Methods for the Use of Aquatic Macrophytes for Assessing Water Quality 1985–86

Methods for the Examination of Waters and Associated Materials

Her Majesty's Stationery Office

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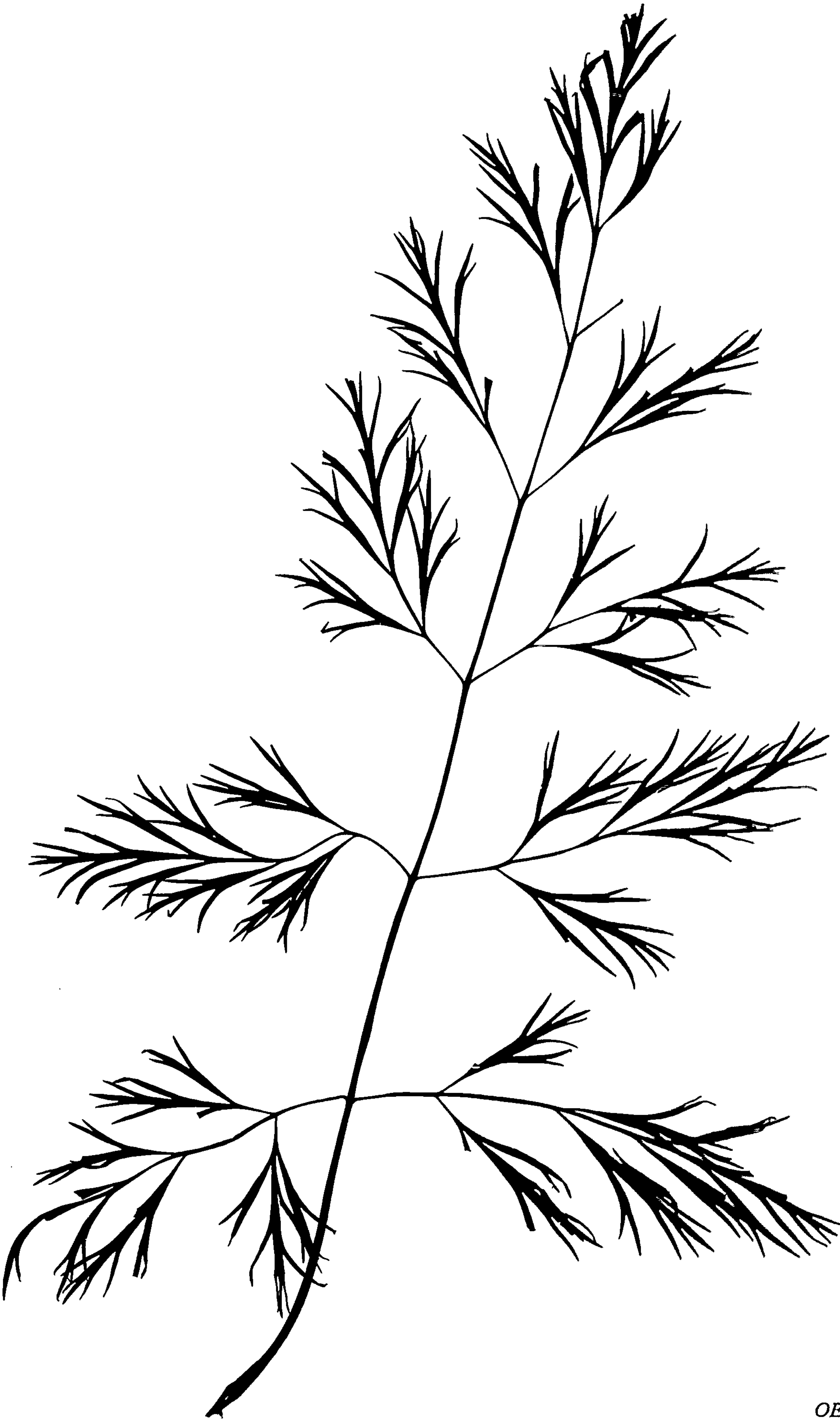

OENANTHE FLUVIATILIS
'River Water-dropwort'

Methods for the Use of Aquatic Macrophytes for Assessing Water Quality 1985–86

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This booklet contains 3 methods for using macrophytes to assess water quality. Two (A and B) are for use with streams and rivers, the third (C) is for lakes and large ponds. Though similar, methods A and B vary in their approach. Users should read both and decide which is the most appropriate to their problem and circumstances. The booklet begins with a few general notes on water safety. It ends with notes on 3 methods for locating sampling station position when out on large open stretches of water. Finally, useful extracts from the Nature Conservancy Council publication "Typing British Rivers According to their Flora", by Nigel Holmes have been included, by permission of the NCC, as reference is made to this book for its assessment of river types and the effect of these types on aquatic flora, the book being now almost unobtainable.

Note that there may sometimes be legal constraints on the use of these methods in certain areas, but these can usually be complied with if permission is obtained in advance. See Warning to Users.

Disclaimer

This booklet mentions known manufacturers of certain highly specialized equipment. This in no way endorses their products; any comparable equipment that will give equivalent or better performance may be used instead.

Contents

About this series

This booklet is part of a series intended to provide both recommended methods for the determination of water quality, and in addition, short reviews of the more important analytical techniques of interest to the water and sewage industries.

In the past, the Department of the Environment and its predecessors, in collaboration with various learned societies, have issued volumes of methods for the analysis of water and sewage culminating in 'Analysis of Raw, Potable and Waste Waters'. These volumes inevitably took some years to prepare, so that they were often partially out of date before they appeared in print. The present series will be published as series of booklets on single or related topics; thus allowing for the replacement or addition of methods as quickly as possible without need of waiting for the next edition. The rate of publication will also be related to the urgency of requirement for that particular method, tentative methods and notes being issued when necessary.

The aim is to provide as complete and up to date a collection of methods and reviews as is practicable, which will, as far as possible, take into account the analytical facilities available in different parts of the Kingdom, and the quality criteria of interest to those responsible for the various aspects of the water cycle. Because both needs and equipment vary widely, where necessary, a selection of methods may be recommended for a single determinand. It will be the responsibility of the users—the senior technical staff to decide which of these methods to use for the determination in hand. Whilst the attention of the user is drawn to any special known hazards which may occur with the use of any particular method, responsibility for proper supervision and the provision of safe working conditions must remain with the user.

The preparation of this series and its continuous revision is the responsibility of the Standing Committee of Analysts (to review Standard Methods for Quality Control of the Water Cycle). The Standing Committee of Analysts is a committee of the Department of the Environment set up in 1972. Currently it has 7 Working Groups, each responsible for one section or aspect of water cycle quality analysis. They are as follows:

1.0 General principles of sampling and accuracy of results
3.0 Empirical and physical methods
4.0 Metals and metalloids
5.0 General nonmetallic substances
6.0 Organic impurities
7.0 Biological methods
9.0 Radiochemical methods

The actual methods and reviews are produced by smaller panels of experts in the appropriate field, under the overall supervision of the appropriate working group and the main committee.

The names of those associated with this method are listed inside the back cover. Publication of new or revised methods will be notified to the technical press, whilst a list of Methods in Print is given in the current HMSO Sectional Publication List No 5.

Whilst an effort is made to prevent errors from occurring in the published text, a few errors have been found in booklets in this series. Correction notes and minor additions to published booklets not warranting a new booklet in this series will be issued periodically as the need arises. Should an error affecting the operation of a method, the true sense not being obvious, or an error in the printed text be discovered prior to sale, a separate correction note will be issued for inclusion in that booklet.

L R PITTWELL
Secretary

1 July 1986

Warning to users

The analytical procedures given in this booklet should only be carried out by competent trained persons, with adequate supervision when necessary.

The provisions of the Wildlife and Countryside Act 1981, the Health and Safety at Work Act, the corresponding Scottish and Northern Ireland legislation, all National and Local Safety Regulations and all laws and regulations with regard to trespass and rights of access must be observed.

Care needs to be taken if plants are removed, not only to comply with the law and with local requirements; but also not to cause permanent denudation or erosion of the bed, or to disturb breeding fauna.

A few riverside plants are highly toxic such as Giant Hogweed and Hemlock Water Dropwort. It is wise to know what these few look like and treat them with care if met.

Field Operations should be conducted with due regard to possible local hazards, and portable safety equipment should be carried. See specific advice in the Hazards section.

Laboratory procedures should be carried out only in properly equipped laboratories.

Care should be taken against creating hazards for one's self, one's colleagues, those outside the laboratory or work place, or subsequently for maintenance or waste disposal workers. Where the Committee have considered that a special unusual hazard exists, attention has been drawn to this in the text so that additional care might be taken beyond that which should be exercised at all times when carrying out analytical procedures. Reagents of adequate purity must be used, along with properly maintained apparatus and equipment of correct specifications. Specifications for reagents, apparatus and equipment are given in manufacturer's catalogues and various published standards. If contamination is suspected, reagent purity should be checked before use. Lone working, whether in the laboratory or field, should be discouraged.

The Hazards section in this booklet contains much good advice and should be read. The best safeguard is a thorough consideration of hazards and the consequent safety precautions and remedies well in advance. Without intending to give a complete checklist, points that experience has shown are often forgotten include: laboratory tidiness, stray radiation leaks (including ultra violet), use of correct protective clothing and goggles, removal of toxic fumes and wastes, containment in the event of breakage, access to taps, escape routes, and the accessibility of the correct and properly maintained first-aid, fire-fighting, and rescue equipment. Hazardous reagents and solutions should always be stored in plain sight and below face level. Attention should also be given to potential vapour and fire risks. If in doubt, it is safer to assume that the hazard may exist and take reasonable precautions, rather than to assume that no hazard exists until proved otherwise.

There are numerous handbooks on first aid and laboratory safety. Among such publications are: 'Guide to Safe Practices in Chemical Laboratories' and 'Hazards in the Chemical Laboratory' issued by the Royal Society of Chemistry, London; 'Safety in Biological Laboratories' (Editors Hartree and Booth), Biochemical Society Special Publication No 5, The Biochemical Society, London, which includes biological hazards; and 'The Prevention of Laboratory Acquired Infection' Public Health Laboratory Service Monograph 6, HMSO, London.

Some very unusual parasites, viruses and other microorganisms are occasionally encountered in samples and when sampling in the field. In the latter case, all equipment including footwear should be disinfected by appropriate methods if contamination is suspected.

It cannot be too strongly emphasised that prompt first aid, decontamination, or administration of the correct antidote can save life; but that incorrect treatment can make matters worse. It is suggested that both supervisors and operators be familiar with emergency procedures before starting even a slightly hazardous operation, and that doctors consulted after any accident involving chemical contamination, ingestion, or inhalation, be made familiar with the chemical nature of the injury, as some chemical injuries require specialist treatment not normally encountered by most doctors. Similar warning should be given if a biological or radiochemical injury is suspected. If an ambulance is called or a hospital notified of an incoming patient, give information on the type of injury, especially if poisoning is suspected, as the patient may be taken directly to a specialized hospital.

Introduction

This booklet describes methods for surveying water quality in rivers and lakes by observing the larger aquatic plants. Rivers are passages of aquatic life traversing countries and regions, passages which connect in one direction only: downstream. Wider water bodies, lakes, are usually sited intermittently on rivers. Connections for plants between river systems are only by transport, usually birds, so species may be absent solely because incoming transport failed. However, if assemblages or patterns of species are absent, this can be ascribed to an unsatisfactory habitat which is hindering development. The methods in this booklet make use of the larger freshwater plants (commonly termed aquatic macrophytes or macrophytae), including flowering plants (angiosperms) with ferns, horsetails (pteridophytes), mosses and liverworts (bryophytes) and larger algae.

Freshwater macrophytes have often been neglected as pollution monitors, being regarded only as weeds which may hinder flow. Where macrophytes occur, however, the habitat range of the site can be deduced from the species present. (If species are absent, the primary cause, which need not be water quality, can be identified, even when pollution is severe). Each species has a range of tolerence to each habitat factor, comprising a range in which it can grow well, peripheral ranges in which it can grow less well or occur less frequently, and conditions from which it is excluded. When some but not all the habitat factors are known, the vegetation can be used to assess the remaining factors. Consequently if water and soil quality can be deduced, both the pollution, and the base-line quality of the clean water can be assessed.

As a diagnostic tool, macrophytes have several advantages. They are large, most being easily recognised from a distance. They are few in number, diagnosis within a region usually being possible from about 50 species. They are stationary, so their absence is easily ascertained. Most are rooted, and so reflect soil as well as water quality (soil status is usually more stable). In its simpler forms macrophyte monitoring is exceptionally rapid, and so can be recommended for initial surveys and when man-power is limited.

The main disadvantages of macrophyte monitoring are that most species die back in winter, so preventing recording at that time, and that assessment is possible only in places where clean-water vegetation could be expected to be both plentiful and predictable. In rapid current scours, deep lakes and heavy shade, for instance, macrophytic vegetation is necessarily negligible, and cannot be much further decreased by pollution.

Completely clean, and grossly polluted waters give equivalent indices with all forms of monitoring, botanical, zoological or chemical. In moderately polluted waters, however, different groups of organisms may react differently to different types of pollution, and show the maximum impact of the pollution at different distances from the inflow, hence using more than one method of assessment may add greatly to the total understanding of the pollution. Thus plants can oxygenate water and so are less susceptible to oxygen sag downstream of oxygen consuming effluents than are macroinvertebrates. Conversely some indicators can migrate and so escape intermittent pollution which plants cannot avoid. Trace metal and other requirements are also species dependent.

The primary factors influencing freshwater vegetation are:

Rivers

Water force (related to landscape and precipitation)
Rock type and land use
Upstream-downstream variation
Mans' activities

Lakes

Size variation
Rock type and land use
Circulation and disturbance
Mans' activities

Those are made up of various components:

Flow (in rivers) or Circulation (for lakes), Disturbance, Substrate texture and stability, Depth, Light reduction (turbidity, shade) Width (of rivers), Area (of lakes), Water (chemical) quality, Substrate (chemical) quality, Bank type, Propagule availability.
Temperature
Effects of past history, and long term changes in, for instance, weather.

These combine in different ways, for instance, turbidity may be due to the run-off particles (which are dependent on rock type, land use, topography and precipitation), to phytoplankton, or to pollution. The effect is the same, the cause is different.

Freshwater vegetation is influenced by many of man's activities, including:

Activities normally considered polluting

Effluent, both treated and untreated. Organic wastes from houses, farms, boats and factories. Industrial wastes from factories, mines etc.
Aquatic biocides.
Agricultural run-off, fertilizer, biocides and increased soil particles.

Urban road and similar run-off
Air pollution, both generalized and from near-by sources (eg factories).
Pollution is predominantly chemical, but can also be heat, radioactivity, non-toxic particles etc.

Activities with a substantial chemical effect on waters

Arableization
Intensity of farming
Removal of acid top soil (peats, conifer forest etc)
Other changes in land use
Water transfers (when the recipient water is different in quality from the donor)

Activities with a smaller chemical element

Navigation (boats, canalization)
Control of flow (by weirs, dams, sluices, reservoirs etc)
Channelling (channel shape and position)
Lining and culverting
Drainage and irrigation
Abstraction, water transfer (except as above)
Cutting and dredging for river maintenance
Grazing by mammals, fish etc, trampling by mammals
Shading by trees and buildings
Disturbance from leisure activities (angling, paddling etc)

Species can occur only in suitable chemical regions. They may, however, be excluded from any part of this range if other factors (eg depth or flow) are unsatisfactory. Sensitivity to such other factors may increase at the periphery of the range. Correlations of special occurrences with nutrient status may be due directly to the nutrient requirements of the species. They may also be excluded due to a second essential factor such as cleanliness or flow being present in only part of the suitable nutrient range. Nutrient status is primarily determined by rock type, though soil type may have an independent effect as with intensive farming or acid top-soil. Aquatic species have observed associations with these nutrient regimes, though in most habitats studied the major plant nutrients are not nutritionally limiting; though limitation can occur for instance in resistant rocky mountains and humus-free quartz sands.

A polluted community exhibits at least one of the following:

- decreased diversity
- decreased abundance of species not favoured by pollution.
- increased proportion of species present which are tolerant to the incident pollution.
- increase in species favoured by the pollution.

At the simplest level, as said earlier, polluted aquatic vegetation can be distinguished on the basis of about 50 identifiable species, a list of their pollution tolerance, and a slight knowledge of what vegetation can be expected where if the water is clean. Recently dredged rivers, much-trampled lake edges, deep waters etc are anomalous.

Two semi-quantitative methods are given in the booklet for rivers:

The rapid method A compares the vegetation found in a site with that described for a clean undamaged and similar site (see Haslam and Wolseley (1981) for Britain, and Haslam (1987) for some other Western European countries). Sites are classified by rock type, landscape and size. A damage rating is produced, assessing the reduction of vegetation irrespective of cause (eg shade, drought or pollution). This leads to a pollution index.

Method B uses a more detailed recording system, and the species present, cover and biomass are all allocated points. This leads to both a plant community description and a plant score. The plant score assesses pollution in the same way as invertebrate scores. An appendix (from an out-of-print book) (Holmes 1983) describes plant communities classified on data from a Method B survey, using TWINSPAN computer analysis.

Method C, for lakes, describes survey methods, but unfortunately lakes have not yet received the attention required to produce a full pollution index, only a general division into categories.

Hazards (see also section B4 and References (WAA and HSE 1981))

1. The provisions of the Health and Safety at Work Act and the detailed information given in the relevant Health and Safety Executive publications should be carefully studied and put into effect.

