.13	6.00	19.8	0.012	16.4	1.55	0.072	0 240	0.015	0.93
Juncus inflexus	10	30	175	7 9	9 4	1.26	6.94	22.3	0 014	17 3	1 20	0.081	0.305	0.016	1.03
Monostroma bullosum	6	25	185	8.1	9.3	1.37	7.77	25 1	0.014	17.3	1.16	0.079	0 312	0.016	1.02
Botrydium granulatum	10	20	190	8.2	9.3	1.43	8.19	26.4	0 015	17.2	1.14	0.077	0.312	0.016	1.03
Tetraspora sp(p).	34	20	185	8.1	9.3	1.37	7.73	24.9	0.016	17.4	1.15	0.078	0.315	0.016	1.03
Fissidens crassipes	38	15	195	8.2	9.4	1.47	8 16	26.3	0.015	17.5	1.15	0.077	0.359	0.016	1.04
Vaucheria sp(p)	91	75	155	7.7	8.5	1.15	6.18	20.7	0.012	16.3	1.60	0.063	0 246	0.012	0.92
Equisetum fluviatile	113	95	155	7.7	8.2	1.07	5.73	19.5	0.013	15.8	1.78	0 055	0 213	0 012	0.89
Tortula mutica	88	100	150	7.6	8.0	1.04	5.57	18.9	0.011	15.5	1.89	0.052	0.205	0.012	0.87
Hildenbrandia rivularis	237	90	150	7.6	8.2	1.10	6.00	20.0	0.012	15.5	1.71	0.055	0.235	0.012	0 90
Phalaris arundinacea	272	100	150	7.6	8.0	1.05	5.87	19.6	0.012	15.3	1.72	0.054	0 227	0.012	0.87
Brachythecium rutabulum	189	70	160	7.7	8.5	1.17	6.38	21.3	0.013	16.3	1.56	0.065	0.256	0.013	0.74
Ranunculus penicillatus var. calcareus	239	80	155	7.7	8.4	1.14	6.18	20 6	0.012	16.2	1.69	0 062	0 243	0.012	0.93
Eleocharis palustris	185	75	155	7.7	8.5	1.16	6.08	21.0	0.012	16.3	1.61	0.063	0.249	0.012	0.91
Sparganium erectum	141	90	150	7.6	8.2	1.10	5.94	19.7	0.012	16 0	1.85	0.056	0.228	0.012	0.89
Polygonum amphibium	111	60	165	7.8	8.7	1.20	6.64	21 8	0.013	16.4	1.48	0.067	0 265	0.014	0.95
Elodea canadensis	241	80	155	7.7	8.4	1 12	6 15	20.5	0 012	16.0	1.69	0.061	0.241	0.012	0.93
Potamogeton crispus	150	80	155	7.7	8 4	1.13	6.11	20.4	0.013	16.0	1.70	0.061	0 24[illegible]	0.012	0.9[illegible]
Cladophora glomerata	214	80	155	7.7	8.4	1.13	6.16	20.6	0.013	1.60	1.65	0 060	0 244	0.012	0.93
Rorippa amphibium	163	50	180	7.8	9.0	1.23	6.71	21.8	0.013	16.7	1.36	0.075	0 263	0.016	0.96
Leptodictyum riparium	37	50	175	7.7	8.9	1.32	6.95	22.8	0 016	17 6	1.51	0.076	0.300	0.017	1.07
Ranunculus fluitans x ?	130	30	180	7.9	9.4	1 32	7 30	23.5	0.016	17.5	1.20	0.083	0.299	0.017	1.02
Zannichellia palustris	54	15	195	8.1	9.4	1.44	8.13	26.1	0.017	17.5	1.15	0.076	0.314	0.016	1.02
Potamogeton x salicifolius	57	15	195	8.2	9.3	1.45	8.18	26.3	0.016	17.4	1.15	0.076	0 324	0.016	1.03
Potamogeton pectinatus	79	15	195	8 1	9.4	1.45	8.17	26.3	0.017	17.5	1.14	0.076	0 322	0.016	1.02
Myriophyllum spicatum	80	15	195	8.1	9.4	1.45	8.17	26.3	0.017	17.5	1.13	0.076	0.323	0.016	1.02
Potamogeton pusillus	48	15	195	8.1	9.4	1.45	8.17	26.3	0 017	17.5	1.14	0.077	0.324	0.016	1.02
Enteromorpha sp(p).	62	15	195	8.1	9.4	1 45	8 17	26.2	0.018	17.7	1.13	0.077	0.322	0.016	1.02
Potamogeton perfoliatus	39	5	200	8.1	9.6	1.45	8.13	26.0	0.019	18.0	1.18	0.075	0.332	0.016	1.00
Potamogeton lucens	4	5	200	8.1	9.6	1.53	8.18	26.3	0.023	18.3	1.08	0.083	0 335	0.017	1.05
Potamogeton x suecicus	7	5	200	8.2	9.6	1.44	8 13	2.59	0.019	18.0	1.21	0.073	0.336	0 017	0.99

Table 9.7a continued.

species	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Gongrosira incrustans					7	10	23	21	49	37	57	26
Heribaudiella fluviatilis	10	50	12	60	46	63	94	85	115	86	147	68
Enteromorpha sp(p).							5	5	25	19	145	67
Cladophora glomerata			1	5	34	47	64	58	114	85	205	94
Hygrohypnum luridum	20	100	20	100	38	52	37	34	14	10		
Leptodictyum riparium					6	8	8	7	20	15	75	35
Eurhynchium riparioides	20	100	20	100	73	100	110	100	133	100	173	80
Fontinalis antipyretica	20	100	20	100	73	100	106	96	96	65	145	67
Scapania undulata	10	50	5	25	19	24	1	1				
Solenostoma triste	17	85	9	45	30	39	11	10				
Elodea canadensis					36	49	62	56	107	80	193	89
Myriophyllum alterniflorum	18	90	16	80	57	78	85	77	76	57	35	16
M. spicatum							3	3	52	39	163	75
Potamogeton berchtoldii							4	4	28	21	16	7
P. crispus					28	38	40	36	107	80	152	70
P. lucens											7	3
P. natans					7	10			4	3	8	3
P. x olivaceus					29	40	35	32	14	10	12	6
P. pectinatus											105	48
P. perfoliatus									3	2	56	26
P. pusillus									13	10	65	30
P. x salicifolius											69	32
P. x suecicus											15	7
Ranunculus aquatilis agg.					37	51	69	63	17	13		
R. circinatus + hybrid							5	5	4	3		
R. penicillatus var. calcareus					30	41	80	73	98	73	160	74
R. fluitans x ?							5	5	50	37	174	81
Zannichellia palustris									41	31	132	61
altitude (m)	330 - 275		274 - 220		219 - 165		164 - 110		109 - 55		54 - 0	

Table 9.7b Primary data of 28 species for calculation of Spearman Rank coefficients (r_s). The number of records in each of the six ranks, and the percentage of the maximum possible is given for each species.