2. Sampling on or close to open, deep or fast flowing water carries a risk, even if only slight, in addition to the normal risks from falls, of drowning and, especially in cold weather, of hypothermia. Remedial action should be rapid; but do not abandon attempts at resuscitation unless medically advised, or other criteria overrule, because instances are known where the effects of hypothermia have modified the effects of drowning. In cold weather warmth and shelter should be available if the work is in exposed windy places or there is risk of falling into water. Always carry spare warm clothing. Wear a life jacket if near fast flowing or deep water.

3. Weather and if applicable tide conditions should be ascertained prior to sampling; but allow for unexpected changes and spates.

4. Personnel engaged in sampling must make themselves familiar with the safety equipment and procedures available to avoid physical injury etc, and, if used, with boats and motors, snorkels, aqua lungs, and navigational equipment.

5. Before attempting to obtain samples the Officer must be satisfied that both access to and the egress from the sampling point can be achieved with complete safety bearing in mind the sampling and other equipment which may have to be carried. Where sampling is from exposed road bridges etc retroflective jackets must be worn.

6. Quick sands and bogs are a hazard, hence if ground is not known to be firm, it should be tested for firmness before being walked on or driven over. Safety lines and harness should be used when there is any doubt and life jackets should be worn when near or on water. Duckboards, sand trays and similar devices may also be a help. Attention should also be given to unstable slopes and overhanging rock or structures.

7. Information on one's whereabouts and an approximate timetable should be left with a reliable person prior to starting. Always ensure that this person is notified on your return to avoid placing the rescue services needlessly at risk. In hazardous situations provision of a 'safety man', who stays in a known safe place to keep watch on and for the sampler is recommended. Such a person should always summon help prior to going to the assistance of a sampler in distress lest both should get into difficulties and be unable to summon help. A radio or telephone is useful.

8. Lone working should not be permitted. When working as part of a group, each operator should know the location of every operator and contact with each individual in the group must be made at regular intervals.

9. Always ensure that at least one, preferably more members of the party are familiar with the local terrain and its climatic hazards. In unfamiliar areas it is wise to consult the local organizations such as Water Authorities for information on hazards such as weirs and sluices. In coastal areas consult the local Coastguards.

10. If any of the following circumstances apply, the Officer must not enter the river unless secured with a harness or safety line, and wearing an approved buoyancy aid and then only if satisfied that it is safe to proceed;

(a) Rivers where access is by steeply graded banks the slope of which continues up to the edge of the river;

(b) When the river is more than 2 ft deep or when the bed of the river has an accumulation of soft (penetrable) mud, as a general rule rivers which require the use of thigh waders would fall within this category;

(c) The sampling point although shallow is just upstream of very deep water; and/or

(d) Where the river is in flood or is so discoloured that any dangerous obstructions may be hidden from view.

Field personnel should identify sites where even though harnessed, access is considered unsafe. These sites should be notified to the Area Pollution Control Officer who will arrange to either eliminate or change the sampling point, as appropriate. If there is any risk of losing one's footing wear a safety harness and life line, which is firmly anchored ashore. Where river flow is fast, a catenary chain or rope should be hung downstream at water level.

11. Care may also be needed in some localities to guard against bacterial and parasitic infection, pathogenic fungal spores, plants with toxic or vesicant parts and harmful wildlife, nor must it be forgotten that exceedingly dangerous compounds ranging from toxic wastes, to inflammable oils, high explosives and white phosphorus have been found in both bank and river bed deposits and that flammable gases such as methane and

phosphines, alkyl mercury and arsenic and compounds such as chloromethyl sulphonium salts can be synthesized by natural organisms. Proper protective clothing and first aid equipment should be used when necessary.

12. Use of Boats. For Small Boats see 12.1 to 12.17 (for larger boats see 12.14–12.23).

12.1 No boat, vessel, or pontoon is to be used without the knowledge of the appropriate Supervisor. If relevant, permission of the appropriate operations controller for the site must be obtained and observance of the site safety rules and those relating to working in boats is imperative.

All occupants of vessels must wear life jackets.

12.2 The single manning of vessels is approved only where the occupant is a proficient swimmer and is in verbal contact with one or more colleagues on the bank, at least one of whom is also a proficient swimmer.

12.3 Before any activity is undertaken it must be clearly agreed who is in charge of the vessel. That person must be proficient in boat handling and have attended an approved training course on boat handling. If practical, work boats should not be deployed during the hours of darkness, fog, heavy rain or any seriously reduced visibility.

12.4 Not more than one non-swimmer will be permitted in or on a vessel at any one time. Non-swimmers are not permitted to take charge of a vessel.

Persons in charge of a vessel must ensure the following:—

(a) The regulations are adhered to;

(b) Safe loading and unloading procedures are used;

(c) All occupants on a vessel conduct themselves in a manner which does not endanger themselves or others;

(d) That the vessel is fit for its intended use and in good repair;

(e) Keep a watch on the weather and be prepared to abandon work if it deteriorates seriously enough to make the use of the vessel hazardous. All scientific staff should be able to interpret weather forecasts and when appropriate a record of weather forecasts should be kept for planning purposes.

(f) Before using an inflatable Dinghy, a careful check should be made to ensure it is adequately inflated.

12.5 The person in charge must make sure that they know the carrying capacity, speed and endurance of boat and that there is an adequate reserve of fuel. Obtain local knowledge of hazards (hidden obstacles, outfalls, weirs, currents, tides, quicksands etc).

12.6 The boat's equipment should consist of oars or paddles, pump, bailer, torch if deployed at night and no navigational lights are fitted, small anchor and line, bow line, man overboard line and grommet, hand held distress flares kit and any other equipment which may be practically stowed in the boat to enhance the safety of personnel, such as a spare bung, bellows, and repair kit if relevant, a reserve fuel tank, a tool box carrying basic tools such as pliers, screwdriver, shifting spanner etc together with a basic spares kit, plugs etc. Anyone using part of the spares kit should make it their duty to replace any items used up at the earliest possible opportunity. If the boat has an engine, the proper fire extinguishers must be carried. The person in charge should have clear ideas on what steps to take regarding safety and have a knowledge of the use of life saving and any fire fighting appliances.

12.7 In large lakes and wide rivers equipment such as compass, distress flares and engine spares may be needed. (See also the section on Navigational Aids, at the back of this booklet). Temporary geographical disorientation can occur when the task in hand requires all the attention. Maintain a general awareness of geographical orientation, especially when drifting, by checking on suitable landmarks. Try to cultivate the habit of checking a changing situation with respect not only to weather but geographical orientation.

12.8 Before deploying the boat, the officer in charge should be briefed on the operation, possible navigational dangers, weather, traffic and pick-up point.

12.9 Keep a watch on weed and debris which could foul propellers or intakes.

12.10 Personnel in the boat should wear protective oilskins or survival suits as well as lifejackets and safety helmets at all times. Warm protective clothing should be carried. A lifejacket is a safety garment which guarantees that an unconscious victim will float face uppermost.

12.11 A hand held portable VHF radio should be carried by the crew member in charge of the boat. The Home Base should monitor the agreed frequency at all times while the boat is deployed.

Each operator should check his radio before setting out.

Radios must not be physically abused and any breakdowns must be reported immediately.

Radio transmissions must be brief to allow all users free access to the network.

Care must be taken to avoid accidental transmissions.

No operator should leave the network without 'signing off' to at least one other operator in the group.

At the end of each day all radios should be returned for charging.

12.12 Try to keep the boat 'shipshape' at all times as accidents are less likely in a tidy boat. A very common cause of danger is loose rope and odd bits of equipment lying around.

12.13 Keep to the centre-line of the boat and avoid standing-up whenever possible.

12.14 If the boat is taken ashore or into a harbour it should not be left unattended. Care should be exercised on the approach to any landing to ensure adequate water for the motor and reduce the risk of seriously damaging the boat on submerged or protruding obstacles. The use of a boat rope is recommended when recovering or launching the boat.

12.15 The Recommendations made in the Department of Trade and Industry (DTI) booklet 'How safe is your craft' should be adopted. Obey the seaway code 'A guide for small boat users' prepared by the Department of Trade and Industry and be familiar with the collision regulations. If a small boat becomes flooded it is important to keep engines going as total loss of power on a flooded craft presents a much more dangerous situation and it may be impossible to get the engines started again, whereas a half baled out boat under power can be readily drained by use of the drain cock at the stern. In case of accident stay with the boat.

12.16 The International Regulations for Preventing Collisions at Sea in 1972, which came into effect in 1977 and which were amended in 1983 must be obeyed.

These Regulations together with other safety recommendations are outlined in:—

1. The Macmillan and Silk Cut Yachtsman's Handbook.
2. The Macmillan and Silk Cut Nautical Almanac.
3. Reed's Nautical Alumanac.

Hired Survey Vessels should be covered by the same controls as Vessels owned by those sampling.

12.17 If there is a risk of entering tidal water or open sea Scientific Staff should also have a working knowledge of Admiralty Charts, Admiralty Tide Tables and basic Navigation, Radar and Communications Equipment.

12.18 For larger boats the following may apply:

HMSO. THE COLLISION REGULATIONS ORDER 1965 NO 1525
MERCHANT SHIPPING (SAFETY CONVENTION) ACT 1949
MERCHANT SHIPPING (LIFE-SAVING APPLIANCES) RULES 1965
MERCHANT SHIPPING (FIRE APPLIANCES) RULES 1965
HOW SAFE IS YOUR CRAFT? DTI PUBLICATION
SEAWAY CODE—A GUIDE FOR SMALL BOAT USERS, DTI PUBLICATION
MEDICAL SCALES STATUTORY INSTRUMENT 1974 NO 1193

12.19 The coxswain of a large boat may need to posess a Board of Trade Boatman's Licence, dependent on vessel size.

12.20 The coxswain of a sampling vessel should be made aware of all personnel on board before departure. If the boat is so large that life jackets are not worn all the time, all personnel must be familiar with the location and fitting of life jackets and will wear life jackets when ordered to do so by the coxswain. All personnel must have a working knowledge of the inflation of life rafts. All personnel must be familiar with the position and operation of fire fighting equipment. All personnel should be able to take the helm and operate the main controls in the event of an emergency. Scientific staff may enter the engine room only with the approval of the coxswain. Extreme caution is to be exercised in the use of winches and lifting gear.

12.21 Anyone discovering a fire on board is to raise the alarm until assistance arrives, and attempt to extinguish it or contain it within a localised area using any portable fire-fighting apparatus to hand. Should there be a risk of fairly immediate explosion or toxic danger at the source of the fire, ensure that other personnel are out and shut all doors and hatches on leaving. Staff should make a point of learning about fire fighting equipment when they are first introduced to survey work on large boats.

12.22 Flooding: Any person discovering the ingress of water is to inform the coxswain, when measures will be arranged to locate the source and carry out a repair.

12.23 Whenever the order 'Emergency Stations' is given, all personnel will without delays go to the life raft position on deck taking life jackets with them.

13. Emergencies

13.1 'MAN OVERBOARD'

It is possible to fall overboard unobserved even when other people are on deck, and the two aspects of the matter should be kept in mind—first, going over is very easy and second getting back is usually very difficult. When working over the side make use of tails and in adverse conditions a tended lifeline.

If a person overboard is not seen, do not make a turn until the compass direction is checked, and if possible, a transit line on prominent landmarks taken in order to work out the reciprocal course. If the boat has been sailing on a compass course then the boat must be turned right round and steered on a reciprocal.

The instant it has been realised that someone has gone overboard the marker supplied for the purpose should be jettisoned to act as a reference point, and if Decca Navigator survey or similar equipment is in use a more accurate ship's position can be determined. Once the person has been seen the first thing is to throw a buoyance aid, marker and rope. The buoyance aid may of course act as a marker. In the situation where a person is seen to go over, the first thing is to get a life belt or any aid to buoyance into the water as near the person as possible and then raise the alarm.

Under power great care must be taken to avoid the possibility of causing injury with a propellor, and since it may be impracticable to stop the engines precisely at the right moment it will be better to come up to leeward of the person. In that position the greater windage of the boat will tend to take it away, and although a parting is not what is really desired it will be better than having the boat blow down on top of him or her.

If no steps or rope ladder is available the simplest form of aid to allow a person with water logged clothing to get back on to a boat is a bight (loop) of rope for the foot. But unless the victim is agile and circumstances ideal it is wise to take the extra precaution of securing a line around the chest under the armpits. A member of the crew can keep shortening in so as to keep this line short and to ensure that any ground made good is not lost. First a bight of rope is lowered to a length which allows the person in the water to get a foot in it and 'step' up by about six inches. Then the buoyline is shortened in and made fast so that there is no risk of slipping back. Next the foot rope is shortened so that the person can raise himself or herself another six inches by the power of their own leg muscles.

13.2 Artificial Respiration

If possible while proceeding with the advice which follows send for medical assistance and transport. This may be necessary with an unconscious victim. The modern method of artificial respiration is to use your own lungs to pump air into those of the victim. It is simple to do and easy to understand, far more so than any of the older methods.

Speed is important and the drill is as follows:—

Lay the victim on the back.

Clear the mouth of anything that may be obstruction and remove false teeth.

Tilt the head back by pressing the forehead with one hand while the other provides support under the nape of the neck. Now use one hand to hold the forehead back while its fingers pinch the nostrils to close the nose, and with the other hand control the jaw so that the mouth is sufficiently opened to mate with your own. Make sure the tongue has not dropped back to block the throat. Take a deep breath, open your mouth wide and seal your lips around the victim.

Exhale into the lungs until they are filled.

Remove your mouth and watch the chest fall. Then repeat.

If necessary treatment can be begun in the water, and air can be delivered through the nose. The frequency of respiration should be about once every 5 or 6 seconds.

After inflating the lungs 5 or 6 times the patient should begin to look better, if the heart is working.

Heart massage may be necessary. Raise the legs above the level of the chest. Thump the breastbone hard with your fist. Start pressing the breastbone rhythmically at a rate of about once a second. If single handed, do that about 15 times before going back to forced respiration. Then after 5 lungs inflations go back to heart massage.

13.3 Effects of Cold/Hypothermia

One danger that is not widely understood is that of hypothermia—a lowering of the body temperature due to immersion in cold water. If the rescued person needs no artificial respiration or heart massage, but seems shivery, unable to see, hear or speak properly, or not in normal control, then hypothermia must be considered likely.

One must not make the mistake of trying to warm anyone up rapidly, but at the same time any further loss of heat must be prevented. Time must not be wasted in removing or changing the victims wet clothing, but wrap up and protect from the wind at once. This does not mean merely putting a blanket over the patient lying on a berth—it means cocooning so that all possible routes for heat loss are sealed off.

Sugar, sweetened condensed milk and other forms of sugar can be given, but do not give hot drinks or alcohol at this stage, nor a hot water bottle.

Sudden heating may prove fatal.

Get medical attention as quickly as possible.

Information in Sections 12 and 13 is based on the experiences of the Northern Ireland Department of Development and the Ministry of Agriculture, Fisheries and Food.

A The Surveying of Macrophytes in Watercourses

A1 Summary of the Method

A1.1	Biota determined	Macrophytes (large plants). In this method the term is used to include all plants clearly visible to the naked eye at a distance of several metres.
A1.2	Vegetation surveyed	Macrophytic vegetation in watercourses.
A1.3	Basis for use for pollution assessment	The vegetation is determined by its habitat. The normal water plant communities of a region can be listed in relation to rock type, stream size and flow regime. The lists are prepared by recording clean reaches not damaged by trampling, recent cutting, dredging or similar disturbance. The vegetation of a given site is then compared with that listed. The reduction or alteration of vegetation due to navigation, pollution or other causes is then assessed. The survey method described is applicable to all watercourses. Pollution indicators are currently usable only where undamaged vegetation is plentiful and predictable. For interpretation of the data see Section A8 and for uses of the method Section A9.
A1.4	Basis of operation	Recording species present and various factors influencing vegetation by viewing from bridges or other suitable access points from which the watercourses can be studied easily.
A1.5	Limit of detection	a. The vegetation is usually up and suitable for evaluation between mid-June and mid-September, but cannot be recorded during storm flows. b. The method records only species which can be observed easily. A species with, for instance, a single shoot 5 cm long, or with short brown-tinged shoots growing on the bed of non-clear channels are likely to be overlooked. The error rarely affects diagnosis of river quality.
A1.6	Form of data	Species lists, with estimates of plant cover and species abundance. Notes on dates of appearance and decline should also be recorded where practicable eg up by....
A1.7	Range of application	Any watercourse with reasonable access via bridges or other suitable viewing point. Small channels can be recorded from one bank, or by wading. Large channels without bridges in suitable places may be recorded from both banks if light and water clarity permit clear viewing. (For this method, the entire width of the watercourse should be seen).

A1.8 Bias

Different observers may record abundance differently and identify species differently in difficult taxonomic groups (eg Batrachian *Ranunculus*). In addition some species may be overlooked, see above. Bias between observers is reduced by confining the study largely to the more easily recognisable macrophytes.

A1.9 Logistics

Surveying. One of the advantages of the method is the speed with which the species and abundance of macrophytes can be assessed. This enables a relatively large number of sites to be evaluated in a working day. The time spent at each site will depend on the expertise and experience of the worker and the need or otherwise of wading or grapnel searches. Time must be allowed for the following:

i. Identification of plant material. The time required depends on the experience of the operator.

ii. Beginners must allow time for preservation of plant material (voucher collection).

iii. Presentation of data in a logical and retrievable form and the preparation of river maps. This normally requires substantially less time than the field work.

iv. Interpretation of the data, allow a time similar to iii. above. When using the index given in the appendix (Haslam index) allow 5 minutes per site minimum.

A2 Introduction

A2.1 Macrophytes

Macrophytes are the larger plants of fresh water. They are usually attached to the substrate but may also be free-floating. Their shoots and leaves may grow out of the water, they may have floating leaves only or they may be fully submerged plants. Some species are heterophylous (have more than one kind of leaf, both floating and submerged). Macrophytes consist mainly of angiosperms (flowering plants) with some Vascular cryptogams such as horsetails; they also include Charophytes (stone worts) and Bryophytes (mosses and liverworts); algae such as *Cladophora Vaucheria* and *Entermorpha* should be included when they are readily observable.

A2.2 Types of record

The species present must be identified, and their abundance and cover estimated. Other characters such as width and depth, shade, navigation and recent dredging are also recorded. Quantitative measurements such as biomass or standing crop, shoot density, and the cover and frequency of species recorded in random quadrats, grid-sited quadrats or transects are valuable in their own right (see the booklet in this series on biomass estimations); but are not required for general monitoring. See also sections 8 and 9. Standard record sheets can be used with advantage particularly where the data is to be transferred to computer for storage and retrieval. Record sheets should have ample space for notes.

A3 Equipment Needed

A3.1 Equipment in the field

a. Notebook or equivalent; ball-point pen or pencil; polythene bag large enough to write in (for use in wet weather).

b. Gum boots or thigh boots.

c. Plant grapnel or heavily weighted hook on a rope.

d. Polythene bags, and firm containers (eg buckets) in which to place bags containing wet plants; if travelling by car or van, a thick rug or equivalent to keep the containers cool in warm or sunny weather; towel).

e. Labels or scrap paper. (Names written in ball-point pen and soft pencil will remain legible for several days in wet polythene bags.)

f. Plant press. Mesh versions are now difficult to buy, but can be made from 2 oven trays and 2 strong straps. Newspaper, 1–2 cm thick, should be placed in the press, with thin typing paper (copy paper) at one end. Specimens are put between sheets of typing paper, and placed evenly through the press, so that wet specimens are kept separate. Until the plants are dry, the press should be kept in a dry warm place. If a car or van is being used reguarly in summer, the warmth in the boot or back is satisfactory.

g. Walking aid (spade or stick) to prevent slipping on steep banks, in swift water etc. This or another stick should be calibrated for measuring depth. If the walking stick is secured to the belt with a suitable cord approximately 1.5 m long, the risk of it being lost downstream is avoided.

h. 1:250,000 or larger-scale maps of the area.

i. Identification books, eg Haslam, Sinker and Wolseley (1982). Spencer-Jones and Wade (1986).

j. Binoculars.

k. Hand lens eg 10x.

l. Polarizing sunglasses (if desired).

m. A good camera with flash attachment and a polaroid filter, capable of close-up pictures may be useful when specimen collection is not desirable. Reflex cameras, equipment for rapid prints or other ways of veryifying the record before leaving the site are invaluable. See also A5.4.1.

A3.1.1

Various methods of airborne survey can also be used for such surveys. In some circumstances aerial photographs can provide additional records.

A3.2 Equipment in the Laboratory

a. Identification books, see section A6.1.

b. 10×lens and/or dissecting microscope; white dishes in which living plants can be examined under water.

c. Thick white paper or thin card of at least A4 size on which to mount pressed specimens. Plants may be attached by transparent tape or gum and may be protected with clear transparent film or cling film. Full identification details should be put on each sheet (plant name, site, habitat and date of collection). A reference collection (voucher collection) is very useful for beginners. Under the Wildlife and Countryside Act (1981), plants must not be uprooted when samples are collected. With a little practice, most species can be identified in situ while looking down from bridges, and collection of samples will be unnecessary except for unfamiliar species. It is advisable to identify these species as far as possible before collection, by reference to the identification books, as rare species should not be collected.

d. Geological maps. These need not be owned by the Laboratory as access once or twice a year is usually sufficient. 1:250,000 maps are usually adequate, and are the easiest to read for botanical purposes. A simple rock type map is provided in Haslam, and Wolseley (1981). Larger scale maps may be needed when the rock types vary within a small area. Solid maps should be examined first with later reference to drift maps in regions with much recent deposits.

e. For a full understanding of a river, available information on its past history should be collected.

A3.3 Introductory literature

Before starting serious field work, beginners should familiarize themselves with the commoner macrophytes (eg Table 1 and most of those in 'Key to the common species of rivers' in Haslam, Sinker and Wolseley (1982)). This can be done through illustrations and keys. Whenever possible beginners should undertake the preliminary field visit under the guidance of an experienced worker.

A4 Planning a Survey

A4.1 Season

Mid-June to mid-September is the best time for surveying as late developing species have usually appeared by mid-June. In Southern England however even late-growing species may be up by late May. In cold years in North Scotland surveying should wait until July. The first severe autumn storms usually disrupt stream communities. In mild autumns vegetation may remain unchanged until October. During this recording period, plant cover, and species abundance as measured on a 2 point scale usually remain unchanged during steady conditions so that repeat surveys give comparable results.

A4.2 Day

Submerged plants cannot be seen in muddy or very swirling water, so after storms, surveying must wait until the water has cleared and the level is nearly back to normal. It storms have caused much damage to vegetation, a survey in the next few weeks will correctly record the damage done by the storm, but this may partly mask the effects of pollution etc. Recording the pollution assessment should therefore be postponed. Such damaging spates are, however, rare. The same principles apply when vegetation is removed by cutting. Spraying with herbicides is similar, except that there may be a delay between spraying and plant death, and a much longer period between spraying and vegetation recovery.

A4.3 Number of sites to record

The number chosen depends on the purpose of the survey and the variability of the river. For a general survey of a whole river on a single rock type and with normal topography, a suitable number is the number of miles (or half the number of km) from source to mouth, the sites being spread over tributaries as well as the main river. (Note that tributaries which are not Main River may still influence the main river, and the records should include these.) These general surveys are adequate for the diagnosis of stream type, and for the detection of pollutions extending over long lengths, but may miss pollutions etc influencing short lengths only. Three sites are advisable for the interpretation of reaches of a uniform habitat, or of a slowly changing habitat (eg gradual downstream self-purification). If the survey is for a more specialized purpose, such as the effect of one particular effluent, sites must be recorded more frequently, perhaps even every 25–50 m.

A4.4 Choice of sites

For this method sites are needed where the stream can be seen across its width, and preferably from above rather than from both banks, since species viewing and identification is easier in deeper channels when looking down on the water. Bridges are therefore particularly useful when available. A distance of at least 15 m upstream and downstream from the fixed point should normally be recorded. After recording from the bridge, wading along the sides (in an upstream direction if much mud is dislodged) will show beginners which vegetation types may reveal differences to the pattern seen from the bridge, (eg more species, other than those with only small shoots). The distribution of bridges should therefore be studied in relation to the river and the purpose of the survey. Where bridges are inadequate, and the river runs through private land, permission for access at appropriate points must be obtained, except by such as Water Authority personnel with legal authority for access.

A5 Surveying

A5.1 Site Identification

Records should start with identifying data (name, date, code number, and National Grid Reference number to 6, 8 or 10 figures as necessary).

A5.2 Physical Characteristics to be recorded

The categories defined here are simple to apply in the field. Very precise measurements seldom improve the botanical interpretation of this type of survey.

a. Width of channel, approximate. If in doubt, place in 0–3 m, 4–8 m and 10+ m categories. The 0–3 m category is further sub-divided into 'water supported species absent' and 'water supported species present'.

b. Depth of most of the channel centre during normal (not storm) flows.

After practice with a measuring stick or for deeper waters, a measuring rope, depth can be estimated by eye to the nearest 25 cm in waters up to one metre deep, and to the nearest 50 cm in deeper places. Waters too turbid to see the river bed, and in which measuring is not practicable may be placed in an extra category. In deeper channels, the parts less than one metre deep or the sides of the watercourse are used for the estimation of plant cover see below.

c. Substrate types present, whether boulder, stone, gravel, sand, silt plus mud, and peat. Any particular patterns such as silt banks at the side should be noted if they are associated with a vegetation pattern.

d. Flow type. Turbulance is as important as velocity for macrophytes, and a simple classification (correlated with Froude Number* during non-storm flows) is:

- Negligible: water barely moving.
- Slow: water obviously moving, water surface calm in the absence of strong winds), and trailing plant parts still.
- Moderate: water surface somewhat disturbed and swirling, trailing plant parts moving.
- Fast: water surface obviously disturbed and swirling, trailing plant parts moving vigorously.
- Rapid: water surface broken by boulders or stones, trailing plant parts usually absent or sparse.

e. Water clarity. This is conveniently recorded as Turbid: bed, banks, etc cannot be seen over 30 cm down. Semi-turbid: bed etc visible between 30 and 75 cm down. Clear: bed etc visible at more than 75 cm down. Shallow clear: waters which appear clear, but are too shallow to determine whether they should be rated as semi-turbid or as clear.

Where water clarity is important eg for patterning of deep water vegetation, visits on more than one occasion and records with an underwater light meter are needed.

f. Other habitat factors which are likely to influence vegetation, eg shadings, navigation, paddling, piling or bricking of sides or base, very steep or gentle banks, recent dredging, cutting, herbicide application, obvious pollution etc. (New pollutions should be reported to the relevant authority.)

A5.3 Banks above normal Water level

The bank height and slope (gentle to undercut) should be recorded, and any other bank characters which may influence the channel vegetation, eg ledges by the water, tall vegetation shading the waters' edge or preventing short emergents growing there. When management practices are being studied, add the current vegetation and any evidence of management.

A5.4 Plants of the channel

All channel macrophytes present should be recorded. Emergent aquatics on the bank (rather than those within the main water) should be recorded separately if required. Beginners should concentrate on the commoner species (eg those in the 'Key to Commoner Species of River Plants' in Haslam, Sinker and Wolseley 1982). Plant shapes, and the way trailing plants move in currents are very distinctive, and should be noted. Plants which cannot be named from a bridge should either be collected by grapnel or by wading or photographed (see A5.4.1 below), and a grapnel should be used to search for plants where turbid or coloured water etc prevents their being visible (but see A5.4.1 below). Observers will soon learn the few stream types in which such a search is needed. New species should be added to the observers' voucher collection (see Section A3.2).

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*The Froude number which is a measure of the liability to form waves is given by u^2/dg where u is the water velocity, d is channel width and, g is the acceleration due to gravity. It can also be used for the liability to cause waves, in which case d is a measure of the object size. The related Reynolds number is $\frac{udp}{\mu}$ where p is density and μ is viscosity.

A5.4.1

The collection of rare species should be avoided. It is often possible using close up or narrow angle zoom or telescopic lenses and colour film with flash or other illumination to photograph specific plants and sampling areas in sufficient detail to make surveys of this type possible, especially if print enlargement is also used when necessary. Films (usually fine grain) should be chosen with this in mind. A polaroid filter is recommended to remove surface glare. (See also A3.1m). For information on use of film consult photographic handbooks.

A5.5 Abundance

Plant abundance can be recorded on a 2 or a 4 or more point scale. The 2 point categories can be termed Much (M) and Little (L), the M referring to species covering at least 20% of the channel. This scale has the advantage that different observers are likely to record sites similarly and, over the 3 month period of summer, the species abundance normally remains constant. The disadvantage is that much variation occurs within the M and L categories. A 4 point scale can be given as:

Present: one of 2 plants visible from the viewpoint.
Frequent: several plants or clumps seen.
Abundant: 10% or more of the stream bed covered by the plant.
Dominant: 50% of more of the stream bed covered by the plant or where, when there is somewhat less than this amount of cover, this is the only species providing substantial cover.

The advantage of the 4 point scale is that more precise descriptions can be given allowing comparisons between different months, years, stages after dredging etc.

The disadvantage is that observers may record differently and species may vary in their grade during the summer because of natural development, or from storms, management etc. This variation, though unfortunate when comparing descriptions taken singly in different months or of different years etc, is useful when studying vegetation development through the summer. If sites are monitored regularly, more detailed comments are useful, such as 'abundant on silt bank to the left above the bridge', 'A 2×1 m clump c 10 m beyond the first fence downstream'.

The total percentage cover of the vegetation should be noted. In waters up to one metre deep this is the average cover over the whole width. In deeper water, that of the parts less than one metre deep or (if these are negligible) that of the bands at the side of the river. In larger streams, bridge piers, weirs by bridges etc, may alter the flow depth etc of the channel. Where this occurs, each main community should be recorded (eg slow flow upstream of the weir, fast flow downstream of it). By looking at the river further from the viewpoint, the uninfluenced community type can be identified (ie that of fast, or of slow flow). Vegetation of this type is used for pollution assessment etc. Any other communities present demonstrate the differences occurring with the appropriate variations in physical characters within a uniform water quality.

A6 Records to be Completed in the Laboratory

A6.1 Complete records

a. Complete identification, and mount specimens wanted for reference. Living plants may be stored (in their polythene bags) in a refrigerator for a few days. Even if species are wrongly named, if the specimens are in a voucher collection, the mistakes can be rectified later. Without specimens, wrong identification may lead to permanently false interpretations. Voucher collections are particularly necessary for 'difficult' groups such as *Ranunculus* spp, narrow leaved *Potamogeton* spp etc.

b. Determine the rock type of each catchment from geological maps. Table 2 can be used for interpretation.

c. Determine the landscape type of the sites seen. One method is given in Table 3, another is to classify rivers according to altitude of source: +500 m, 200–500 m, less than 200 m. (See Holmes N, 1979 and 1983 for a scheme based on stream bed gradient.)

d. Determine such factors concerned with past history, management, land use of the catchment, and the sites of (known) effluents as may be relevant for the investigation in question.

e. Trophic status assessed as given in Haslam and Wolseley 1981 or in Haslam 1987.

Reference manuals include:

Vascular plants

- In general—Clapham, Tutin and Warburg (1962)
- Aquatic species—Haslam, Sinker & Wolseley (1982)
- *Ranunculus* spp—Holmes (1979)
- Grasses—Hubbard (1968)
- Sedges—Jermy & Tutin (1968)
- Introduced by spp—Stodola (1967)

Mosses

- Smith (1978)

Charophytes

- Allen (1950)
- Moore (1986)

General

- For recording, the codes in Holmes, Whitton and Hargreaves 1978 can be used along with Whitton, Holmes and Sinclair 1978 for Charophytes. These manuals give complete check lists and more information on identification.

Note: Useful identification keys are given in heavy type in the reference section at the end of the booklet.

A6.2 Preliminary analysis

a. Present the field records in a clear and retrievable form, including the information from 6.1 above.

b. Prepare diagrams of the surveyed river, showing the channel plants and any other relevant information (Figs A1–4). The accuracy needed varies with the purpose of the survey. The diagrammatic form of Figs A1a, A2a and A3 shows the general vegetation type the more clearly though the accurate river maps of Figs A1b, A2b and A4 are needed to locate sites exactly.

A6.3 Further analysis

The results can now be analysed for pollution, physical damage, effects of management practice, species behaviour, effect of habitat factors, and improvement or deterioration over a fixed period and so on. However, since high water force greatly reduces angiosperms within the channel in highland country, the records of impoverished vegetation there are often unsatisfactory for pollution etc assessment.

A7 Rock Types

Different rock types favour different plant communities. This is described and discussed in Haslam 1978, Haslam and Wolseley 1981, Holmes 1983 and Haslam 1987 qv.

The rock types which influence watercourse vegetation can be summarized as:

Alluvium, subdivided into peat, silty and sandy alluvium.

Clay, usually including marl.

Limestone, softer lowland rocks (eg chalk) and harder mainly hill rocks (eg Carboniferous limestone).

Sandstone, softer lowland rocks (eg Bunter sandstone), harder mainly hill rocks (eg Old Red Sandstone), and calcareous sandstones etc.

Coal Measures

Resistant Rocks, those resistant to both erosion and solution, such as slate, schist, granite.

1:250,000 geological maps are usually accurate enough; but larger-scale ones are needed when there is a complex of rock types in a small area, as in alluvial plains because different alluvial types are seldom marked on the 1:250,000 maps), or where one formation consists of 2 or more rock types (which are differentiated only on larger scale maps as with the clay and limestone or Corallian). Large scale maps are also needed to check the composition of Boulder Clay (which in some areas is not clay, but sand). (See Table 2.)

In catchments of more than one rock type, stream vegetation usually reflects the proportions of each rock type in the catchment, except that:

1. Rock types of the headwaters have the most influence, and those near the mouth away from the river, the least influence.
2. Vegetation is more influenced by a rock type close to, than far from, the site.
3. In lowlands, limestone and clay have a stronger influence on the vegetation than does sandstone.
4. In hills, limestone and sandstone have a stronger influence on the vegetation than does resistant rock.
5. The smaller drift deposits, such as Boulder Clay in highland areas, and clay with flints on the Chalk Downs, can normally be ignored.
6. Thick Boulder Clay usually has the same influence as solid clay. In parts it may be chalky, and in parts (see large scale map, or map in Haslam and Wolseley 1981) may be composed of sand.
7. Alluvium is relevant only when large enough to have watercourses (dykes etc) sited entirely within it. When a river rises outside an alluvial plain, and flows into the plains the vegetation slowly changes from that of the higher ground towards that of an eutrophic slow flowing stream. Because the channel receives silt and water from the higher ground, the vegetation rarely completely alters to that of a watercourse which is sited entirely in the plan.