species	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Gongrosira incrustans					37	24	66	62	20	74	13	46
Heribaudiella fluviatilis	71	7	133	84	98	63	76	71	26	96	18	64
Enteromorphansp(p),					74	47	55	51	26	96	20	71
Cladophora glomerata	23	22	132	83	106	68	104	97	26	96	28	100
Hygrohypnum luridum	68	68	3	2	58	37	2	2				
Leptodictyum riparium	3	3	21	13	23	15	37	35			21	75
Eurhynchium riparioides	97	100	159	100	121	78	97	91	27	100	28	100
Fontinalis antipyretica	96	99	133	84	107	68	93	88	15	56	19	69
Scapania undulata	29	29	1	1	5	3						
Solenostoma triste	52	53	8	6	7	5						
Elodea canadensis	21	21	159	100	92	59	83	77	12	44	13	46
Myriophyllum alterniflorum	88	89	154	97	23	15	17	16	8	30	21	75
M. spicatum					82	53	91	85	24	89	21	75
Potamogeton berchtoldii					17	11			24	89	7	25
P. crispus	16	16	103	65	71	46	90	84	25	93	25	89
P. lucens					4	2	3	3				
P. natans	2	2	6	4	2.	1	4	4	6	22	2	7
P. x olivaceus	17	17	54	34	3	2			12	44	3	11
P. pectinatus					79	51	19	18	4	15	3	11
P. perfoliatus	39				39	25	8	8	11	41	1	4
P. pusillus					47	30	22	21	8	30	2	7
P. x salicifolius					57	37	12	11				
P. x suecicus					7	4	8	7				
Ranunculus aquatilis agg.	26	26	78	49	4	3	9	8				
R. circinatus + hybrid									22	39		
R. penicillatus var. calcareus	20	20	151	95	99	63	72	67	15	56	1	4
R. fluitans x ?			48	30	99	63	44	41	27	100	11	39
Zannichellia palustris			1	1	65	42	81	76	14	52	12	43
	< 124		125 - 174		175 - 224		225 - 273		275 - 324		> 325	

c o n d u c t i v i t y (micro- mhos)

Table 9.7b continued.

species	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Gongrosira incrustans							46	70	82	84	8	53
Heribaudiella fluviatilis	75	73	142	86	76	61	37	56	80	82	8	53
Enteromorpha sp(p),			12	7	76	61	12	18	60	61	15	100
Cladophora glomerata	29	28	134	81	121	97	24	36	95	97	15	100
Hygrohypnum luridum	68	66	5	3	2	2	54	82	2	2		
Leptodictyum riparium	9	9	15	9	47	38	1	1	24	24	24	93
Eurhynchium riparioides	103	100	165	100	82	86	66	100	98	100	15	100
Fontinalis antipyretica	103	100	142	86	73	59	57	88	87	88	8	53
Scapania undulata	29	28	1	1	5	5						
Solenostoma triste	52	51	10	6	5	5						
Elodea canadensiss	27	26	156	95	109	87	18	27	76	78	8	53
Myriophyllum alterniflorum	96	93	160	97	7	6	7	11	21	21		
M. spicatum					102	82	13	20	89	91	14	93
Potamogeton berchtoldii			17	10			10	15	14	14	71	47
P. crispus	22	21	109	66	79	63	18	27	89	91	13	87
P. lucens					5	5	3	5	2	2		
P. natans	7	7					3	5	10	10		
P. x olivaceus	17	17	54	33	3	3	8	12	4	4	3	20
P. pectinatus					84	67	4	6	17	17		
P. perfoliatus					42	34	8	12	9	9		
P. pusillus					49	39	4	6	24	24	2	13
P. x salicifolius					57	46			12	12		
P. x suecicus					15	12						
Ranunculus aquatilis agg.	30	29	74	45			4	6				
R. circinatus + hybrid									22	11		
R. penicillatus var. calcareus	26	25	162	98	88	70	7	11	75	77		
R. fluitans x ?			66	40	109	87	12	18	34	35	7	47
Zannichellia palustris			12	7	73	58	12	18	69	70	7	47
	10.4-17.4		17.5-24.9		25.0-32.4		32.5-39.9		40.0-47.4		> 47.5	

Ca (mg l^{-1})

Table 9.7b continued.

species	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Congrosira incrustans	37	29	11	6	14	9	30	70	37	67	7	88
Heribaudiella fluviatilis	74	59	139	78	122	76	41	95	37	67	3	38
Enterimorpha sp(p).			40	22	79	49	2	5	46	84	8	100
Cladophora glomerata	18	14	152	85	111	69	39	91	53	96	8	100
Hygrohypnum luridum	115	91	9	5			2	5				
Leptodictyum riparium	1	1	36	20	38	24	6	13	21	38	8	100
Eurhynchium riparioides	126	100	170	95	128	80	42	98	55	100	8	100
Fontinalis antipyretica	125	99	157	88	89	55	39	91	44	80	6	75
Scapania undulata	23	18	12	7								
Solenostoma triste	48	39	19	11								
Elodea canadensis	8	6	150	84	154	96	39	91	45	82	1	13
Myriophyllum alterniflorum	68	54	130	73	62	39	16	37				
M. spicatum	2	2	35	19	92	57	29	67	53	96	7	88
Potamogeton berchtoldii			31	17	10	6			7	13		
P. crispus	8	6	129	72	90	56	34	79	51	93	6	75
P. lucens			1	1	3	2			2	4		
P. natans	2	2	9	5	4	2			5	9		
P. x olivaceus	1	1	60	34	21	13	6	13	3	6		
P. pectinatus			5	3	83	52			14	25	3	38
P. perfoliatus			6	3	48	30			5	9		
P. pusillus			1	1	52	32	7	16	19	33	5	63
P. x salicifolius					57	35			12	22		
P. x suecicus			8	4	7	4						
Ranunculus aquatilis agg.	10	8	79	44	18	11	7	16				
R. circinatus + hybrid			22	6								
R. penicillatus var. calcareus	5	4	89	50	144	89	36	84	40	73	1	13
R. fluitans x ?			63	35	139	86	7	16	21	38		
Zannichellia palustris	1	1	35	20	65	40	26	61	45	82	1	13
	$<.010$		.010-.054		.055-.099		.100-.144		.145-.189		.190-.234	

PO_4-P ($mg\ l^{-1}$)

Table 9.7b continued.

species	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Gongrosira incrustans			37	42			50	28	37	20	12	67
Heribaudiella fluviatilis	28	57	55	63	44	86	145	81	138	75	15	83
Enteromorpha ap(p).							70	39	93	52	12	67
Cladophora glomerata	1	2	23	26	43	84	166	91	153	83	17	94
Hygrohypnum luridum	46	94	72	82			4	2				
Leptodictyum riparium			4	5	12	24	45	25	36	19	10	56
Eurhynchium riparioides	49	100	88	100	51	100	168	94	155	85	18	100
Fontinalis anti¡yretica	49	100	87	99	50	98	138	78	121	65	15	83
Scapai.'anundvlata	23	46	6	7	3	6	1	1			2	11
Solenostoma triste	48	99	6	7	5	10	7	4			1	5
Elodea canadensis	2	4	15	17	43	84	153	85	151	82	9	50
Myriophyllum alterniflorum	44	90	34	39	43	84	74	41	77	42	5	28
M. spicatum			2	2	6	12	97	54	105	56	8	44
Potamogetoı berchtoldii							41	23	7	4		
P. crispus			16	18	38	75	133	74	128	69	17	94
P. lucens							2	2	4	2		
P. natans	1	2	3	3	7	14	3	4	5	3		
P. x olivaceus	1	2	5	6			27	33	16	9		
P. pectinatus							17	21	71	38	3	17
P. perfoliatus							18	10	41	[illegible]		
P. pusillus							31	17	47	25	1	6
P. x salicifolius							19	11	50	27		
P. x suecicus							8	4	7	4		
Ranunculus aq.iatilis agg.	6	12	11	13	24	48	42	23	16	9		
R. circinatus + hybrid							23	7				
R. penicillatus var. calcareus	1	2	13	15	38	75	137	77	176	95	1	6
R. fluitans x ?							95	53	129	69	5	28
Zannichellia palustris.							72	40	76	39	5	28
	< 0.20		0.20-0.47		0.48-074		0.75-1.01		1.02-1.28		1.29-1.55	

NO_3 - N (mg l^{-1})

Table 9.7b continued.