A8 Interpretation

A8.1 Important variables

River vegetation is determined by many variables of which the most important are:

1. Flow regime

This is primarily controlled by precipitation and topography. Within Britain, the two are usually correlated, so classification can usually be solely on topography. There are a few discrepancies, eg water force is higher on similar topography in south-west than in north-east England because of the higher rainfall. Useful categories, defined in Haslam (1978) are very mountainous, mountain, upland, lowland and plain.

2. Rock type

The primary rock types are listed above. Subdivisions may also influence vegetation (see Holmes 1983).

3. Downstream variation: stream size

When streams become larger downstream, their vegetation changes. A four point division can be used to separate vegetation categories (eg Haslam 1986, Haslam and Wolseley (1981).

4. Mans' activities

Pollution is not the only activity influencing macrophytes. Others include navigation, the insertion and removal of controls to flow, the repositioning and reshaping of channels, the planting and removal of trees, normal management (removing macrophytes by routine dredging, cutting and herbicides), trampling by domestic animals, and swimming. At a fine level of interpretation, the use and management and cultural history of the riverscape and catchment are also important.

A8.2 Indices

1. Because vegetation is so affected by the habitat variables, macrophyte indices require the provision of ecological information. In undamaged places, each habitat type bears a specific plant community. These communities can be listed (as in Haslam 1987 and Haslam and Wolseley 1981). They vary in both quality (species composition) and quantity with the habitat variables listed above. Some of these variables are accounted for directly in the descriptions, eg chalk or clay streams, while others are incorporated into regional difference, eg lowland sandstone in Caithness or Southern England. Indices can be used where this undamaged vegetation is both plentiful (several species are present and cover is at least 30%) and where it can be predicted from simple habitat variables. This occurs throughout most lowlands and areas of low hills. In higher hills, however, if the water force varies greatly with topographical changes which are not easily quantifiable (eg combinations of slopes and altitude), or if the water force is too high to permit much macrophyte growth anyway, pollution can be estimated only on a 2- to 4-point scale. Moss indices, which have not yet been published, would permit monitoring further into the mountains than is at present possible with angiosperm indices.

2. The vegetation occurring at a site is compared with that listed for the undamaged vegetation of a similar site (eg a lowland chalk stream 4–8 m wide or clay stream 10–20 m wide).

3. In the index given in Haslam (1982) (1987) and Haslam and Wolseley (1981), the comparison between the site and the standard community is of:

Diversity
Cover
Nutrient status
Range of species

The following criteria are also used:

Diversity allowance
Proportion of pollution-tolerant species present
Cover due to pollution-favoured species
Clay etc in the catchment (this criterion may not apply outside Britain).

This calculation leads to a DAMAGE RATING, which assesses all factors reducing the vegetation, both chemical (pollution, herbicides) and physical (weed-cutting, recent dredging, shading, navigation etc). To convert this to a POLLUTION INDEX, the non-pollution factors must be negligible (when the pollution index is the same as the damage rating) or mild (when a doubtful index can be given, at least one grade better than the rating). An example of a typical index is given in A9.1. Other indexes are possible. It must also be remembered that pollution effects are not only species dependent but agent dependent, and may vary by causative agent.

4. Where macrophytes are eliminated, eg by shade or navigation, the damage is total, but pollution is irrelevant to the elimination and so cannot be assessed.

A9 Uses of the Method

1. Macrophytes are an integral part of the river ecosystem, so when river health is being ascertained, macrophyte health should be included.

2. Macrophytes, in many river types, provide cover, substrate or food essential for the fauna, so a deterioration in vegetation leads to a deterioration in fauna.

3. Macrophyte monitoring is the most rapid form of surveillance. It is particularly useful when it is desirable to record large numbers of sites on a river and where manpower is very limited it may be the only practicable method of monitoring.

4. Minor organic effluents are often detected by the macrophytes response when they are too slight to show in invertebrate indices without more detailed studies. The method is also useful for pin-pointing the location of small sources of pollution.

5. In organic pollution, macrophytes respond primarily to toxicity, and are only influenced by oxygen deficiency in extreme conditions. The invertebrate response is almost the reverse, with the lowest index usually some way downstream of an effluent entry or where oxygen depletion is greatest. In contrast, the lowest macrophyte index is normally close to the point of entry where toxicity is highest. Comparing the 2 indices below the same effluent, therefore, can help in interpretation of the nature of the pollution.

6. Macrophyte monitoring is less sensitive to heavy metals than invertebrate monitoring, so (if oxygen depletion is not in question) a low invertebrate index associated with a high macrophyte grade is of possible use when investigating heavy metal pollution.

7. The larger and more abundant macrophytes add greatly to the amenity value of a river and riverscape. Both the total amount of vegetation, and its diversity in respect of plant habits are important. Amenity and aesthetic value are of commercial importance in some places. Regular monitoring can detect early signs of deterioration, at the stage when remedial measures are most practicable.

8. Macrophytes are often important for fish and so for anglers; Here again regular monitoring can detect deterioration and over-abundance at a time when remedial measures can be taken.

9. Individual species may be used to assess pollution where good ecological information is available on their behaviour in relation to river quality (nutrients, pollutants etc). This assessment can be related to, but is obtained differently from, the pollution assessment described above, which is based on communities. The basic information is not currently available in a manual. Some information can be found in, particularly, the European literature (Spence 1967; Kohler, Vollroth and Beisl 1971; Seddon 1972; Euenborg 1973; Kohler, Wonneberger, and Zelton 1973; Kohler, Brinkmeirer and Vollroth 1974; Kohler 1975a, 1975b; Whitton 1975; Labus and Kohler 1976; Labus, Nobel, Smetana and Kohler 1976; Latov and Agami 1976; Carbinier 1977; Glanzev, Haber and Kohler 1977; Lachavanne 1977; Labus, Schuster, Nobel and Kohler 1977; Weher-Oldecop 1977; Latov and Lehrer 1978; Sand-Jensen and Rasmussen 1978; Rasmussen and Sand-Jensen 1979; Kohler, Pensel and Zeltner 1980; Nobel 1980; Lachavanne 1981; Labus and Kohler 1981; Whitton, Say and Wehr 1981; Claasen 1982; Dethioux 1982; Janauer 1982; Kohler 1982; Meriaux 1982; Holmes 1983; Kohler and Labus 1983; Nobel, Mayer and Kohler 1983; Holmes and Newbold 1984; Kohler and Schiele 1985).

10. Macrophytes derive their nutrients from the substrate as well as the water. They may extend into waters too nutrient-poor for invertebrate monitoring.

11. If the vegetation is plentiful, vegetation can be assessed by the community index method described in section A8. If plants are sparse, assessment should be made as in section A5.4 above.

12. When water is to be used for irrigation, macrophyte monitoring is the most likely means of detecting pollutants harmful to crops. Growth tests should, however, also be run as plant species are not equally susceptible to different pollutants.

Table A1 Common River Macrophytes (Angiosperms) in Lowland Streams

† *Agrostis stolonifera*	*Polygonum amphibium*
Apium nodiflorum	† *Potamogeton crispus*
Berula erecta	*P.natans*
Callitriche spp	* *P.pectinatus*
Ceratophyllum demersum	*P.perfoliatus*
Elodea canadensis	*Ranunculus spp*
Glyceria maxima	*Rorippa nasturtium-aquaticum agg (Nasturtium officinale agg)*
† *Lemna minor agg*	*Sagittaria sagittifolia*
Myriophyllum spicatum	† *Scirpus (Schoenoplectus) lacustris*
Myosotis scorpioides	† *Sparganium emersum*
† *Nuphar lutea*	† *S.erectum*
Oenanthe fluviatilis	*Veronica spp*
Phalaris arundinacea	*Zannichellia palustris*
Phragmites communis (australis)	

† Tolerant species (the easily observed alga *Enteromorpha* is also tolerant).
* *P.pectinatus* and the alga *Cladophora* are in a special class (see A9.1).

Table A2. Conversion from Geological Names (on Geological Survey Maps) to Rock Types as they Affect Stream Vegetation

The geological names, which comprise names of rock formations and of geological periods, are arranged alphabetically within each vegetation rock type. Small outcrops of other rocks may occur within the types listed here, eg sandstone and chalk in the Weald. These are usually irrelevant as a rock type must outcrop in a substantial part of the catchment to influence vegetation. Only small streams able to bear aquatic vegetation are affected. Where the vegetation corresponds to the undamaged listed community of another rock type, detailed geological maps and their accompanying monographs can be consulted for confirmation. Normally, however, an experienced worker needs no confirmation and a beginner will seldom meet such rare streams.

This list is only applicable to Britain: similar lists can be complied for other places.

1. *Alluvium*

Listed as such. The type (peat, silt or sandy) can usually be obtained from one inch maps. Ignore small areas. A river in an alluvial flood plain should be noted as more eutrophic than the alluvium concerned (see section A7.7).

2. *Clay*

Boulder Clay (check that it is clay, and see section A7)
Barton (contains some soft sandstone)
Bovey Tracey (also contains soft sandstone)
(Bracklesham, is mainly soft sandstone)
(Clay-with-flints. Ignore unless over more than half the catchment.)
Corallian (also contains soft limestone)
Cornbrash
Gault
Hastings (also contains soft sandstone)
Kimmeridge
Lias
London
Marl (eg Keuper)
Oxford
(Purbeck, is mainly limestone)
Snettisham
Speeton
Weald
Woolwich (also contains soft sandstone)

3. *Limestone* (soft rocks, mainly lowland)

Chalk (the purest limestone)
Corallian (also contains clay)
Oolite (except the Coralline of Yorkshire)
Portland (also contains soft sandstone)
Purbeck (also contains marl)

4. *Limestone* (hard rocks, mainly highland)

Aymestry
(Bala, if limestone is specified, not Cambrian, see also Resistant)
(Cambrian, if limestone is specified, see also Resistant)
Carboniferous limestone
Carboniferous limestone series (includes rocks classified as Resistant)
Carboniferous limestone shale (includes rocks classified as Resistant)
(Coniston, if limestone is specified)
Coralline Oolite, Yorkshire
(Devonian, if limestone is specified)
Llandeilo limestone
Magnesian limestone
Magnesian limestone series (may contain resistant rocks)
(Metamorphic, if limestone is specified)
(Ordovician, if limestone is specified)

Pen-y-garnedd limestone
(Pre-Cambrian if limestone is specified)
(Silurian, if limestone is specified)
Wenlock, if limestone is specified

5. *Sandstone* (soft rocks, mainly lowland)

Bagshot
(Barton, mainly clay)
Bovey Tracey (also contains clay)
Bracklesham (contains some clay)
Breccia (Permian or Triassic)
Bridport
Bunter sandstone
Carstone
Crag
Drift sands (if in large amounts)
Eocene, lower
Gravels (if in large amounts in lowlands)
Greensand (Upper and Lower)
Hastings
Headon (contains a little clay)
Keuper sandstone
Norwich and Red Crags
Oldhaven
Pebble Beds
Permian sandstone (except on hilly ground)
Portland (also contains limestone)
Reading (contains a little clay)
Sandringham
Thanet
Triassic sandstone (except on hilly ground)
Woolwich
Yeovil

6. *Sandstone* (hard rocks, mainly highland)

Cambrian, (if sandstone is specified)
Conglomerate
Devonian sandstone
New Red Sandstone (if on hilly ground)
Old Red Sandstone
(Ordovician, if sandstone is specified)
Pennant sandstone
Permian sandstone
(Precambrian if sandstone is specified)
(Silurian, if sandstone is specified)
Torridonian sandstone
Triassic sandstone (if on hilly ground)

7. *Calcareous sandstone*

Carboniferous calcareous sandstone
Fell sandstone (contains less limestone than the above category)

8. *Coal Measures*

Coal Measures
Ignore small patches of drift sands and gravels in this type

9. *Resistant*

Agglomerate
Arenig
Bala (unless limestone is specified)
Basalt
Cambrian (unless limestone or sandstone is specified)

(Carboniferous limestone series, mainly consists of limestone)
(Carboniferous limestone shale, mainly consists of limestone)
Charnian
Conglomerate
Culm Measures
Dalradian (unless limestone is specified)
Diabase
Diorite
Dolerite
Downtonian
Dyke rocks, various
Felsite
Flags, Coniston
Gabbro
Garnscathe
Gneiss
Granite
Granophyre
Grit
Igneous
Ingletonian
Lava
Lewisian
Llandovery
Longmyndian
Ludlow
(Magnesian limestone series consists mainly of limestone)
Metamorphic (unless limestone is specified)
Mica schist
Millstone
Moine (unless limestone is specified)
Mylor
Ordovician (unless limestone or sandstone is specified)
Pennant (unless sandstone is specified)
Picrite
Porphyry
Precambrian (unless limestone or sandstone is specified)
Quartzite
Schist
Serpentine
Silurian (unless limestone or sandstone is specified)
Shale (except in Triassic or younger rocks)
Slate
Syenite
Tarannon
Tuff
Volcanic
Wenlock (unless limestone is specified)

Table A3. River Classification by Landscape (from Haslam and Wolseley, 1981)

When these characters do not correspond, the fall from hill top to valley is the most relevant. See also Holmes (1979 and 1983).

Topographical class	Hill Height m (usual)	Fall from hill top to stream channel in upper reaches (as shown on 1:250,000 OS maps) (usual)	Slope of channel of upper streams (usual)	Liability to spate
Plain	–	–	–	Nil
Lowland	up to 245 m (800′)	up to 60 m (200′)	flatter than 1:100	Negligible
Upland	245–365 m (800′–1,200′)	90–150 m (300′–500′)	1:40 to 1:80	Some
Mountain	610+ m (2,000′+)	185+ m (600′+)	steeper than 1:40	Much
Very mountainous	610+ m	185+ m	much steeper than 1:40	Great

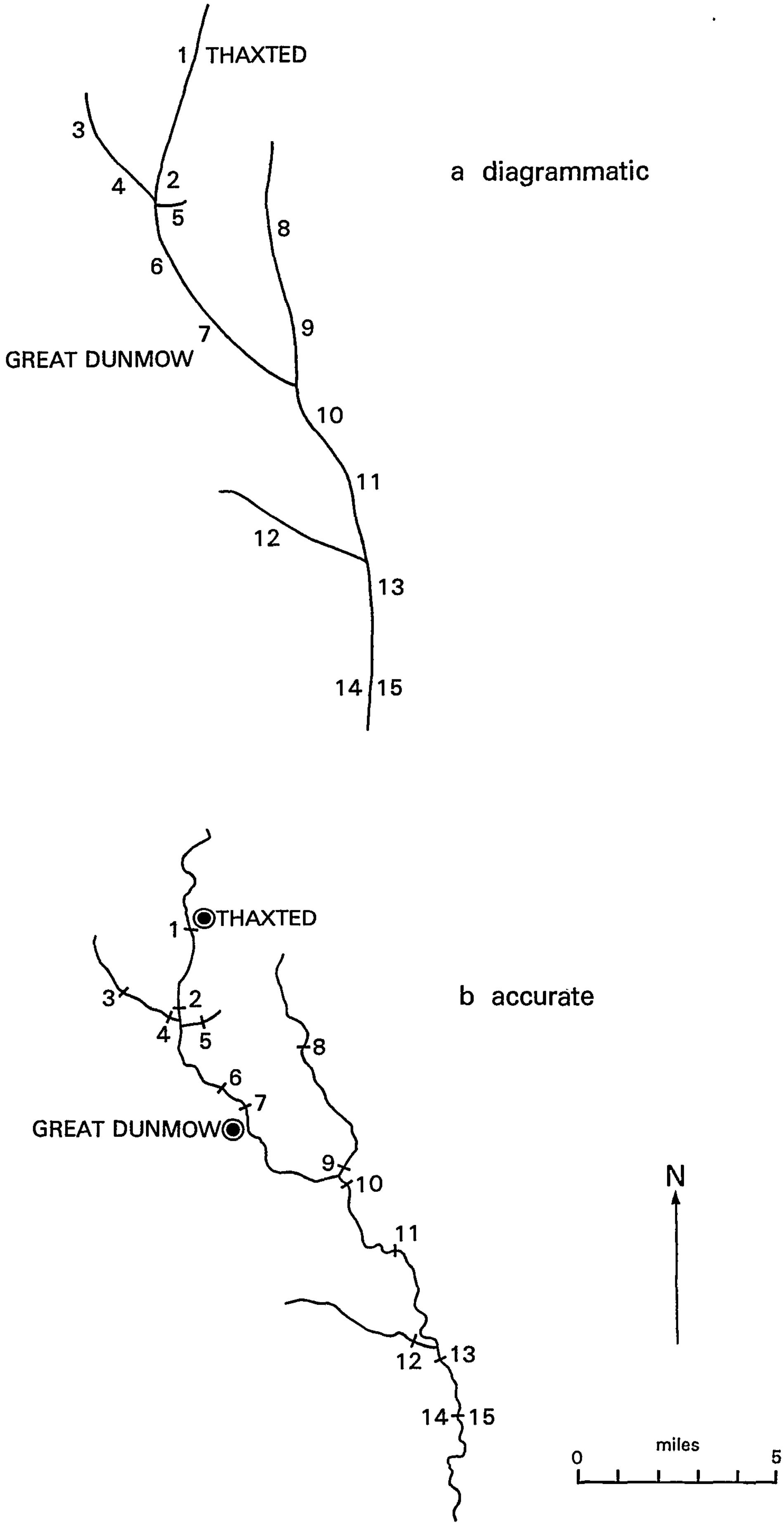


Figure A1 and Table A4
Lowland Clay Stream, Upper River Chelmer, Essex (1972)

Table A4. To be read with Figures 1a and 1b

Lowland Clay Stream, Upper R Chelmer, Essex (1972)

Species Present at the Sites Numbered.

Stars indicate 'Much'. Blanket weed = trailing algae, usually *Cladophora.*

1. *Apium nodiflorum, Callitriche sp, Sparganium erectum.*
2. *Apium nodiflorum, Callitriche sp, Elodea canadensis, Epilobium hirsutum, Phalaris arundinacea, Rorippa nasturtium-aquaticum agg, Sparhanium erectum.*
3. *Veronica anagallis-aquatica agg.*
4. Nil.
5. *Epilobium hirsutum. Rorippa nasturtium-aquaticum agg.*
6. *Agrostis stolonifera, Apium nodiflorum, Epilobium hirsutum, Phalaris arundinacea, Sparganium erectum, Zanichellia palustris*.*
7. *Elodea canadensis, Epilobium hirsutum, Phalaris arundinacea, Sparganium emersum, Sparganium erectum, Enteromorpha sp,* Blanket weed*.
8. *Carex acutiformis, Iris pseudacorus, Potamogeton natans, Rorippa nasturtium-aquaticum agg.*
9. *Groenlandia densa,* Blanket weed.
10. *Lemna minor agg, Potamogeton crispus*, Sparganium emersum*, Sparganium erectum*, Entermorpha sp,* Blanket weed.
11. *Callitriche sp, Potamogeton crispus, Potamogeton pectinatus*, Sparganium emersum, Zannichellia palustris*, Enteromorpha sp,* Blanket weed.
12. *Apium nodiflorum*, Callitriche sp, Rorippa nasturtium-aquaticum agg, Veronica beccabunga.*

13: *Butomus umbellatus, Nuphar lutea, Potamogeton crispus, Sagittaria sagittifolia, Scirpus (Schoenoplectus) lacustris, Sparganium emersum, Sparganium erectum.*

14. (Millstream), *Agrostis stolonifera, Apium nodiflorum, Butomus umbellatus, Glyceria maxima, Phalaris arundinacea, Rorippa nasturtium-aquaticum agg, Sagittaria sagittifolia*, Sparganium erectum, Enteromorpha sp,* Blanket weed.
15. (Main stream), *Agrostis stolonifera, Nuphar lutea, Phalaris arundinacea, Sparganium erectum*, Enteromorpha sp,* Blanket weed*.

Note that while in many river surveys rivers are numbered from the mouth or tidal limit upstream, in botanical work the reverse convention is customary. This latter convention is used here.

Figure A2 and Table 5
Mountain Stream, Upper River Teme/Severn (1973, 1975)

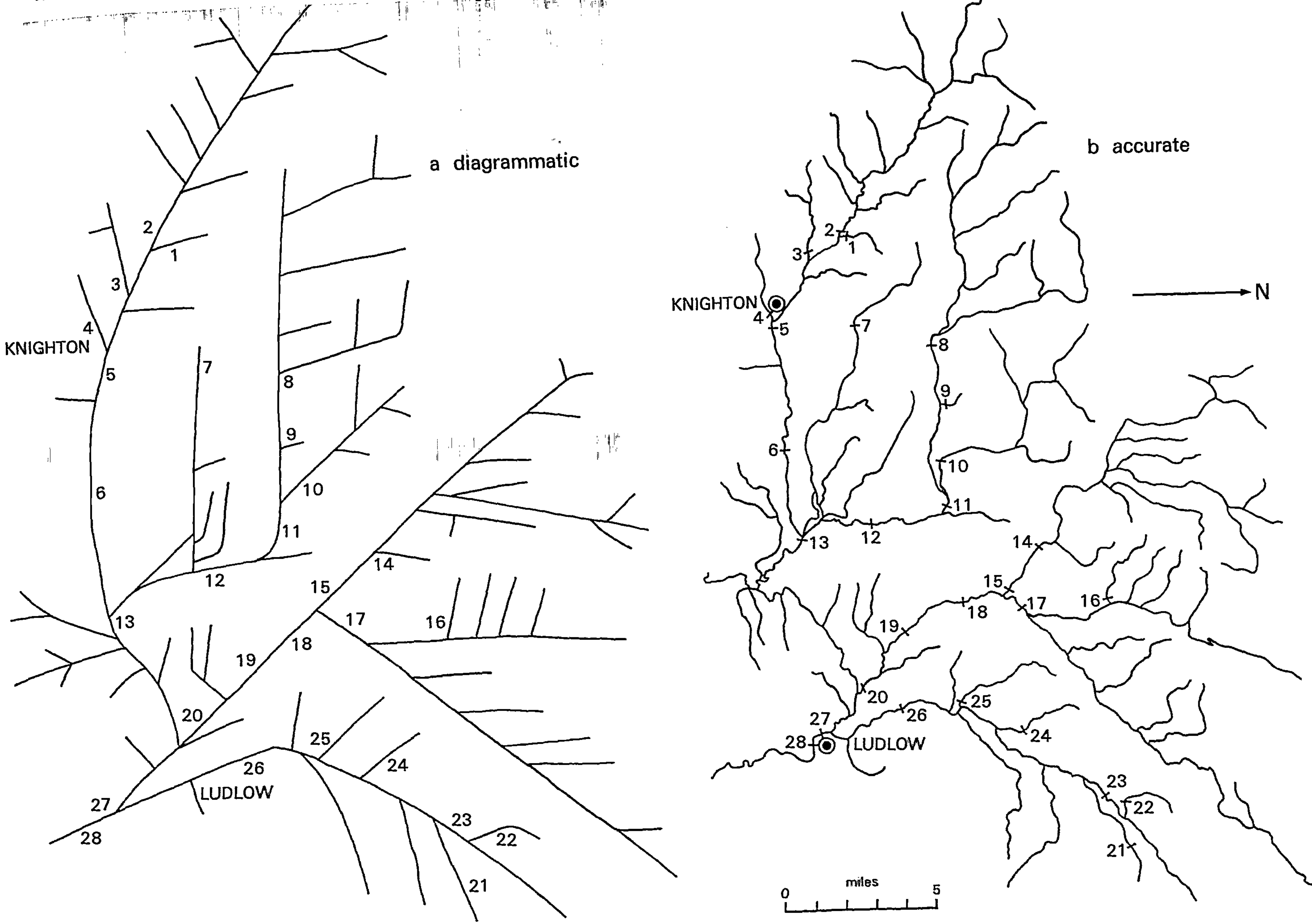


Table A5. To be read with Figures 2a and 2b

Mountain Stream. Upper R Teme (Severn) (1973, 1975)

Species Present at the Sites Numbered.

Stars indicate 'Much'. Blanket weed = trailing algae, usually *Cladophora.*

1. Nil.
2. Nil.
3. *Agrostis stolonifera, Mimulus guttatus, Ranunculus sp.*
4. *Agrostis stolonifera.*
5. *Phalaris arundinacea, Ranunculus aquatilis?,* Moss.
6. *Ranunculus sp,* Moss.
7. *Agrostis stolonifera,* Moss.
8. *Callitriche sp.*
9. *Agrostis stolonifera, Apium nodiflorum, Veronica beccabunga.*
10. *Callitriche sp*.*
11. Nil.
12. *Callitriche sp, Myosotis scorpiodes, Ranunculus sp, Sparganium erectum.*
13. *Agrostis stolonifera, Ranunculus sp, Sparganium erectum,* Moss.
14. *Agrostis stolonifera, Phalaris arundinacea, Ranunculus sp,* Moss, Blanket weed.
15. Nil.
16. *Agrostis stolonifera, Catabrosa aquatica, Epilobium hirsutum, Myosotis scorpioides, Ranunculus sp, Rorippa nasturtium-aquaticum agg, Sparganium erectum,* Blanket weed (site on sandstone, so species-rich).
17. *Myosotis scorpioides, Phalaris arundinacea, Ranunculus sp, Sparganium erectum.*
18. *Phalaris arundinacea, Ranunculus sp,* Blanket weed.
19. *Agrostis stolonifera, Phalaris arundinacea,* Blanket weed.
20. *Myosotis scorpioides, Veronica beccabunga.*
21. *Callitriche sp, Myosotis scorpioides, Veronica anagallis-aquatica agg, Veronica beccabunga,* Blanket weed.
22. *Veronica beccabunga?*
23. *Myosotis scorpioides, Rorippa nasturtium-aquaticum agg, Veronica beccabunga.*
24. Nil.
25. *Agrostis stolonifera, Myosotis scorpioides, Veronica beccabunga.*
26. *Sparganium erectum, Veronica beccabunga,* Moss.
27. *Myriophyllum spicatum, Phalaris arundinacea, Ranunculus sp, Sparganium erectum.*
28. *Phalaris arundinacea, Ranunculus sp,* Moss.

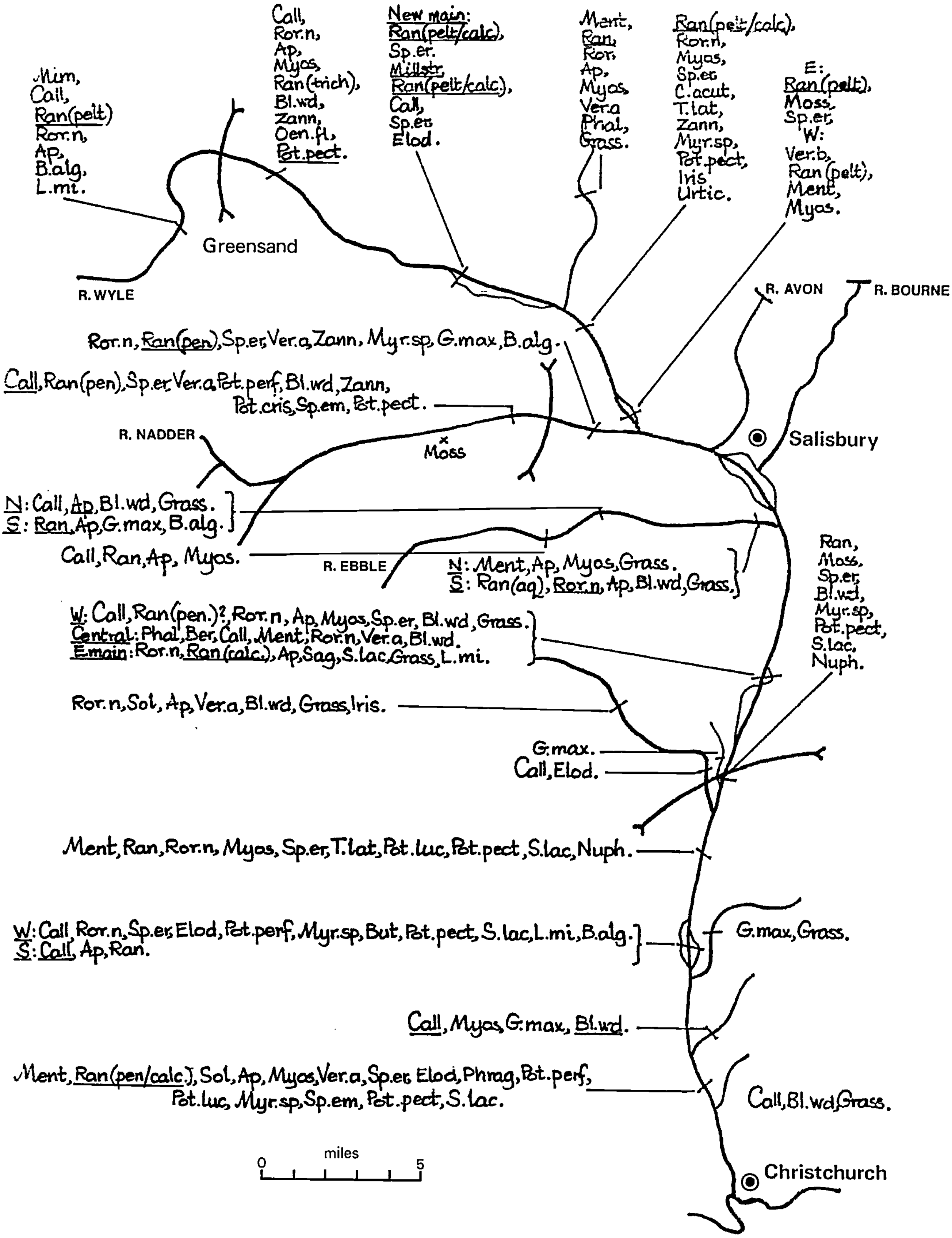


Figure A3 River Avon (Lower) 1977

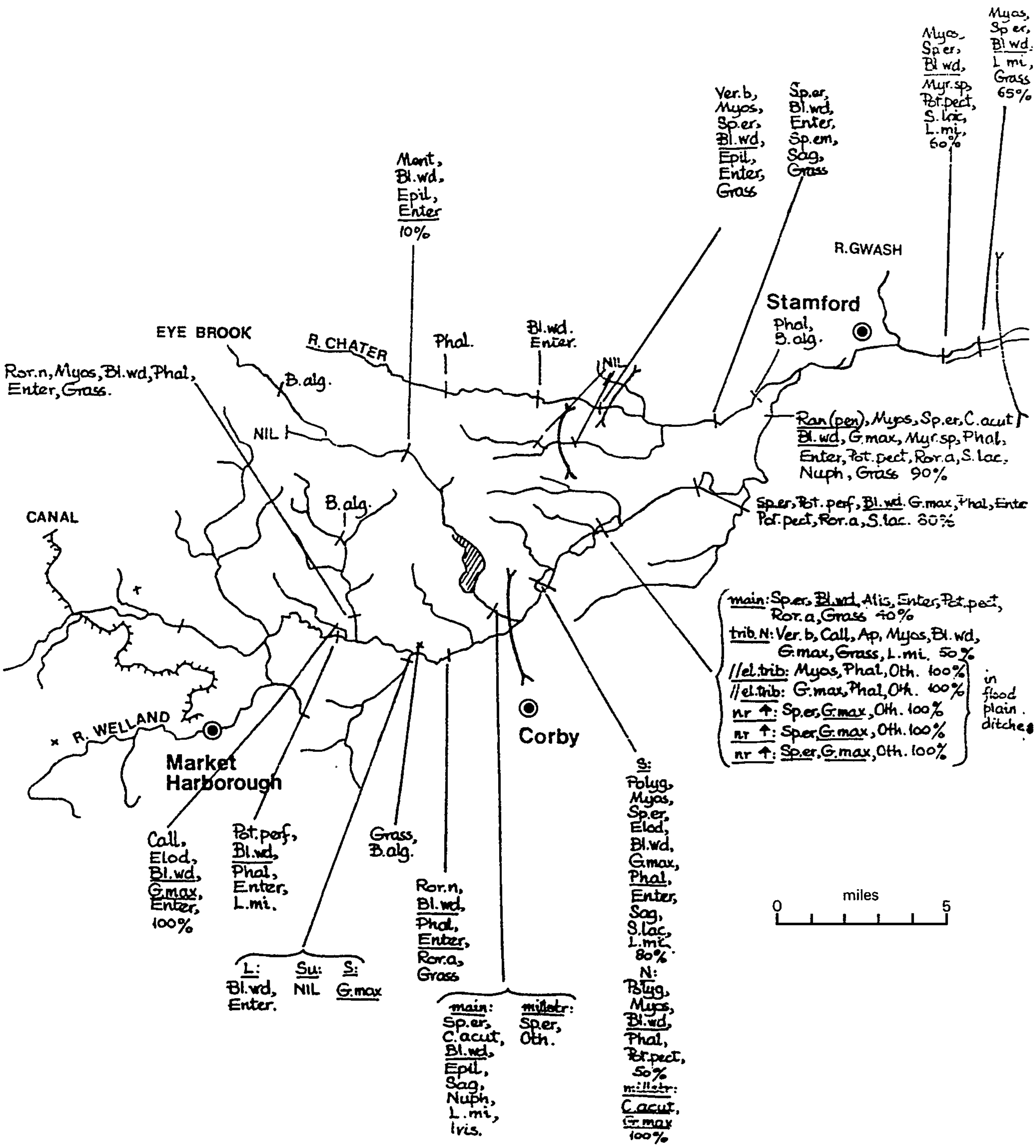


Figure A4 River Welland 1979

A9.1 Example of the use of the Method for Determination of a Stream Damage Rating Index (in conjunction with Haslam and Wolseley 1981) with a worked example.

Once the ecological principles determining river vegetation are understood, indices for assessing any of these controlling factors can be devised. An example of a general damage (including pollution-damage) rating is given below. As described in the text, it is applicable where vegetation is both plentiful and predictable, ie to streams in lowlands and low hills which are large enough to bear water-supported species. This is presented as a guide, not as the only suitable index. Although all indices would estimate vegetation quantity and quality, the methods of assessment as well as the details of a points system, could vary.

A9.1.1 Stream Damage Rating (from Haslam and Wolseley 1981)

In criteria 2, 3 and 4 the site vegetation is compared with the minimum expected in a similar undamaged site (listed separately) assessed as given in Haslam and Wolseley 1981. For criterion 5, a list of species tolerant and semi-tolerant to the particular pollution type is compiled separately. Criterion 7 seems to be applicable in Britain but not in other EEC countries (were the clays etc form less eutrophic habitats for macrophytes).