BIBLIOGRAPHY

Ackenheil H. V. (1944) Strömung und höhere Vegetation im Flusse Lagan bei Ågård. Medd. telmat. Stn Ågard 1, 1-31.

Ahl T. (1972) Plant nutrients in Swedish lake and river waters. Verh. int. Verh. theor. angew. Limnol. 18(1), 362-369.

Allorge P. (1925) Sur quelques groupements aquatiques et hygrophiles des Alpes du Brianchnais. Festschr. Carl Schroter, 105-126.

Ambuhl H. (1959) Die Bedeutung der Strömung als ökologischer Faktor. Schweiz. Z. Hydrol. 21, 135-259.

American Public Health Association (1971) Standard Methods for the Examination of Water and Wastewater, 13th Edit. American Public Health Association, Inc., 1970 Broadway, New York. 874 pp.

Angus W. (1894) Ettrick and Yarrow: A Guide. James Lewis, Selkirk. 228 pp.

Arber A. (1920) Water Plants, a Study of Aquatic Angiosperms, Cambridge. 436 pp.

Backhaus D. (1967) Die Makrophytenbesiedlung der obersten Donau und ihrer Quellflüsse. Arch. Hydrobiol. Suppl. 30, 306-320.

Backhaus D. (1967a) Ökologische Untersuchungen an den Aufwuchsalgen der obersten Donau und ihrer Quellflüsse I Voruntersuchungen. Arch. Hydrobiol. Suppl. 30(4), 364-399.

Backhaus D. (1968) Ökologische Untersuchungen an den Aufwuchsalgen der obersten Donau und ihrer Quellflusse II Dieraumliche und zeitliche Verteilung der Algen. Arch. Hydrobiol. Suppl. 34(4), 251-320.

Bance H. M. (1946) A comparative account of the structure of Potamogeton filiformis Pers. and P. pectinatus L. in relation to the identity of a supposed hybrid of these species. Trans. Bot. Soc. Edin. 34(3), 361-368.

Becking, R. W. (1957) The Zürich-Montpellier School of Phytosociology. Bot. Rev. 23(1), 411-488.

Bellis V. J. and McLarty D. A. (1967) Ecology of Cladophora glomerata (L.) Kütz. in Southern Ontario. J. Phycol. 3, 57-63.

Berrie A. D. (1972) Productivity of the River Thames at Reading. Symp. zool. Soc. Lond. 29, 69-86.

Bleasdale J. K. A. (1964) The flowering and growth of water cress (Nasturtium officinale R. Br.). J. hort. Sci. 39, 277-233.

Bliding C. (1963) A critical survey of European taxa in Ulvales. Part I: Capsosiphon, Percusaria, Blidingia, Enteromorpha. Opera Botanica Uppsala. 8(3), 160 pp.

Bliding C. (1968) A critical survey of European taxa in Ulvales, II. Ulva, Ulvaria, Monostroma, Kornmannia. Bot. Notiser 121(4), 535-629.

Bogg E. (1898) Two Thousand Miles of Wandering in the Border Country, Lakeland and Ribblesdale. Bogg, Leeds. 2 parts 1-364 and 1-236.

Bolas P. M. and Lund J. W. G. (1974) Some factors affecting the growth of Cladophora glomerata in the Kentish Stour. J. Soc. Wat. Treat. Exam. 23, 25-51.

Boyd C. E. (1967) Some aspects of aquatic plant ecology. Reservoir Fisheries Research Symp., April 5-7. Am. Fisheries Soc. (from Peltier and Welch, 1969).

Blum J. L. (1956) The ecology of river algae. Bot. Rev. 22, 291-341.

Blum J. L. (1972) North American Flora, Series II: Vaucheriaceae Part 8. New York Botanical Garden. 64 pp.

Bostrack J. M. and Millington W. F. (1962) On the determination of leaf form in an aquatic heterophyllous species of Ranunculus. Bull. Torrey bot. Club. 89, 1.

Bourrelly P. (1966) Les Algues d'Eau Douce I: Les Algues Vertes. N. Boubée & Co.,Paris. 511 pp.

Bourelly P. (1968) Les Algues d'Eau Douce II: Les Algues Jaunes et Brunes; Chyrsophycees, Pheophycees, Xanthophycees et Diatomees. N. Boubée & Co., Paris, 438 pp.

Bourelly P. (1970) Les Algues d'Eau Douce III: Les Algues Bleues et Rouges: Les Eugleniens, Peridiniens et Cryptomonadines. N. Boubée & Co., Paris. 512 pp.

Bowen H. J. M. (1968) The Flora of Berwickshire. Holywell Press, Oxford. 389 pp.

Braun-Blanquet J. (1921) Prinzipen einer Systematik der Pflanzengesellshaften auf floristischer Grundlage. St. Gall. Naturwiss. Gesell. Jb. 57, 305-351.

Braun-Blanquet J. (1932) Plant Sociology; the Study of Plant Communities (English translation). McGraw-Hill, New York.

Braun-Blanquet J. (1964) Pflanzensoziologie: Grundzuge der Vegetationskunde. Springer, Wien and Berlin (also editions in 1928 and 1951).

Braun-Blanquet J. and Tüxen R. (1943) Übersicht der höheren Vegetationseinheiten Mitteleuropas. Comm. S.I.G.M.A. 84, Montpellier. 11 pp.

British Standard Institution (1970) The International System of Units (SI). British Standard 3763, UDC 389.151, 12 pp.

Britton R. H. and Morgan N. C. (Unpublished) Open Waters. In: Ratcliffe D. A. (Ed.) A Nature Conservation Review. An Account of Sites of Importance to Nature Conservation in Great Britian.

Brock E. M. (1960) Mutualism between the midge Cricotopus and the alga Nostoc. Ecology 41, 474-483.

Brown W. H. (1913) The relation of the substratum to the growth of Elodea. Philippine J. Sci. 8, 1-20.

Burnett G. (1938) Companion to Tweed. Methuen, London. 293 pp.

Bursche E. M. (1971) A Handbook of Water Plants (Translated from Czech). Warne, London. 128 pp.

Butcher R. W. (1927) A preliminary account of the vegetation of the River Itchen. J. Ecol. 15, 55-65.

Butcher R. W. (1933) Studies on the ecology of rivers. I. on the distribution of macrophytic vegetation in the rivers of Britain. J. Ecol. 21, 58-91.

Butcher R. W. (1933a) Fisherman's Weed. The Salmon and Trout Magazine. Sherrat and Hughes, Manchester. 42 pp.

Butcher R. W. (1940) Diversity of the reaction to submergence in the batrachian Ranunculi. Proc. Linn. Soc. Lond. 152 (2), 180-189.

Butcher R. W. (1961) A New Illustrated British Flora. Leonard Hill, London. Vol. I, 1016 pp., Vol. II. 1080 pp.

Butcher R. W. Pentelow F. T. K. and Woodley J. W. A. (1931) A biological investigation of the River Lark. Fisheries Investigations Series 3 (3).