1. Species diversity allowance*

No species present	0	1–2	3–4	5–6	7–8	9+
Assign figure of:	5	4	3	2	1	0

2. Decrease in diversity: difference between expected and actual number of species*

3. Percentage decrease in percentage vegetation cover

% loss in cover in water up to 1 m deep	100	80–95	60–75	40–55	20–35	0–15
Assign figure of:	5	4	3	2	1	0

4. Change in trophic status band

Change	Over one band	One, or change to uncertain or nil	Half	Dubious	No change
Assign figure of:	4	3	2	1	0

5. Percentage of pollution-tolerant species.
Add once for each tolerant species (and one if one or more land species are rooted in streams ii-v), a half for each semi-tolerant species.

	Nil spp	100% tolerant	75–95	50–70	30–45	15–25	0–10
Assign figure:	5	5	4	3	2	1	0

Assign 4 if only sensitive spp are present but the number present is not over one-sixth of those expected, and 3 if one-quarter (or approx).

6. Weighting for special species

	Much *Potamogeton pectinatus*	Sparse *P. pectinatus* the only sp	Much Blanket Weed Cladophera etc
Assign figure of:	4 (2 if intermediate)	1	2

7. Weighting for clay etc (lower reaches and lowlands only)

clay (iv) clay-mix with much clay (iv)	subtract 2
clay (iii) slower flatter sandstone (iii)–(iv) clay-mix (iv), or if flat, (iii)	subtract 1

Add the numbers in section 1–7. The damage rating is then:

Total	Damage rating
0–4	a
5–7	b
8–10	c
11–13	d
14–16	e
17–18	f
19–21	g
22+	h

If channels with over 15% cover are assessed as h, they are re-classified as g.

* In some instances aggregates are used instead of species, eg *Callitriche* spp (excluding *C. hamulata*) and all mosses.

Mosses restricted to manmade structures (bridge piers, concrete slopes etc) should be disregarded.

By Blanket Weed is meant trailing filamentous algae, easily visible, mostly cladophera, but also including other filamentous green algae.

A9.1.2 Worked Example of Damage Rating (from Haslam 1982)

Details given for each site:

a. stream size	(given as category eg i, ii, iii or iv ie 0–3 m water supported species absent, 0–3 m water supported species present, 4–8 m 10)
b. diversity	(given as the minimum number of species to be expected in an undamaged site of this type eg 6+ spp means 6 or more species expected)
c. % cover	(given as the minimum expected cover for an undamaged site of the same type eg 50+% means 50 or more % of the suitable area of the site is covered)
d. trophic band	(Given in terms of trophic class) eg dystrophic (almost no nutrients) Oligotrophic mesotrophic eutrophic (ample nutrients) intermediate states may be included.
e. species occurring	listed by name if abundant listed as Much if sparse listed as Little.

In this example the expected vegetation at 14 stations falls into the listed categories and is tabulated below

Stream type all lowland

Stream Size	ii	iii	iv
Diversity	6+ (4+) spp	7+ spp	9+ spp
Cover	50+%	60+%	60+%
Trophic bands expected	mesotrophic to semi-eutrophic	semi-eutrophic or semi-eutrophic to eutrophic	semi-eutrophic to eutrophic

R (Severn) Avon, passing downstream. 1975.

1. ii 5 spp, 60%, mesotrophic–semi-eutrophic
   Little: *Phalaris arundinacea*
   Potamogeton crispus
   Ranunculus spp
   Rorippa nasturtium-aquaticum
   Sparganuim erectum

2. ii 6 spp, 80%, mesotrophic–semi-eutrophic
   Much: *Callitriche* spp
   Glyceria maxima
   Little: *Carex acutiformis*
   Myosotis scorpioides
   Phalaris arundinacea
   Sparganium erectum
3. ii–iii 4 spp, 60%, semi-eutrophic
   Much: *Enteromorpha* sp
   Little: *Phalaris arundinacea*
   Sparganium erectum
   Blanket weed
4. (R Swift) ii, 7 spp, 50% (mesotrophic)–semi-eutrophic
   Much: *Enteromorpha* sp
   Little: *Agrostis stolonifera*
   Apium nodiflorum
   Glyceria maxima
   Rorippa nasturtium-aquaticum
   Sparganium emersum
   S. erectum
5. (below Rugby sewage works and R Swift entry) iii, 4 spp, 80%, semi-eutrophic–eutrophic
   Much: *Potamogeton pectinatus*
   Blanket weed
   Little: *Callitriche* spp
   Sparganium erectum
6. iii, iv, 6 spp, 60%, semi-eutrophic–eutrophic
   Much: *Potamogeton pectinatus*
   Little: *Glyceria maxima*
   Scirpus lacustris
   Sparganium emersum
   Sparganium erectum
   Blanket weed
7. iii–iv, 7 spp, 40%, semi-eutrophic–eutrophic
   Much: Blanket weed
   Little: *Iris pseudacorus*
   Nuphar lutea
   Potamogeton pectinatus
   Scirpus lacustris
   Sparganium emersum
   S. erectum
8. iv, 11 spp, 40%, semi-eutrophic–eutrophic
   Much: *Nuphar lutea*
   Sparganium emersum
   Little: *Callitriche* sp
   Lemna minor agg
   Phragmites communis
   Sagittaria sagittifolia
   Scirpus lacustris
   Sparganium erectum
   Typha latifolia
   Enteromorpha sp
   Blanket weed
9. iv, 6 spp, 30%, semi-eutrophic–eutrophic
   Little: *Nuphar lutea*
   Scirpus lacustris
   Sparganium emersum
   S. erectum
   Enteromorpha sp
   Blanket weed

10. (R Sowe) iii, 10 spp, 60% semi-eutrophic
Much: *Nuphar lutea*
Blanket weed
Little: *Callitriche* spp
Elodea canadensis
Phragmites communis
Potamogeton pectinatus
P. perfoliatus
Ranunculus sp
Scirpus lacustris
Sparganium erectum

11. (R Sowe below Coventry sewage works) iii, 4 spp, 80%, (semi-eutrophic)–eutrophic
Much: *Potamogeton pectinatus*
Scirpus lacustris
Little: *Myosotis scorpioides*
Sparganium erectum

12. (below Sowe confluence) iv, 5 spp, 80% (semi-eutrophic)–eutrophic
Much: *Potamogeton pectinatus*
Scirpus lacustris
Little *Sparganium emersum*
S. erectum

12. (Tewkesbury, E) iv, 5 spp, 10%, semi-eutrophic, more boats than W
Little: *Enteromorpha* sp
Glyceria maxima
Nuphar lutea
Sparganium erectum
Blanket weed

14. (Tewkesbury, W) iv, 12 spp, 10%, semi-eutrophic–eutrophic
Little: *Butomus umbellatus*
Glyceria maxima
Nuphar lutea
Phragmites communis
Polygonum amphibium
Potamogeton pectinatus
Rorippa amphibia
Sagittaria sagittifolia
Scirpus lacustris
Sparganium erectum
Enteromorpha sp
Blanket weed

Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Diversity allowance	2	2	3	1	3	2	1	0	2	0	3	2	2	0
2. Diversity decrease	0	0	2	0	3	2	1	0	3	0	3	4	4	0
3. Cover decrease	0	0	0	0	0	0	1	1	9	0	0	0	4	4
4. Trophic band change	0	0	0	0	1	1	1	0	0	0	1	1	½	0
5. Sewage pollution tolerant spp	2	2	4	3	4	4	4	3	4	2	4	5	4	2
6. Special spp	0	0	0	0	6	4	2	0	0	2	4	6	0	0
7. Silting	0	0	0	0	−1	−1	−1	−2	−2	−1	−1	−2	−2	−2
Total	4	4	7	4	16	12	9	2	9	3	14	16	13	4
Rating	a	a	b	a	e	d	c	a	c	a	e	e	d	a

Main Zone influenced by Rugby Sewage

Site 13 is damaged mainly or entirely by boats. Its pollution index must be substantially better than its damage rating, and so be B+ (B or A).

Site 9 had overhanging trees.

B The Survey and Assessment of Macrophytes in Watercourses

B1 Summarized Description of the Method

B1.1	Biota sampled	Macrophytes (plants identifiable with the naked eye).
B1.2	Habitats sampled	'River' habitats (as defined in B5.4) in all watercourses.
B1.3	Basis of operation	Use of check-list to record presence and absence of macrophytes in defined lengths of watercourse surveyed by wading, walking along banks and use of sampling aids. Estimation of relative macrophyte volume and percentage area covered by each macrophyte recorded.
B1.4	Form of data	Qualitative (records of presence and absence of taxa) and semi-quantitative (estimates of relative abundance and cover).
B1.5	Limitations of method	Operator safety (depth, current velocity, bed stability). Season (surveys should generally be carried out during the main growing season of . Mid-June to September). River flow (surveys should not be carried out when increased flow and associated turbidity might lead to macrophytes being overlooked). Water clarity (algal blooms may impair clarity in slow lowland rivers).
B1.6	Efficiency of method	May vary between sites according to ease of safe access to all parts of site, depth and clarity of water.
B1.7	Logistics of sampling	Surveying by one operator, or 2 where safety considerations make this desirable. The length of time spent at each site will depend on ease of access, the nature of the macrophyte community the weather, the experience of the surveyor and the survey length chosen. At most lowland sites surveyors should be able to make a 100 m survey in 1½ hours or a 500 m survey in 3 hours, after previous experience of 2 or 3 such surveys and acquaintance with the common species. This does not include travel time, nor base work before and after the survey, which may require another 2–3 days until most species are readily recognized.

B2 Introduction

B2.1 Principles

The survey technique described in this section provides a means of assessing the occurrence and abundance of macrophytes relatively rapidly and is applicable to a variety of survey purposes. It is flexible, allowing for a total of 7 different combinations of defined survey length and scales for recording the relative biomass and percentage cover of plant taxa defined in a single check-list. Thus to monitor the effects of a discharge on a recipient stream several short (10 m) lengths might be assessed using the most detailed percentage area scale, whereas longer (500 m) lengths would be surveyed to obtain a broad description of the vegetation of a whole river or catchment. All of the options are based on the following conventions to maximize standardization and minimize differences between workers:

a. Definition of the term macrophyte.

b. Recording from a standard survey length of watercourse at each site.

c. Definition of the 'river' habitat surveyed within a survey length.

d. Use of a single, standard check-list to ensure that records of both presence and absence are meaningful.

e. Collection of 2 separate subjective estimates of abundance (Relative Macrophyte Biomass and Percentage Cover) for each macrophyte recorded within the survey length.

B2.2 Definition of Macrophyte

'Any plant observed by the naked eye and nearly always identifiable when observed' (Holmes & Whitton 1977). This definition includes all higher aquatic plants, vascular cryptogams and bryophytes, together with growths of algae which can be seen to be composed predominantly of a single species.

The above definition is an extension of the more traditional definition of a macrophyte which is usually taken to include all higher plants, the few ubiquitous aquatic bryophytes and algae belonging to the Characeae. The inclusion of all bryophytes and larger algae enables the scope of macrophyte surveys to be widened to provide a realistic species complement for rivers with rapid current velocities and rocky substrata. For the purposes of some surveys it may also be useful to extend the above definition by including macroscopic growths which may be composed of several species (eg diatom patches, blue-green films, 'sewage fungus' organisms), and the field check-list (Table B II) may be modified to allow this.

B3 Equipment

B3.1 Field

The following equipment should be available for use in the field, but depending on individual situations some items may not be required.

Boat (only required in some cases, see B5.6), underwater viewing aid (a suitable design is described in method C in this booklet).

Waders, waterproof clothing, approved buoyancy aid, safety harness and rope, wading aid such as stick or rake.

Grapnel, double-headed rake made by wiring 2 rake heads together.

Polarizing glasses, binoculars, 10× hand lens.

SLR Camera with polarizing filter.

Tape measure at least 10 m long.

Clip-board, duplicated check-lists, maps, note-book, pens and pencils, large polythene bag to write in, identification keys, see Reference section, items marked in heavy type.

Polythene bags for collection of larger specimens, tubes for collection of small algae/bryophyte specimens, permanent waterproof markers, labels for insertion in bags.

B3.2 Laboratory

Identification keys (see Reference section, items marked in heavy type), binocular microscope, compound microscope, plant press, thick white paper or card for mounting pressed specimens.

B4 Safety

When carrying out the survey procedures described in Section B5, precautions laid down or recommended in **'Working in or Near Water'**, Water Authority Association, Safety Adviser Broadsheet, must be followed. An additional note on safety is given at the beginning of this booklet, and the following additional precautions are recommended:

B4.1 Lone working is discouraged. Always inform someone of the localities to be visited and estimated times of arrival and departures, and report when home (eg in a 'signing in/out' book). It is strongly recommended that provision be made for summoning help immediately should an accident occur to the surveyor. Portable radios and telephones are useful for this.

B4.2 The survey procedure described below involves entering the river at a number of points within the defined survey length, and in a typical river with a variety of shallow and deeper areas it is often possible for all necessary wading to be carried out in shallow areas with a firm, stable bed and safe access. However, under the following circumstances do not enter the river unless secured with a harness or safety line and wearing an approved buoyancy aid:

a. Sites where access is down a very steeply sloping bank which continues to the edge of the river.
b. Sites where the river is fast flowing and more than 0.5 m deep or where the bed of the river has an accumulation of soft (penetrable) mud more than 0.3 m deep.
c. Sites where the sampling point although shallow is closely upstream of very deep places.

B4.3 Under certain circumstances use of a boat may be required for survey work (see B5.6). Safety procedures for the use of boats are described separately in the initial Hazards Section of this booklet.

B4.4 Rivers may be polluted with pathogens or toxic chemicals. An anti-tetanus injection is recommended and injuries should be treated as soon as possible.

B5 Methods of Surveying

B5.1 Timing of Survey

June to September is the recommended period for surveys: the 4 months when macrophytes are at their most obvious. The growing season in the south varies greatly from that in the north and from year to year, and it may be feasible to extend the survey period for one month either side of the defined 'prime' period. However, the growing season may also be shortened by the effects of pollution, and if a river is to be surveyed only once it should be visited during the recommended June to September period. Both the timing of the survey and the relative abundance of vigorous species will influence the accuracy of identification achieved with some of the macrophytes. This reflects both the availability of taxonomically-useful characteristics (eg flowers, specialized leaves) and the smothering of small species by large aggressive ones.

Surveys for macrophytes in rivers should be carried out at a time of normal low flow when the river is not discoloured, ideally when the river has been at low flow for several days. Apart from safety considerations (Section B4) it should be recognized that a survey carried out when a river is in flood or highly discoloured is unlikely to provide useful information. Timings of weed cuts should be taken into account, since these frequently occur between June and September.

B5.2 Length of Sampling Site

The macrophyte community in a particular stretch of river frequently forms a mosaic of areas dominated by single species, and local environmental factors (eg nature of bed, riffle/pool pattern, shading) cause further variations in species composition. Small sites may therefore not reflect the overall character of the river vegetation, and greater survey lengths may be expected to give a greater representation of microniches, downstream succession and annual changes in populations.

One major study (Holmes, 1983) initially recommended that the ideal survey length to provide the maximum information in the minimum time is 1 km (1000 m) of river. Comparison of results from different survey units has demonstrated that the number of taxa recorded from 0.5 km (500 m) lengths often compares very favourably with the 1 km 'ideal' length and for this reason 0.5 km is the basic unit recommended for macrophyte assessment. 0.5 km lengths are very well suited to providing broad, detailed descriptions of macrophyte communities, but they are not suitable for some other purposes (eg point monitoring at a series of sites to assess quality changes below discharges). For this reason 2 alternative shorter survey lengths of either 0.1 km (100 m) or 0.01 km (10 m) may be employed. The use of one of these shorter lengths means that a significant proportion of species will not be represented, but this may be balanced against the ability to survey greater numbers of closely spaced sites in a given time, and the greater accuracy of abundance estimates attained within smaller sampling units. In the case of the shortest (0.01 km) length this greater accuracy allows the use of the most detailed (9 point) scale for estimating macrophyte cover (see B5.7) and this length is particularly suited for relatively detailed vegetation mapping.

Examples of different applications of the 0.5 km, 0.1 km and 0.01 km survey lengths are summarized in Table B1.

B5.3 Position of Sampling Sites

The number of sites to be surveyed on a particular watercourse or catchment may vary according to the objectives of the survey, for example in relation to the entry of effluent discharges in pollution investigations. However for broad investigations using 0.5 km survey lengths it is suggested that a survey of sites 5–10 km apart represents an efficient use of field time. Wherever possible sites should be included on major tributaries prior to confluence with a river being surveyed, since this helps determine whether changes in the vegetation of the main river below their inflows are due primarily to changes of a physical or chemical nature, or due to the innoculation of new species from the tributaries which are unlikely to be important in the long term.

When selecting the position of individual sites, care should be taken to choose areas that are as typical of the stretch of river being studied as possible, and not influenced by atypical environmental factors. Thus shaded stretches of river should not form the basis of a survey if the channel is generally open, and conversely open stretches in an otherwise occluded watercourse should not be used. Where possible, 0.5 km or 0.1 km lengths should include a variety of habitats (eg riffles, pools). 0.01 km lengths are too small to include a variety of such habitats, and before choosing a series of such sites for monitoring or mapping purposes it must be decided whether to (a) designate 0.01 km lengths irrespective of habitat and/or floral assemblage or (b) deliberately choose lengths of similar habitat and floral assemblage. If the latter is chosen a more comparable assessment can be made of the river's recovery or degradation following inputs made to it.

When designating sites, use should be made of permanent landmarks (eg buildings, trees, hedges) wherever possible to aid relocation of the site limits by other workers or during follow-up surveys. Bridges are particularly useful since they are easily accessible if sites are to be visited frequently, and allow easy access to both banks where wading is impossible. Bridges also allow the surveyor to look down on the vegetation, and a complete 0.01 km length may be viewed from above and photographed if placed next to a bridge. However, in deciding whether to take advantage of bridges in such cases it should be borne in mind that the 0.01 km length may be subject to atypical local factors such as shading, local channel management and disturbance caused by easy access.

The limits of 0.5 km and 0.1 km lengths should be determined accurately by measurement on a suitable Ordnance Survey map (eg 1:50,000 scale) and marked on the map for future reference. Occasionally access to a full 0.5 km or 0.1 km length may prove impossible (eg in towns), and the limits of the actual site surveyed should be marked on the map and the length determined on completion of fieldwork. The exact limits of 0.01 km lengths should be determined using a tape measure, and marked using pegs etc.

B5.4 Habitats Surveyed

The survey technique consists of recording all macrophytes seen wholly or partly submerged within the survey length when the river is at low flow. At the sides of the river all parts of the substrata are included which are likely to be submerged for more than 85% of the time. In general terms, therefore, records are collected for those macrophytes which occur in the region of the river which is rarely uncovered, and those shallow sections which have an upper limit that may be exposed for a maximum of 50 days in any year. In most cases such estimates involve guesswork, but at least the adoption of a particular submergence level provides a quantitative basis which could be employed under ideal conditions. Although the technique does not include bankside species growing above the waterline, other accounts (eg Holmes, 1983) define the 'Bank' habitat and suggest conventions for recording such species. Whilst surveying submerged macrophytes the presence of 'nuisance' bankside species (eg *Impatiens glandulifera*, *Heracleum mantegazzianum*) may also be noted with little extra effort. (Very recently the practice of surveying river corridors as a whole, including trees has been developed (see Nature Conservancy Council (1985).

B5.5 The Check-List

Before commencing fieldwork a check-list of macrophytes that might be expected to occur in the watercourses being surveyed should be prepared or obtained, and used to construct a recording sheet that can be duplicated and used in the field. **The use of a check-list is important, since it implies that if a macrophyte included in the list is not recorded it is not present in a visible form, and that records for the absence of macrophytes are as reliable as records of occurrence.** For the purposes of this method a single Check-List has been constructed (Table BII) for use with any of the 7 acceptable combinations of survey length and abundance scale shown in Table B 1. The list was constructed using the following principles:

a. inclusion of all relatively common or widespread aquatic macrophytes found in river habitats during a previous study throughout the British Isles;
b. exclusion of particularly rare aquatic species;
c. exclusion of those species whose habitat is typically the river bank or marginal mud even if such plants may occasionally extend into the 'river' habitat;
d. inclusion of 'dumping ground' categories to allow all macrophyte material to be recorded even where identification is not possible;
e. inclusion of spaces so that additional taxa may be added if required for specific purposes, or if the definition of the term 'macrophyte' is extended to include growths such as diatom patches or 'sewage fungus' (see B2.2).

B5.6 Recording of Macrophytes

Whilst recording macrophytes wading should generally proceed in whichever direction takes best advantage of available light. However, it is less tiring to wade swiftly flowing rivers with rocky or gravel beds from upstream to downstream. Silt-bedded rivers should be surveyed from downstream to upstream, so that silt disturbed during wading is carried away from the surveyor. In shallow rivers with a firm bed the whole of the length should be surveyed by wading in a zig-zag pattern, with frequent inspection of different habitats (eg riffles, boulders, banks, tree roots). Where safe access for wading is more restricted within a 0.5 km length an attempt should be made to survey a total of about 0.1 km intensively by wading (including unshaded riffle areas) with the remainder of the length being surveyed by walking along the banks and entering the river frequently by suitable safe points. Where all or most of a 0.5 km length cannot be surveyed by wading, a 0.1 km section should be surveyed intensively by the use of a grapnel or double-headed rake, and the remainder surveyed primarily from the banks or by boat. Grapnel searches may uproot or damage rare plants, and they should therefore only be carried out where absolutely necessary, and after seeking advice from the local Nature Conservancy Council Office or Naturalists' Trust. Grapnel hauls near locally rare or visually attractive plants should be avoided if possible, and every effort should be made to avoid damaging or uprooting plants scheduled under the Wildlife and Countryside Act 1981 (see advice at the end of this section and sections A3.1m and A5.4.1 of this booklet). When carrying out grapnel or rake searches at a particular point it is suggested that several separate hauls should be taken at different widths across the channel. By taking as many as 6 hauls, the entire width may be sampled but the loss of less abundant species which might occur due to clogging of the grapnel or rake during a single long haul can be avoided. However it should always be remembered that fine-leaved or deep-rooted macrophytes may be seriously under-recorded by grapnel sampling, whereas the abundance of bushy species such as *Elodea* may be over-estimated. In the case of deep 0.01 km lengths where accuracy is especially important, a tethered boat should be used together with a suitable underwater viewing aid (eg glass-bottomed box).

All macrophytes observed in 'river' habitats should be ticked-off on the check-list as they are encountered. Plants being transported by the current should not be included, with the exception of floating species such as *Lemna* which can build up temporary populations in near stagnant areas. The levels to which individual macrophytes are identified is a matter of choice according to the objectives of the survey, providing that the check-list makes these levels clear. For example if no attempt is to be made to separate species of *Callitriche*, all records for the genus should be recorded against *Callitricha* indet on the list. As a general guide identification should be taken to species level where material permits, with the use of the 'dumping ground' categories on the check-list (eg for unidentified grasses) in cases where accurate identification is attempted but proves impossible.

The number of macrophytes that can be identified in the field will increase with experience, but the collection of specimens for later identification will form a necessary part of most surveys. Where plants have been noted as separate macrophytes in the field but not identified they should be specified by marginal notes on the check-list (eg as Moss 'A', *Ranunculus* 'B') with later modification of the list when specimens have been identified. Even where most larger macrophytes can be identified without the collection of specimens it is advisable to collect small representative samples of algae and bryophytes so that records can be confirmed in the laboratory.

B5.6.1 It should be remembered that macrophytes are protected by law under the Wildlife and the Countryside Act (1981). Permission to collect specimens should be obtained from the owner or occupier of the land or the relevant local authority, and material collected should be confined to the minimum necessary for identification. Whole plants should never be uprooted, and portions of scarce macrophytes should only be removed where absolutely necessary (under no circumstances must those rare species listed in Schedule 8 of the Act have any parts whatsoever collected). As in Method A, in circumstances such as this, where a record is required, photography should be considered (see Sections A3.1 and A5.4.1).

B5.7 Assessment of Relative Abundance and Percentage Cover

When all macrophytes present in river habitats within the survey length have been noted on the check-list, 2 separate semi-quantitative estimates of abundance are allocated to each macrophyte within the length, ideally in 2 separate headed columns alongside the macrophyte name on the check-list. These estimates are for: (a) Relative Macrophyte Biomass and (b) Percentage Area. Different survey objectives may require differing levels of definition in estimating macrophyte abundance, and the method therefore allows one of 3 scales to be used for estimating Percentage Cover. When combined with the 3 alternative survey lengths described in B5.2, 7 separate survey approaches are possible. These options are listed in Table B1.

a. Relative Macrophyte Biomass

This represents a straightforward comparison of the relative amount of one macrophyte species against all other macrophytes within the defined survey length, using a scale increasing from one to 5 as follows:

1 Very sparse

2 Sparse

3 Moderate

4 Abundant

5 Very Abundant

Such estimates are subjective, but it may be helpful to keep in mind the ideal situation where the biomass might be determined more accurately by measurement of dry weight (Methods, 1985).

As the total biomass of macrophytes varies greatly between different sites, a particular number (1–5) on the relative macrophyte biomass scale may represent quite different amounts of the same species in different lengths. For instance, one length might contain only one plant each of a large *Ranunculus* species and a tiny plant of *Fontinalis antipyretica,* whereas a second length might be choked by growths of the former which overlie growths of the latter. In both cases the *Ranunculus* would be scored as 5 relative to the *Fontinalis* which would probably be scored as 2, although the 2 lengths have very different standing crops.

b. Percentage Cover

This estimate is made to distinguish between survey lengths with different percentage cover, as in the example given above, and is based on subjective estimates of the percentage area of river covered by each macrophyte within each survey length. Where one macrophyte occurs closely intermingled with another, or overlying it, the area covered by each species is estimated separately from the other species.

One of 3 species scales (A, B or C) may be used for estimating percentage cover, and the scale to be used must be selected before surveying is commenced:

Scale A	*Scale B*	*Scale C*	
A1 $<$ 0.1%	B1 $<$ 0.1%	C1 $<$ 0.1%	C6 10–25%
A2 0.1–1%	B2 0.1–5%	C2 0.1–1%	C7 25–50%
A3 1–5%	B3 $>$ 5%	C3 1–2.5%	C8 50–75%
A4 5–10%		C4 2.5–5%	C9 $>$ 75%
A5 $>$ 10%		C5 5–10%	

Scale A provides quite detailed information on percentage cover, and may be used when Surveying 0.5, 0.1 or 0.01 km lengths. In practice its use has been found to result in a good measure of agreement (with differences rarely exceeding 2 categories) when surveyed by different individuals. Scale A must be employed if the Plant Community Description (see B6.2.2) is to be used for monitoring purposes. The simplified Scale B may be used where detailed information on percentage cover is not required. Use of the most detailed scale (C) requires a higher degree of accuracy, and it is only suitable for use with the shortest (0.01 km) survey length during detailed monitoring or mapping exercises.

When surveying 0.1 or 0.01 km lengths estimating percentage cover values for the whole site is relatively straightforward. However estimation within 0.5 km lengths may prove more difficult, and it is often helpful to concentrate on relatively small areas and then relate these to the whole site. Thus for example a dense strand of vegetation which stretches from bank to bank, and extends for 5 m downstream, will cover 1% of the 500 m stretch. Similarly to record a macrophyte as covering an area of 5% requires it for instance to cover the bed for 25 m, cover half the bed for 50 m, a quarter of the bed for 100 m or occur throughout the whole 500 m but only sparsely.

At some sites, macrophyte vegetation may show longitudinal banding with a strip of marginal vegetation adjacent to each bank and a central deeper channel supporting other species. In such cases it may be helpful to estimate the area of a measured length of marginal vegetation (eg 10 m) occupied by each species and then calculate the marginal contributions as a percentage of the total site area:

$$\text{Marginal Width } (W_M) \times \text{length of margins } (2L) \; (2 \times \text{site length}) = \text{Marginal Area } (A_M)$$

$$\text{and Percentage Marginal Vegetation } (M\%) = \frac{A_M}{\text{Total Site Area } (A_T)}$$

An example of how the records for 2 species might be expressed (using the Relative Biomass Scale and Percentage Cover Scale A) is as follows:

Potamogeton pectinatus 5A5 — ie most abundant macrophyte, cover more than 10%.

Cladophora spp 3A2 — ie less abundant, cover between 0.1% and 1%.

To avoid possible confusion, it is important to record the actual scale used for estimation of percentage cover by ticking one of the boxes provided on the check-list for this purpose, and by prefixing cover estimates with A, B or C as shown above.

B5.8 Recording of Additional Relevant Information

Recorded details of habitat features of river sampling sites can aid considerably in understanding the environmental factors influencing macrophyte communities, as well as providing additional information of use when assessing sites for nature conservation purposes. Where survey lengths coincide with sites sampled by Water Authorities for other purposes, some information on permanent features (eg altitude, distance from source and confluences) may already be archived, and additional features such as surface geology and channel slope may be obtained from relevant maps. Further information on physical features affecting a particular length (eg range of substrata, water depth, water velocity, river width, bank slope, bank type, habitats within the river, shade, stability, adjacent land use) can be collected whilst surveying. As with data on macrophytes, it is important that data on habitat features are collected in a consistent way, for example by the use of a recording sheet printed on the reverse side of the macrophyte check-list. An example of such a recording sheet is shown in Table BIII.

B6 Uses of Data

The survey technique described above provides a compromise between detailed vegetation mapping procedures (eg Wright *et al,* 1981) which may be time-consuming, and the technique for rapid assessment of macrophytes described in Method A of this booklet. The present technique has been developed from one used originally to collect data to assess the effects of a proposed water transfer scheme (Holmes & Whitton, 1977), and modified versions of this original method have subsequently been used for other purposes in the UK. However, river macrophytes have generally received far less attention by biologists than other biota (eg invertebrates, fish), and the following sections have therefore been included as examples of actual studies in which data on macrophyte distribution have been put to practical use. Section 6.1 describes a study carried out throughout the UK with the aim of classifying river vegetation for conservation purposes, and section B6.2 describes a study carried out within one Water Authority area to assess the value of macrophyte surveys for pollution monitoring. In addition section B6.3 suggests further reading on another technique (for monitoring metal contamination) which may usefully be carried out at the same time as surveys of macrophyte distribution.

B6.1 Typing Rivers According to their Flora for Conservation Purposes (Studies Carried out Throughout the UK by Nature Conservancy Council)

Macrophytes were used in a national survey of rivers in an attempt to construct a classification system for British rivers (Holmes, 1983). In all cases a checklist of species was used and 1 km lengths of river were surveyed. However each 1 km unit comprised of two 0.5 km lengths so that an assessment of the effectiveness of the shorter survey unit could be made. Analyses illustrated that the smaller unit was a viable unit for a satisfactory classification of rivers using plant assemblages.

The survey of each site involved recording the presence and abundance of macrophytes within the channel and on the banks immediately above the low-water mark. In this respect the survey differed from those proposed in this document since the prime consideration of the latter is for plants rooted within the permanently submerged parts of the channel. The survey required adherence to a checklist so that the absence of a record for a species was as important for the analysis as the positive records of species present.

One of the prime purposes of the surveys was to erect a working classification of rivers in Britain which could be used for nature conservation purposes. Since most previous work of this nature had culminated in essentially descriptive accounts, this publication provided a more objective classification of rivers based upon rigorous computer analyses of data collected from over 1,000 sites on over 150 rivers.

The classifications of survey sites produced from the computer analyses were better than predicted. At the coarse end of the classification all upland rivers on acid soils were grouped together whilst those in the lowlands were classified together. Virtually all exceptions to this generalization were usually obvious; for instance the rivers on the acid soils of the New Forest were classified amongst the upland sites whilst enriched sites on more upland rivers were classified amongst the lowland communities. At the detailed end, the classification proved to be exceptionally sensitive in accurately classifying small differences in the physical and chemical features of sites. For instance all Chalk rivers had their communities predictably classified together but surprisingly the macrophytes were sensitive enough to recognise 4 distinct, and definable, types of Chalk streams. In other examples different 'broad river categories' were further classified to reflect differences in past management, habitat variety and water quality.

For nature conservation evaluation it is important to have a working classification which enables national and regional differences to be considered. The data from the survey were used to create a hierarchical system of classification based upon altitude, geology and trophic status. This system has provided an objective classification which enables the floral assemblages of rivers to be used to not only illustrate downstream successional changes but also to assess why such changes occur in relation to both the national expectation for the river type and the local character of the river and the individual site.

The use of macrophytes has allowed an objective evaluation of the extent, range and variation in plant communities in different types of rivers. With the development of this classification it has been possible to assess the recorded macrophyte community at a site with that which should have been expected. For instance, a clay river will have several key species which are common to this type of river and if the recorded assemblage departs from the expected one, certain conclusions may be drawn. Possible assessments may involve comparing the species richness of comparable sites or the presence or absence of individually rare species. Since any major deviations from the expected flora are likely to reflect the variety (or lack) of habitat diversity, water and/or substrate chemistry and quality, or even extent of recent management, the use of macrophytes in a river has been shown to be a valuable tool for both Water Authority biologist and nature conservationist alike, and is less time consuming than other approaches. Details of the survey methodology and classification are given in Holmes (1983). This document also describes the different community types and where they are distributed within Britain. Further information on the system can be obtained by writing to the author at the address given at the end of this booklet. Details can be provided enabling biologists to survey and classify their rivers using this nationally applicable system.

B6.2 Monitoring of River Quality—The Plant Score and Plant Community Description (Studies Carried out by North West Water Authority)

B6.2.1 Background

The use of indices to reduce or condense biological data and so present it in a clear and concise form has been justified on several occasions in the scientific literature. As Hellawell (1978) points out: 'Loss of information is inevitable but this may be balanced against the overall gain in general comprehension particularly by the non-biologist'. The work of Haslam (Haslam, 1978; Haslam & Wolseley, 1981) has contributed greatly to the use of macrophytes for pollution monitoring, and to date her Damage Rating and Pollution Index (described in Method A of this booklet) are the only macrophyte indices that have been tested nationally. However, as with invertebrates, a variety of approaches is possible and potential still exists for working biologists to develop systems that could be used to supplement the various invertebrate indices that are used throughout the UK for pollution monitoring.