Butcher R. W., Longwell J. and Pentelow F. T. K. (1937) Survey of the River Tees, Part III. The Non-tidal Reaches - Chemical and Biological. H.M.S.O., London. Code No. 47-78-6. 189 pp.

Chancellor A. P. (1958) The Control of Aquatic Weeds and Algae. H.M.S.O., London. 20 pp.

Chudyba H. (1965) Cladophora glomerata and accompanying algae in the Skawa River. Acta Hydrobiol. 7 (1), 93-126.

Clapham A. R., Tutin T. G. and Warburg E. F. (1962) Flora of the British Isles, (2nd edit.). Camb. Univ. Press. 1269 pp.

Claus G. (1961) Monthly ecological studies on the flora of the Danube at Vienna in 1957-58. Verh. int. Verein. Theor. angew. Limnol. 14, 457-465.

Cook C. D. K. (1963) Studies in Ranunculus subgenus Batrachium (D.C.) A. Gray II. General morphological considerations on taxonomy of the subgenus. Watsonia 5, 294-303.

Cook C. D. K. (1966) A monographic study of Ranunculus subgenus Batrachium (D.C.) A. Gray. Mitt. Bot. München. 6, 47-237.

Cook C. D. K. (1967) The Ranunculus penicillatus group. Notes and keys of papers read at the local Flora Writers Conference, Bristol 1966. Proc. bot. Soc. Br. Isl. 6, 366-367.

Cook C. D. K. (1969) On the determination of leaf form in Ranunculus aquatilis. New Phytol. 68, 469-480.

Cook C. D. K. (1970) Hybridization in the evolution of Batrachium. Taxon 19, 161-166.

Cox E. R. and Bold H. C. (1966) Phycological Studies VII. Taxonomic Investigation of Stigeoclonium. Univ. of Texas Publ. No. 6618, 166 pp.

Crosby N. T. (1967) The determination of nitrite in water using Cleve's acid, 1,napthylamine-7,sulphonic acid. Proc. Soc. Wat. Treat. Exam. 16(1), 51-55.

Curphey W. S. (1896) Pollution of the River Tweed. Royal Commission on Tweed Fisheries. Appendix IV.

Dandy J. E. and Taylor G. (1946) An account of x Potamogeton suecicus Richt. in Yorkshire and the Tweed. Trans. Bot. Soc. Edin. 34(3), 348-360.

Dansereau P. (1957) Biogeography, an Ecological Perspective. The Ronald Press Co., New York. 394 pp.

Dawson F. H. (1973) Notes on the production of stream bryophytes in the High Pyrenees (France). Annales Limnol. 9, 231-240.

Degelius G. (1954) The lichen genus Collema in Europe. Symb. bot. upsaliens. 13, 1-499.

Denny P. (1966) A Study of some Factors Affecting the Distribution of Aquatic Macrophytes. Ph.D Thesis, St. Andrews University.

Department of Health for Scotland (1931) First Report of the Scottish Advisory Committee on Rivers Pollution Prevention.
I. Summary of the Law Relating to Rivers Pollution Prevention.
II. The River Tweed and its Tributaries. H.M.S.O., 49-218-1.

Department of Health for Scotland (1950) Prevention of Pollution of Rivers and Other Waters. Report of the Rivers Pollution Prevention Sub-committee of the Scottish Advisory Committee. H.M.SO. C.M.D. Paper 8111.

Desikachary T. V. (1959) Cyanophyta: I.C.A.R. Monograph on Algae. New Delhi. 686 pp.

Dixon H. N. (1942) Student's Handbook of British Mosses (3rd edit.). Sumfield, Eastbourne. 582. pp.

Douglas D. (1880) Notes on the water-thyme (Anacharis alsinastrum, Bab.). Science Gossip (Hardwicke's) 16, 227-229.

Drouet F. (1943) Myxophyceae of eastern California and western Nevada. Field Mus. Bot. Ser. 20, 156.

Duncan U. K. (1959) A Guide to the Study of Lichens. T. Buncle and Co., Aberdeen. 164 pp.

Edwards R. W. and Owens M. (1960) The effects of plants on river conditions: I Summer crops and estimates of net productivity of macrophytes in a chalk stream. J. Ecol. 48, 151-160.

Edwards R. W. and Owens M. (1962) The effects of plants on river conditions: IV The oxygen balance of a chalk stream. J. Ecol. 50, 207-220.

Eyre-Todd G. (N.D.) Byways of the Scottish Border. James Lewis, Selkirk. 226 pp.

Fitzgerald G. P. (1970) Aerobic lake muds for the removal of phosphorous from lake waters. Limnol. Oceanogr. 15, 550-555.

Fjerdinstad E. (1964) Pollution of streams estimated by benthal phytomicro-organisms. I. A system based on communities of organisms and ecological factors. Int. rev. ges. Hydrobiol. 49(1), 63-131.

Fjerdinstad E. (1965) Taxonomy and saprobic valency of benthic phytomicro-organisms. Int. rev. ges. Hydrobiol. 50, 475-604.

Flint L. H. (1970) Freshwater Red Algae of North America. Vantage Press, New York. 110 pp.

Fogg, G. E. (1973) Phosphorus in primary aquatic plants. Wat. Res. 7, 77-91.

Fogg, G. E. (1974) Nitrogen Fixation. In: Stewart W. D. P. (Ed.) Algal Physiology and Biochemistry. Blackwell Sci. Publications, Oxford. 989 pp., pp. 560-582.

Forsberg C. (1960) Subaquatic macrovegetation in Ösbysjön, Djursholm. Oikos 11, 182-199.

Frémy P. (1930) Les myxophycées de l'Afrique équatoriale française. Arch. Bot. Mém., Caen 3(2), 507 pp.

Fritsch F. E. (1929) The encrusting algal communities of certain fast-flowing streams. New Phytol. 28(3) 165-196.

Fryer A., Bennett A. and Morgan R. (1915) The Potamogetons (Pond-weeds) of the British Isles. Reeve and Co., London. 94 pp + 60 plates.

Gessner F. (1950) The ecological importance of current speed in flowing waters and its measurement in a very small space. Arch. Hydrobiol. 43, 159-65.

Gessner F. (1955, 1959) Hydrobotanik: Die Physiologischen Grundlagen der Pflanzenverbreitung im Wasser. I. Energiehaushalt. II. Stoffhaushalt. V.E.B. Deutscher Verlag der Wissenschaften, Berlin. I, 517 pp., II, 701 pp.

Geitler L. (1932) Cyanophyceae: Rabenhorst's Kryptogamen-Flora, 14. Leipzig. 1196 pp.

Glime J. M. (1968) Ecological observations on some bryophyte in Appalachian Mountain streams. Castanea 33, 300-325.

Glime J. M. (1970) Zonation of bryophytes in the headwaters of a New Hampshire Stream. Rhodora 72 (790), 276-279.

Gojdics M. (1953) The Genus Euglena. University of Wisconsin, Madison. 268 pp.

Golübic S. and Kann E. (1966) Zür Klarung der taxonomischen Beziehungen zwischen Tolypothrix distorta Kützing und T. penicillata Thuret (Cyanophyta). Schweiz. Z. Hydrol. 29(1), 145-160.

Government White Paper (1966) The Scottish Economy 1965 to 1970. A plan for expansion. Cmnd 2864. Edin.

Groome F. H. (1887) A Short Border History. Rutherford, Kelso. 224 pp.

Guppy H. B. (1893) The River Thames as an agent in plant dispersal. J. Linn. Soc. (Bot.) 29, 333-346.

Greig D. C. (1971) British Regional Geology: the South of Scotland (3rd edit.). H.M.S.O., Edin. 125 pp.

Gunn W. and Clough C. T. (1895) The Geology of part of Northumberland, including the Country between Wooler and Coldstream. Memoirs of the Geological Survey, London. 97 pp.

Hagström J. O. (1916) Critical researches on the Potamogetons. K. Svenska Vetensk Akad. Lejnab 55(5), 1-281.

Hamel B. (1931-39) Pheophycées de France. Paris. 179 pp.

Hammond E. W. (1959) A rapid method for the determination of nitrate in drinking water using 3,3 dimethylnapthidine. Proc. Soc. wat. Treat. Exam. 8, 173-175.

Hannan H. H. and Dorris T. C. (1970) Succession of a macrophyte community in a constant temperature river. Limnol. Oceanogr. 15, 442-453.

Hanson H. M. (1934) A comparison of methods of botanical analysis of the natural prairie in Western North Dakota. J. Agric. Res. 49, 815-42.

Hartog C. Den. (1956) Deux stations d'Hildenbrandia rivularis en Bretagne. Rev. Algol. N. S. 2, 194-195.

Hartog C. Den (1959) The Batrachospermeto-Chaetophoretum. Acta Bot. Neerl. 8, 247-256.

Hartog C. Den and Segal S. (1964) A new classification of the water-plant communities. Acta Bot. Neerl. 13, 367-393.

Haslam S. M. (1971) Physical factors and some river weeds. Proc. Eur. Weed Res. Counc., 3rd int. Symp. 29-39.

Haslam S. M. (1973) The distribution of chalk stream macrophytes. Unpublished, Seminar, Reading.

Hawkes H. A. (1975) River zonation and classification. In: Whitton B. A. (Ed.) River Ecology, Blackwell Sci. Publications, Oxford. pp. 312-374.

Heslop-Harrison J. W. (1942-44) Notes and records (Ed.) Vasculum. 27-29.

Heslop-Harrison J. W. and Clarke W. A. (1942) More notes on local pond-weeds. Vasculum. 27(4), 29.

Hillebrand D. (1950) "Verkrautung und Abfluss" (Translated by Dept. of Sci. Ind. Res. "Weed growth and flow") Dtsch Gewasskund. Jb. Bes. Mitt. 2, 1-30.

History of the Berwickshire Naturalists' Club. Alnwick, Northumberland. 1831.

Hoek C. van den (1963) Revision of the European species of Cladophora. J. E. Brill, Leiden. 248 pp. + 55 plates.

Holmes N. T. H., Lloyd E. J.H., Potts M. and Whitton B.A. (1972) Plants of the River Tyne and future Water Transfer Scheme. Vasculum 57(3), 56-78.

Home D. L. (1874) Letter in: Evidence given on Enquiry into the Operation of the Tweed Fisheries Acts before Walpole and Young. Neill and Co., Edin. 430 pp.

Hustedt F. (1930) Die Süsswasser-flora Mitteleuropas 10 Bacillariophyta (Diatomaceae). G. Fischer, Jena. 466 pp.

Hutchinson G. E. (1957) A Treatise on Limnology, Vol. I. Geography Physics and Chemistry. J. Wiley, New York. 1015 pp.

Hynes H. B. N. (1960) The Biology of Polluted Waters. Liverpool Univ. Press. Liverpool. 202 pp.

Hynes H. B. N. (1970) The Ecology of Running Waters. Liverpool Univ. Press, Liverpool. 555 pp + 93 Figs.

Israelsson G. (1942) The freshwater Florideae of Sweden. Symb. bot. upsaliens 6(1), 134 pp.

Iverson J. (1929) Studien über die pH-Verhältnisse danischer Gewässer and ihren Einfluss auf die Hydrophyten Vegetation. Bot. Tidsskr. 40, 277-333.

Iverson J. (1936) Biologische Pflanzentypen als Hilfsmittel in der Vegetations Forschung. Thesis, Copenhagen, 224 pp.

Iverson J. and Ohlsen S. (1943) Die Verbreitung der Wasserpflanzen in Relation zur Chemie des Wassers. Bot. Tidsskr. 46, 136-145.

Jaag O. (1938) Kryptogamenflora des Rheinfalls und des Hochrheins von Stein bis Eglisau. Mitt. Naturf. Ges. Schaffhausen 14, 1-158.

Jaag O. (1945) Untersuchungen über die Vegetation und Biologie der Algen des nackten Gesteins in den Alpen, im Jura und im Schweizerischen Mittelland. Beiträge zur Kryptogamen flora der Schweiz. 9, Bern. 560 pp.

James P. W. (1965) A new check-list of British lichens. Lichenologist 3, 95-154.

Javurková-Kratochvilorá V. and Tomšovic P. (1972) Chromosome study of the genus Rorippa Scop. em Reichenb. in Czechoslovakia. Preslia 44, 140-156.

Jeffrey A. (1836) Historical and Descriptive account of Roxburghshire. Fraser and Co., Edin. 424 pp.

Jermy A. C. and Tutin T. G. (1968) British Sedges. B.S.B.I. Publication London. 199 pp.

Johannsen O. A. (1937) Aquatic Diptera, II. Chironomidae: subfamilies Tanypodinae, Diamesinae, and Orthocladiinae. Mem. Cornell Univ. Agric. Sta. 205, 1-84.

Johnston G. (1892) The Flora of Berwick I. J. Carfrae and Son, Edin. 242 pp.

Johnston G. (1853) The Botany of the Eastern Borders. London. 336 pp.

Jones H. (1955) Notes on the identification of some British species of Callitriche. Watsonia 3, 186-192.

Jones J. G. (1973) Use of Nonparametric tests for the analysis of data obtained from preliminary surveys: a review. J. appl. Bact. 36, 197-210.

Jones W. E. (1967) Benthos as Related to Water Temperature, Firehole River, Wyoming. M. S. Thesis, Colorado State Univ. 193 pp.

Kann E. (1972) Zur Systematik und Ökologie der Gattung Chamaesiphon (Cyanophyceae) 1, Systematik. Arch. Hydrobiol. Suppl. 41(7), 117-171.

Kann E. and Komárek J. (1970) Systematisch-olologische Bemerkungen zu den Arten des Formenkreises Phormidium autumnale. Schweiz. Z. Hydrol. 32(2), 495-518.

Kohler A. (1971) Zur Ökologie submerser Gefass-Makrophyten in Fliesswässern. Ber. dtsch. bot. Ges. 84(11), 713-720.

Kohler A. (1973) Wasserflanzen und Gewässerverschmutzung. Der Biologieunterricht 9(2), 4-14.

Kohler A. Vollrath H. and Beisl E. (1971) Zur Verbreitung, Vergesellschaftung und Ökologie der Gefass-Makrophyten im Fliesswässersystem Moosach (Münchener Ebene). Arch. Hydrobiol. 69(3), 333-365.

Kohler A. Wonneberger R. and Zeitner G. (1973) Chemical data and aquatic vascular plants as indicators for pollution in the Moosach river system near Munich. Arch. Hydrobiol. 72(4), 533-549.

Krause W. (1971) Die makrophytische Wasservegetation der südlichen Oberrheinebene: die Aschenregion. Arch. Hydrobiol. Suppl. 37, 387-465.

Kylin H. (1956) Die Gattungen der Rhodophyceen. Gleerup, Lund. 673 pp.

Ladle M. and Casey H. (1971) Growth and nutrient relationships of Ranunculus penicillatus var. calcareus in a small chalk stream. Proc. Eur. Weed. Res. Counc., 3 rd Symp. 53-64.

Lang A. and Lang J. (1923) Highways and Byways in the Border. MacMillan and Co. 439 pp.

Langlet O. (1927) Beiträge zur Zytologie der Ranunculazeen. Bot. Tidsskr. 21, 1-17.

Lauder T. D. (1890) Scottish Rivers. Morrison, Glasgow. 357 pp. (Tweed=pp. 44-273).

Lauterborn R. (1910) Die Vegetation des Oberrheins. Verh. naturh. med. Ver. Heidelb. 10, 450-502.

Lee G. F. (1973) Role of phosphorous in eutrophication and diffuse source control. Wat. Res. 7, 111-128.

Leedale G. F. (1967) Euglenoid Flagellates. Prentice-Hall, London. 240 pp.

Liepolt R. (1967) Limnologie der Donau. Eine Monographische Darstellung. Stuttgart. I, 119 pp. II, 326, II, 146 pp.

Lingelsheim A. and Schröder B. (1918) Hildenbrandia rivularis (Liebman) Bréb. und Pseudochantransia chalybaea (Lyngb.) Braud aus dem Gouvernment Suwalki. Ber. dtsch. bot. Ges. 36, 271-276.

Lohammar G. (1938) Wässerchemie and höhere Vegetation schwedischer Seen. Symb. bot. upsaliens 3.

MacVicar S. D. (1926) The Students handbook of British Hepatics, 2nd edit. (1960). Sumfield, Eastbourne. 582 pp. + 62 plates.

Mann K. H. Britton R. H., Kowalczewski A., Lack T. J., Mathews C. P. and McDonald I. (1972) Productivity and energy flow at all trophic levels in the River Thames, England. In: Kajak Z. and Hillbricht-Ilkowska A. (Eds) Proc. of the IBP-UNESCO Symp. on Productivity Problems of Fresh-waters, 918 pp., pp. 579-596. Pol. Sci. Publ., Warszwawa-Krakow.

Marshall W. (1852) The New Water-Weed: Anacharis alsinastrum. Cambridge Independent Press (available at F.B.A., Windermere).

Marshall W. (1852a) The American water-weed Anacharis alsinastrum. Phytol. 2(2), 194-97.

Maxwell H. (1905) The Story of the Tweed. James Nisbett & Co. 270 pp.

McMichael A. D. (N.D.) Notes by the Way, Chiefly in the Counties of Roxburgh, Selkirk, Peebles, Berwick and Haddington.

Minnikin R. C. (1920) Practical River and Canal Engineering. London.

Misra R. D. (1938) Edaphic factors in the distribution of aquatic plants in English Lakes. J. Ecol. 26, 411-451.

Misra R. D. (1944) Variation of leaf-form in Potamogeton perfoliatus. J. Ind. bot. Soc. 13(2), 44-52.

Moore J. J. (1962) The Braun-Blanquet system - a reassessment. J. Ecol. 50, 761-769.

Mulligan H. F. and Baranowski A. (1969) Growth of phytoplankton and vascular aquatic plants at different nutrient levels. Verh. int. Verein. theor. angew Limnol. 17, 802-810.

Normann H. D. (1967) Versuche zur Aufnahme von Phosphat durch Ranunculus fluitans Lam. Arch. Hydrobiol 33, 243-254.

Nicoll E. H. (1972) Rivers Pollution Survey in Scotland in Retrospect and Prospect. Scottish Development Department Publication (available at T.R.P.B. offices, Galashiels).

Nyholm E. and Arnell S. (1954) Illustrated Moss Flora of Fennoscandia; ed. by the Botanical Society of Lund. Gleerup, Lund. I. Hepaticea, II Musci.

Oberdorfer E. (1928) Lichtverhaltnisse und Algenbesiedlung im Bodensee. Z. Bot. 20, 465 (from Gessner, 1955).

Odum H. T. (1957) Primary production measurements in eleven Florida springs and a marine turtle grass community. Limnol. Oceanogr. 2, 85-97.

Ordnance Survey (1948) Geology Survey maps: Quarter inch to one mile (1:253440) maps of Scotland.

Owens M. and Edwards R. W. (1961) The effects of plants on river conditions - II. Further crop studies and estimates of net productivity of macrophytes in a chalk stream. J. Ecol. 49, 119-126.

Pal B. P., Kundu B. C., Sundaralingam V. S. and Venkataraman G. S., (1962) Charophyta. I.C.A.R. Monograph on Algae. New Delhi. 130 pp.

Pank P. (1957) Studien über Hildenbrandia rivularis (Liebm.) J. Ag. Ann. Univ. Sci. Budapest (Biol.) 1, 205-218.

Pascher A. (1925) Die Susswasser-flora Mitteleuropas 11 Heterokontae, Phaeophyta, Rhodophyta, Charophyta. G. Fischer, Jena. 250 pp.

Paton J. A. (1965) Census Catalogue of British Hepatics (4th edit.) Published by British Bryological Society. 50 pp.

Pearsall W. H. (1918) On the classification of aquatic plant communities. J. Ecol. 6, 75-84.

Pearsall W. H. (1920) The aquatic vegetation of the English lakes. J. Ecol. 8(3), 163-201.

Pearsall W. H. (1921) The development of vegetation in the English Lakes, considered in relation to general evolution of glacial lakes and rock basins. Proc. roy. Soc. B. 92, 259-284.

Pearsall W. H. (1921a) A suggestion as to factors influencing the distribution of free floating vegetation. J. Ecol. 9, 241-253.

Peltier W. H. and Welch E. B. (1969) Factors affecting growth of rooted aquatics in a river. Weed Sci. 17, 412-416.

Perring F. H. and Walters S. M. (1962) (Eds) Atlas of the British Flora. Nelson, London. 432 pp.

Pitcairn C. E. R. and Hawkes H. A. (1973) The role of phosphorus in the growth of Cladophora. Wat. Res. 7, 159-171.

Prescott G. W. (1961) Algae of the Western Great Lakes Area. Brown, Iowa. 977 pp.

Prescott G. W. (1969) The Algae: A Review. Nelson, London. 436 pp.

Pringle J. (1935) British Regional Geology: the South of Scotland. H.M.S.O., Edin. 97 pp.

Printz H. (1964) Die Chaetophoralen der Binnengewasser - Eine systematische ubersicht. Verlag Dr. W. Junk - Den Haag. Hydrobiologia 14 (1-3), 456 pp.

Procter V. W., Griffin D. G. and Hotchkiss A. T. (1971) A synopsis of the genus Chara. Am. J. Bot. 58, 894-901.

Proctor H. G. (1971) Aquatic macrophytes in the Wheel of the Tees. Vasculum 56(3), 59-66.

Raunkiaer C. (1934) The Life Forms of Plants and Statistical Plant Geography. Oxford. 532 pp.

Ridley H. N. (1930) The Dispersal of Plants Throughout the World. Reeve, Ashford, England. (from Sculthorpe, 1967)

Rietz E. G. D. (1921) Zur methodologischen Grundlage der modernen Pflanzensoziologie. Thesis, Uppsala. 272 pp.

Rich F. (1925) The algae of Leicestershire. J. Bot. 63, 229-238 and 322-330.

Richards P. W. M. (1928) Ecological notes on the bryophytes of Middlesex. J. Ecol. 16, 269-300.

Rivers Pollution Commission (1868) Fourth Report of the Commissioners Appointed in 1868 to Enquire in to the Best Means of Preventing the Pollution of Rivers. Pollutions of Rivers in Scotland Vol. 1. Report and Plans. H.M.S.O. 1872 (c 603).

Roberts M. L. (1972) Butomus umbellatus in the Mississippi watershed. Castenea 37, 83-85.

Roll H. (1938) Pflanzengesellschaften östholsteinischer Fliessgewässer. Arch. Hydrobiol. 34, 160-229.

Royal Commission on Sewage Disposal (1912) H.M.S.O. 1, Report 8, Cmnd. 6464.

Royal Commission on Tweed and Solway Fisheries (1896) Report of the Commissioners on Tweed Fisheries. I. Report, Map and Appendix. H.M.S.O. C.8086, 48 pp. II : List of Witnesses, Minutes of Evidence, and Index. H.M.S.O. C-8087, 126 pp.

Ruess K. (1954) Die Makrophyten-Vegetation des fliessenden Wassers im Gebiet umseeon (Chiemgau). Dissertation, münchen.

Russell, J. (1885) Reminiscences of Yarrow. Blackwood and Sons, Edin. 384 pp.

Ruttner F. (1963) Fundamentals of Limnology (3rd edit.) Univ. Toronto Press, Toronto, Canada. 295 pp.

Sauer F. (1937) Die Makrophyten-Vegetation östholsteinischer Seen und Teiche. Arch. Hydrobiol. Suppl. 6, 431-592.

Scottish Advisory Committee (1931) Reports on Rivers Pollution Prevention. H.M.SO., 50 Code No. 49-281-1.

Scottish Development Department (1968) The Central Borders - A Plan for Expansion: Consultants in the University of Edinburgh. H.M.S.O., Edin. (2 vols), I, 115 pp., II, 87 pp.

Scottish Development Department (1972) Towards Cleaner Water, Report of a Rivers Pollution Survey of Scotland. H.M.S.O.

Scottish Water Advisory Committee (1950) Prevention of Pollution of Rivers and Other Waters. Report of the Rivers Pollution Prevention Sub-Committee of the Scottish Water Advisory Committee. H.M.S.O., Cmnd. 8111.

Sculthorpe C. D. (1967) The Biology of Aquatic Plants. Arnold, London, and St Martin Press, New York. 610 pp.

Seddon B. (1972) Aquatic macrophytes as limnological indicators. Freshwat. Biol. 2, 107-130.

Shimwell D. W. (1971) The Description and Classification of Vegetation. Sidgwick and Jackson, London. 322 pp.

Siddall J. D. (1885) The American water weed, Anacharis alsinastrum Bab: its structure and habit; with some notes on its introduction into Great Britain, and the causes affecting its rapid spread at first, and apparent present diminution. Proc. Chester Soc. nat. Sci. 3, 125-133.

Siedlecka-Binder Z. (1967) La végétation des macrophytes dans les torrents du Parc National d'Ojcow. (Polish). Publicationes Instituti Botanica 28(6), 171-206.

Siegal S. (1956) Non Parametric Statistics for the Behavioral Sciences. McGraw-Hill, New York. 312 pp.

Sirjola E. (1969) Aquatic vegetation of the River Teuronjoki, South Finland and its relation to water velocity. Ann. Bot. Fenn. 6, 68-75.

Skuja H. (1926) Zur Verbreitung und Ökologie von Hildenbrandia rivularis (Liebm.) Bréb in Lettland. Acta Univ. Latv. 14, 659-672.

Skuja H. (1938) Comments on fresh-water Rhodophyceae. Bot. Rev. 4, 665-676.

Smith A. L. (1911,1918) British lichens. British Museum, London. Vol. I, 519 pp + 70 plates. Vol. II, 409 pp + 59 plates.

Snow M. and Whitton B. A. (1971) The River Wear: inorganic chemistry relevant to a biologist. Vasculum 56(3), 50-58.

Spearman R. L. (1955) Statistical concepts in microbiology. Bact. Rev. 19, 160-

Spence D. H. N. (1964) The macrophytic vegetation of freshwater lochs, swamps and associated fens. In: Burnett J. E. (Ed.)- The Vegetation of Scotland. Oliver and Boyd, Edin. pp. 306-425.

Spence D. H. N. (1967) Factors controlling the distribution of freshwater macrophytes with particular reference to lochs of Scotland. J. Ecol. 55, 147-170.

Spence D. H. N. (1972) Light on Freshwater Macrophytes. Trans. bot. Soc. Edin. 41, 491-505.

Spence D. H. N. and Chrystal J. (1970) Photosynthesis and zonation of freshwater macrophytes - I. Depth distribution and shade tolerance. New Phytol. 69, 205-215.

Spence D. H. N. and Chrystal J. (1970a) Photosynthesis and zonation of freshwater macrophytes - II. Adaptability of species of deep and shallow water. New Phytol. 69, 219-227.

Spence D. H. N., Campbell R. M. and Chrystal J. (1973) Specific leaf areas and zonation of freshwater macrophytes. J. Ecol. 61, 317-328.

Stake E. (1967) Higher vegetation and nitrogen in a rivulet in Central Sweden. Schweiz. Z. Hydrol. 29, 107-124.

Stake E. (1968) Higher vegetation and phosphorous in a small stream in Central Sweden. Schweiz. Z. Hydrol. 30, 353-373.

Starmach K. (1966) Flora Slodkowodna Polski - 2: Cyanophyta. Polska Akademia Nauk, Warszawa, 807 pp.

Steven W. (1916) Yarrow. A. Walker and Son, Galashiels. 131 pp.

Stoddart T. (1866) In: Reports on the National History and habits of Salmonoids in the Tweed and its tributaries. Blackwood and Sons, Edin. and London. 129 pp, pp 61-63.

Surface Year Water Book of Great Britain. Published by Water Resources Board, H.M.S.O., London.

Swincow T. D. V. (1968) Pyrenocarpous lichens: 13 Freshwater species of Verrucaria in the British Isles. Lichenologist 4, 34-54.

Szemes G. (1967) Systematische Verzeichnis der Pflanzenwelt der Donau mit einer Susammenfassenden Erläuterung. (in Liepolt, 1967 3, 70-131: see ref.).

Tansley A. G. (1911) (Ed.) Types of British Vegetation. Members of the Central Committee for the Survey and study of British Vegetation, Cambridge.

Tansley A. C. (1939) The British Islands and their Vegetation. Cambridge University Press, London. 930 pp.

Tansley A. G. and Chip T. F. (1926) Aims and Methods in the Study of Vegetation. British Empire Vegetation Comm., London. 383 pp.

Thienemann A. (1912) Der Bergbach des Sauerlandes. Int. Rev. Hydrobiol. Suppl. 4/5 (from Gessner, 1955).

Thompson A. (N.D.) Lauder and Lauderdale. Craighead Bros., Galashiels. 380 pp.

Thompson R. D. (1807) Plants of Berwick-upon-Tweed.

Todd D. J. (1971) New algal species record for Colorado. J. Phycol. 7(3), 266-267.

Turula K. (1970) Cyto-taxonomical studies in Ranunculus fluitans Lam. and R. penicillatus (Dumort.) Bab. from Lower Silesia (Poland): Preliminary report. Acta. Biol. Crac. Ser. Bot. 14(2), 153-157.

Turala K. and Wølek J. (1971) A natural tetraploid hybrid of Ranunculus subgenus Batrachium from the Nowy Targ Basin (Poland). Acta Biol. Crac. Ser. Bot. 14(2), 153-157.

Tupa D. D. (1974) An Investigation of Certain Chaetophoralean Algae. Nova Hedwigia, J. Cramer, Lehre, Heft 10. 155 pp + 291 Figs.

Tüxen R. (1937) Die Pflanzengesellschaften Nordwestdeutschlands. Mitt. Flor. soz. Arbeitsgem. 3, 155-176.

Tuxen R. (1955) Das system der Nordwestdentschen Pflanzengesellschaften. Mitt. Flor. soz. Arbeitsgem. 5, 1-170.

Tweed Fisheries Commissions (1866) Tweed Salmon Reports: Reports on the Natural History and Habits of Salmonoids in the Tweed and its tributaries. Blackwood and Sons, Edin. and London. 129 pp.

Tweed River Purification Board (1954-1973) Annual Reports 1-20. Scottish and Universal Newspapers Ltd.

Venkataraman G. S. (1961) Vaucheriaceae: I.C.A.R. Monograph on Algae. New Delhi. 112 pp.

Walker A. O. (1912) The distribution of Elodea canadensis. Mich. in the British Isles in 1907. Proc. Linn. Soc. Lond. 124, 71-77.

Walpole S. and Young A. - Commissioners Appointed by the Home Secretary (1874): Evidence given on Inquiry into the Operation of the Tweed Fisheries Acts. Neill and Co., Edin. 430 pp.

Walpole S. and Young A. (1875) Report by the Special Commissioners appointed to inquire into the operation of the Tweed Fisheries Acts, to the Rt Hon. Assheton Cross. H.M.S.O. C-1117 25 pp.

Warburg E. F. (1963) Census Catalogue of British Mosses. (3rd edit.) published by British Bryological Society. 88 pp.

Watson D. (1873) Trade and Manufactories of Hawick. Hist. Berw. Nat. Club. 7, 81.

Watson E. V. (1968) British Mosses and Liverworts. Camb. Univ. Press, Camb. 495 pp.

Watson W. (1919) The bryophytes and lichens of freshwater. J. Ecol. 7, 71-83.

Weber D. W. (1967) Zur Vegetation einiger Fliessgewässer der Oberpflaz und des bayerischen Waldes. Mitteil. Floristisch-Soziologischen Arbeitsgemeinschaft 11/12, 25-27.

Weber-Oldecop D. W. (1970) Water plant communities in Eastern Lower Saxony (I). Int. Rev. ges.Hydrobiol. 55(6), 913-967.

Weber-Oldecop D. W. (1971) Water plant communities in Eastern Lower Saxony (II). Int. Rev. ges.Hydrobiol 56(1), 79-122.

Weber-Oldecop D. W. (1974) Makrophytische Kryptogamen inder oberen Salmoniden region des Harzbäche. Arch. Hydrobiol. 74(1), 82-86.

West G. (1910) A further contribution to a comparative study of the dominant Phanerogamic and higher cryptogamic flora of aquatic habit in Scottish Lakes. Proc. roy. Soc. Edin. 30, 65-181.

West G. S. and Fritsch F. E. (1927) A Treatise on the British Freshwater Algae. Camb. Univ. Press, London. 534 pp.

Westlake D. F. (1960) Water-weed and water management. Instn publ. Hlth Engrs J. 59, 148-160.

Westlake D. F. (1961) Aquatic macrophytes and the oxygen balance of running water. Verh. int. verein. theor. angew. Limnol. 12,415-425.

Westlake D. F. (1964) Light extinction, standing crop and photosynthesis within weed beds. Verh. int. Verein. theor. angew. Limnol. 15, 415-425.

Westlake D. F. (1965) Some basic data for the investigation of the productivity of aquatic macrophytes. Mem. Ist. Ital. Idrobiol. 18 Suppl., 229-248.

Westlake D. F. (1965a) Some problems in the measurement of radiation under water: A review. Photochem, Photobiol. 4, 849-868.

Westlake D. F. (1966) The light climate for plants in rivers. In: Bainbridge R. Evans G.C. and Rackman O. (Eds) Light as an Ecological Factor - II. Brit. Ecol. Soc. Symp. No.6. Blackwell Sci. Publications, Oxford. 452 pp., pp. 99-119.

Westlake D. F. (1968) The biology of aquatic weeds in relation to their management. Proc. 9th Brit. Weed Control Conf., 372-379.

Westlake D. F. (1968a) The weight of water-weed in the River Frome. River Bds Ass. Yb. 59-68.

Westlake D. F. (1973) Aquatic macrophytes in rivers: A review. Pol. Arch. Hydrobiol 20(1), 31-40.

Westlake D. F. (1975) Macrophytes. In: Whitton B. A. (Ed.) River Ecology. Blackwell Sci. Publications, Oxford. pp. 106-128.

Westlake D. F. Casey H., Dawson H., Ladle M., Mann R.H.K. and Marker A.F.H. (1971) The chalk-stream ecosystem. Proc. IBP-UNESCO Symp. Productivity Problems in Freshwaters, Kazimierz Dolny, 615-635.

Westlake D. F. and Dawson F. H. (1975) The construction and long term field use of inexpensive integrating sub-aerial and aquatic photometers. In: Bainbridge R., Evans G.C. and Rackham O. (Eds) Light as an Ecological Factor - II. Brit. Ecol. Soc. Symp. No. 15 Blackwell. Sci. Publications, Oxford. 452 pp.

Wheaton S. W. and Curphey W. S. (1906) Report on the Pollution of the River Tweed. (A Report on behalf of the Local Govt Board and the Secretary for Scotland). Darling and Son, London. 86 pp.

Whitton B. A. (1970) Biology of Cladophora in freshwaters - a review. Wat. Res. 4, 457-476.

Whitton B. A. (1971) Filamentous algae as weeds. Proc. Eur. Weed Res. Counc., 3rd int. Symp., 249-263.

Whitton B. A. (1972) Environmental limits of plants in flowing waters. Symp. zool. Soc. Lond. 29, 3-19.

Whitton B. A. (1974) Changes in the British Freshwater Algae. In: Hawksworth D. L. (Ed.), The Changing Flora and Fauna of Britain. Academic Press, London and New York. pp. 115-141.

Whitton B. A. and Dalpra M. (1968) Floristic changes in the River Tees. Hydrobiologia 32, 545-550.

Whitton B. A. and Buckmaster R. C. (1970) Macrophytes of the River Wear. Naturalist, Hull 914, 97-116.

Wilson T. (1924) The Stow of Wedale (Gala Water). Aberdeen Newspapers Ltd. 222 pp.

Wółek (1971) Rezmieszcsenie roślin wodnejch w dolinie Dunajca na przedpolu Pienińskiego Parku Narodowego - Distribution of the aquatic plants in the Dunajec River Valley in the foreland of the Pieniny National Park. Fragm. Florist. Geobot. 17(2), 237-250.

Wood R. D. and Imahori K. (1964, 1965) A Revision of the Characeae. I. Monograph of the Characeae. 904 pp. II Iconograph of the Characeae. 394 Icones. Weinheim.

Zimmermann W. (1927) Über Algenbestände aus der Tiefenzone des Bodensees. Zur Ökologie und Soziologie der Tiefseepflanzen. Z. Bot. 20, 1. (from Gessner, 1955).