Between 1978 and 1980 biologists employed by the North West Water Authority (NWWA) undertook a detailed survey of the distribution of macrophytes in 27 rivers within the Mersey and Ribble Basins. The specific aim of the project was to assess whether data on macrophyte distribution and abundance could be used to indicate general river quality in the study area, and, if so, to decide whether such monitoring provided useful information on river quality over and above that gained by invertebrate and chemical monitoring, or provided information of equal value for less effort. A total of 386 0.5 km lengths was surveyed using the technique described in sections B2–B5, with the sites being selected to show a range of water quality conditions from NWC Class I to Class IV (for a description of the NWC classification scheme see Methods, 1983). In addition, sites on one river were surveyed during the first 3 years following a marked improvement in the chemical quality of the river water.

The findings of the survey have been described and discussed in a NWWA report that is available on request (Harding, 1981). The indices described below were developed solely from the findings of the survey, and are therefore likely to prove most reliable in rivers similar to those in the Mersey and Ribble basins. Not all of the macrophytes listed in Table B II were recorded in the survey area, and it is probable that the tolerances of some macrophytes to pollution differ in different geographical and geological areas of Britain. For these reasons further testing and evaluation would be needed before the indices could be recommended for wider use, and it is anticipated that with experience biologists in other areas might wish to suggest 'fine adjustments' and additions which would result in a more universally applicable system. Addresses for relevant correspondence are given at the end of this booklet.

B6.2.2 Indices

Two simple, complementary indices (Plant Score and Plant Community Description) were constructed using the results of the NWWA survey. The Plant Score is designed to reflect both general species diversity and the presence of pollution-sensitive macrophytes, whilst the Plant Community Description provides a concise summary of the relative abundance of important groups of macrophytes. Neither system places too much emphasis on the presence or absence of 'key' macrophytes, since the survey indicated that some species were absent from some sites because of failure of dispersal between catchments.

a. The Plant Score

This score is constructed in a similar way to the BMWP invertebrate score (Biological Monitoring Working Party, 1979), with individual macrophytes being allocated a score between 1 and 10 depending on their estimated relative tolerance to nutrient enrichment and/or organic pollution (low scores for tolerant macrophytes, higher scores for more sensitive macrophytes). Table BIV lists scores for 83 of the macrophyte taxa included in the field checklist (Table BII); scores for several other macrophytes are given in Harding (1978). To calculate the Plant Score for a site the scores for all individual macrophytes recorded within the defined length of river (eg 0.5 km) are simply added together. In this way higher scores reflect both the presence of sensitive macrophytes and greater species diversity. Surveys of 0.01 km lengths should not be used to calculate values of Plant Score, since they are unlikely to provide a representative sample of the total species compliment of a stretch of river. Surveys of 0.5 km lengths will generally yield greater number of macrophytes (and hence higher Plant Scores) than surveys of 0.1 km lengths, and the length used should always be stated when quoting score values. Examples of uses of the Plant Score are shown in Figures B1 and B2.

Comparison and interpretation of Plant Score values from different sites may be aided by calculating values of Average Score per Taxon (ASPT) for each site, where:

$$\text{ASPT} = \frac{\text{Plant Score}}{\text{Number of individual macrophyte score values contributing to Plant Score}}$$

Values of ASPT should provide a better measure of the pollution sensitivity of the contributing macrophytes, whereas Plant Score values alone may be elevated or depressed by factors unrelated to pollution pressure (eg unusually high or low habitat diversity, shading). ASPT values also provide a means of comparing scores from 0.5 km and 0.1 km lengths, although for the reason stated above greater confidence can be placed in ASPT values from 0.5 km lengths.

b. **Plant Community Description (PCD)**

This system is based on a standarized shorthand description of the relative abundance of important macrophyte taxa within a defined survey length. Clearly defined rules are used to assign a 2-letter classification to a sample according to the area of river bed covered by the following key groups:

group a = all bryophytes excluding *Amblystegium riparium* and *Fontinalis antipyretica* (which is not included in any group).

group b = all rooted angiosperms excluding *Potamogeton pectinatus.*

group c = *Cladophora spp.*

group d = *Potamogeton pectinatus* and/or Blue-Green Films and/or *Stigeoclonium spp* and/or *Vaucheria spp* and/or *Amblystegium riparium.*

The decision to asign PCD values to the results of a survey should be taken before commencing fieldwork, since the **total** percentage area covered by macrophytes within each of the 4 key groups needs to be assessed independently from the percentage area estimates for individual macrophytes. On completion of a survey length each group of macrophytes is assigned a number (A1–A5) from percentage cover scale A according to the **total** area covered by plants of that group. Thus if the area covered by rooted angiosperms excluding *Potamogeton pectinatus* was estimated as between 5% and 10%, then Group b plants would be assigned a percentage cover value of A4. Having assigned values to all 4 groups (a–d) in this way, the rules given in Table V are used to calculate the PCD for the site.

In this way a PCD of aa would be applied to a community dominated by mosses; ac might apply to a community dominated by mosses and *Cladophora spp*; db might describe a community dominated by *Potamogeton pectinatus* and *Ranunculus fluitans*, and the macrophyte community of a highly eutrophic or polluted river would probably have a PCD of dd (although *Stigeoclonium* and Blue-Green films may sometimes be dominant in certain environments in clean rivers and streams).

It should be stressed that, despite the emphasis placed on dominance by important quality indicator groups, the PCD should not be used in isolation for monitoring purposes. Rather, it is intended to provide a standardized 'shorthand' description of dominance by major groups which can then be taken into account together with the Plant Score which when quoted in isolation gives no indication of the presence or abundance of important taxa. In order to communicate the maximum possible information on the vegetation of a particular site, it has been found useful to quote values for Plant Score and PCD together. For example, 63bc would signify a fairly diverse community dominated by rooted angiosperms together with quite marked growths of *Cladophora spp* (suggesting some nutrient enrichment).

B6.3 Uses of Macrophytes to Monitor Contamination by Heavy Metals

Many submerged plants accumulate heavy metals from the water surrounding them, and chemical analyses of plant tissues may provide valuable information on metal contamination in rivers and streams. Several workers (eg Whitton, Say & Wehr, 1981) have suggested that such an approach has a number of advantages over more usual methods of chemical and biological surveillance. For example:

a. Macrophyte tissues concentrate metals from water, thereby increasing the sensitivity of monitoring when aqueous levels are at or near the limit of detection.

b. Plant 'monitors' provide an integrated record of pollution within a particular system, because metals are accumulated and released over extended periods. This may be important where pollution is intermittent, and by harvesting plants after a pulse of contamination has passed downstream it is possible to detect pollution after it has occurred.

c. The collection of suitable plant materials provides an easy method for people without access to water sampling facilities. Samples of moss can, for example, be collected by anyone who suspects that contamination may occur at a site.

d. It is reasonable to assume that metal accumulation by a plant gives a better indication of the fraction of the metal in the environment which is likely to affect the aquatic ecosystem than most types of direct chemical analysis.
e. Dried plant materials are much easier to keep than water samples. They are compact and stable (with respect to most elements, though probably not mercury), so they are particularly suitable for long-term storage.

A variety of different methods can be adopted when plant composition is to be used for monitoring levels of heavy metals in a river. Techniques for the collection, fractionation, cleaning, drying, digestion and analysis of macrophyte tissues are to be the subject of a forthcoming booklet in this series, and the main features of such techniques have been summarised by Whitton, Say & Wehr (1981). These authors also recommend a 'package' of 10 macrophytes for which at least some relevant research has been carried out, and which should be sufficient to cover the majority of river sites in Great Britain. Data on macrophyte distribution gained through use of the techniques described in this booklet can be used as a basis for the selection of those 'standard' macrophytes which are sufficiently widespread in a particular catchment to provide useful information on metal contamination.

Table B1 Acceptable Combinations of Survey Length and Scales for Estimation of Percentage Area

Option	Survey Length	Percentage Area Scale	Applications
1	0.5 km (500 m)	Scale A (5 point)	The most suitable option for broad, detailed surveys of macrophyte distribution and abundance. Will provide accurate information on species composition together with detailed information on Relative Biomass and Percentage cover eg Broad-scale river quality investigations, assessment of amenity or conservation value, assessment of overall macrophyte abundance.
2	0.5 km (500 m)	Scale B (3 point)	Less time consuming than option 1, but provides less detailed information on abundance of macrophytes. Recommended for those wishing to do detailed surveys but lacking the experience needed for assessing abundance values.
3	0.1 km (100 m)	Scale A (5 point)	More rapid than options 1 and 2, and allows for closer spacing of sites, but a significant proportion of species will not be recorded. Useful to gain detailed picture of changing macrophyte abundance within individual rivers, or for detecting significant changes in stretches surveyed previously using option 1.
4	0.1 km (100 m)	Scale B (3 point)	More rapid than option 3. Same constraints as option 3 for species list determination, but provides less detailed information on abundance. Useful for rapid follow-up surveys in stretches surveyed previously using option 2.
5	0.01 km (10 m)	Scale A (5 point)	Short survey length enables greater accuracy to be attained in Relative Biomass and Cover estimates, but will not provide a representative species complement. Particularly useful for point monitoring of several sites above/below individual discharges.
6	0.01 km (10 m)	Scale C (9 point)	Provides detailed information on macrophyte cover in relatively short stretches. Suitable for vegetation mapping, or detailed point monitoring above/below discharges etc.
7	0.01 km (10 m)	Scale B (3 point)	The most rapid survey option suitable for use where relatively little information on macrophytes is required. Surveys using option 7 could be appended to other surveys (eg invertebrate sampling) without demanding excessive field time.

Table B 2

MACROPHYTES IN WATERCOURSES—FIELD CHECK-LIST

RIVER ____________________ SITE ____________________ SURVEYOR ____________________

NGR top ____________________ NGR bottom ____________________ Date + time ____________________

Survey method (for keys to Relative Biomass & Percentage Cover scales see overleaf):

Site Length	0.5 km (500 m)				0.1 km (100 m)				0.01 km (10 m)					
Cover scale	A		B		A		B		A		B		C	

	Rel	Cov		Rel	Cov		Rel	Cov
ALGAE:			*Littorella uniflora*			*Elodea canadensis*		
Blue-Green Mats			*Mentha aquatica*			*Elodea nuttallii*		
Batrachospermum sp(p)			*Menyanthes trifollata*			*Glyceria maxime*		
Hildenbrandia rivularis			*Montia fontana*			*Glyceria other sp(p)*		
Lemanea fluviatilis			*Myosotis sp(p)*			*Groenlandia densa*		
Vaucheria sp(p)			*Myosoton aquaticum*			*Iris pseudacorus*		
Enteromorphia sp(p)			*Myriophyllum alterniflorum*			*Juncus acutiflorus*		
Stigeclonium sp(p)			*Myriophyllum spicatum*			*Juncus articulatus*		
Cladophora sp(p)			*Nasturtium officinale agg.*			*Juncus bulbosus*		
Other filamentous Greens			*Nuphar lutea*			*Juncus effusus*		
Chara sp(p)			*Nymphaea alba*			*Juncus inflexus*		
Nitella sp(p)			*Oenanthe crocata*			*Juncus sp(p)*		
LIVERWORTS:			*Oenanthe fluviatilis*			*Lemna gibba (gibbous)*		
Chiloscyphus polyanthos			*Polygonum amphibium*			*Lemna minor agg*		
Marsupella emarginata			*Potentilla palustris*			*Lemna trisulca*		
Nardia compressa			*Ranunculus aquatilis*			*Phalaris arundinacea*		
Pella endiviifolla			*Ranunculus calcareus*			*Phragmites australis*		
Pellia epiphylla			*Ranunculus circinatus*			*Potamogeton alpinus*		
Scapania undulata			*Ranunculus flammula*			*Potamogeton berchtoldii*		
Solenostoma sp(p)			*Ranunculus fluitans*			*Potamogeton crispus*		
Foliose Liverworts indet			*Ranunculus hederaceus*			*Potamogeton friesii*		
Thalloid Liverworts Indet			*Ranunculus omiophyllus*			*Potamogeton gramineus*		
MOSSES:			*Ranunculus peltatus*			*Potamogeton lucens*		
Amblystegium fluviatile			*Ranunculus penicillatus*			*Potamogeton natans*		
Amblystegium riparium			*Ranunculus trichophyllus*			*Potamogeton pectinatus*		
Cinclidotus fontinaloides			*Ranunculus sceleratus*			*Potamogeton perfoliatus*		
Fontinalis antipyretica			*Ranunculus indet*			*Potamogeton polygonifol*		
Fontinalis squamosa			*Rorippa amphibia*			*Potamogeton praelongus*		
Hygrohypnum luridum			*Rumex hydrolapathum*			*Potamogeton pusillus*		
Hygrohypnum ochraceum			*Solanum dulcamara*			*Potamogeton indet*		
Racomitrium aciculare			*Veronica anagalis-aquatica*			*Potamogeton other sp(p)*		
Rhynchostegium riparioides			*Veronica beccabunga*			*Sagittaria sagittifolia*		
Sphagnum sp(p)			*Veronica catenata*			*Scirpus fluitans*		
Mosses indet			MONOCOTYLEDONS:			*S. lacustris/tabernaemon*		
VASCULAR CRYPTOGAMS:			*Acorus calamus*			*Scirpus maritimus*		
Azolla filiculoides			*Agrostis stolonifera*			*Sparganium angustifolim*		
Equisetum fluviatile			*Alisma lanceolatum*			*Sparganium emersum*		
Equisetum palustre			*Alisma plantago-aquatica*			*Sparganium erectum*		
DICOTYLEDONS:			*Alopecurus geniculatus*			*Spirodela polyrrhiza*		
Apium inundatum			*Butomus umbellatus*			*Typha latifolia*		
Apium nodiflorum			*Carex acuta*			*Zannichellia palustris*		
Berula erecta			*Carex acutiformis*			ADDITIONS:		
Callitriche hamulata			*Carex aquatilis*			1.		
C. hermaphroditica			*Carex elata*			2.		
Callitriche obtusangula			*Carex paniculata*			3.		
Callitriche platycarpa			*Carex riparia*			4.		
Callitriche stagnalis			*Carex rostrata*			5.		
Callitriche indet			*Carex vesicaria*			6.		
Caltha palustris			*Carex indet*			7.		
Ceratophyllum demersum			*Carex other sp(p)*			8.		
Epilobium hirsutum			*Catabrosa aquatica*			9.		
Hippurus vulgaris			*Eleocharis sp(p)*			10.		

Table B 3 Macrophytes in Watercourses—Habitat Features

RIVER .... SITE .... SURVEYOR ....

NGR top .... NGR bottom .... Date + time ....

LENGTH SURVEYED (tick) 500 m ☐ 100 m ☐ 10 m ☐

PHYSICAL RECORDS Record 1, 2 or 3 in boxes below, where:

1 = <5% of total, 2 = 5–25% of total, 3 = >25% of total

WIDTH (m)	<1 ☐	1–5 ☐	5–10 ☐	10–20 ☐	>20 ☐
DEPTH (m)	<0.25 ☐	0.25–0.5 ☐	0.5–1.0 ☐	>1.0 ☐	
SUBSTRATES	Bed rock ☐	Boulders ☐	Cobbles ☐	Pebbles ☐	Gravel ☐
	Sand ☐	Silt/mud ☐	Clay ☐	Peat ☐	
HABITATS	Pools ☐	Slacks ☐	Riffles ☐	Fast, deep water ☐	
SHADING Left Bank:	None ☐	Slight ☐	Moderate ☐	Dense ☐	
Right Bank:	None ☐	Slight ☐	Moderate ☐	Dense ☐	

KEYS TO SCALES FOR ESTIMATING RELATIVE MACROPHYTE BIOMASS AND PERCENTAGE COVER

Before selecting scales see Section B5.7 of this booklet.

RELATIVE MACROPHYTE BIOMASS (abbreviated as "Rel" on field check-list).

This scale represents a comparison of the relative amount of one macrophyte species against all other macrophytes within the survey length, using a scale increasing from 1 to 5 as shown

1 = Very sparse
2 = Sparse
3 = Moderate
4 = Abundant
5 = Very abundant

PERCENTAGE COVER (abbreviated as "Cov" on field check-list).

Scale A (5 point)

A1 = < 0.1%
A2 = 0.1–1%
A3 = 1–5%
A4 = 5–10%
A5 = >10%

Scale B (3 point)

B1 = < 0.1%
B2 = 0.1–5%
B3 = > 5%

Scale C (9 point)

C1 = < 0.1%
C2 = 0.1–1%
C3 = 1–2.5%
C4 = 2.5–5%
C5 = 5–10%
C6 = 10–25%
C7 = 25–50%
C8 = 50–75%
C9 = >75%

Table B 3 Plant Score Scores of all individual macrophytes recorded in river habitats within a defined length of river are added together to give the Plant Score for the site. Scores were devised following surveys in north-west England (Harding, 1978), and the tolerance to pollution of some macrophytes may be expected to vary in other parts of the British Isles.

ALGAE		MOSSES		MONOCOTYLEDONS		DICOTYLEDONS	
Batrachospermum sp(p)	7	*Amblystegium fluviatile*	6	*Agrostis stolonifera*	1	*Apium nodiflorum*	4
Blue-green mats	1	*Amblystegium riparium*	2	*Alisma plantago-aquatica*	3	*Callitriche sp(p)*	6
Cladophora spp	3	*Cinclidotus fontinaloides*	7	*Butomus umbellatus*	7	*Caltha palustris*	6
Enteromorpha sp(p)	3	*Fontinalis antipyretica*	4	*Carex sp(p)*	8	*Ceratophyllum demersum*	6
Hildenbrandia rivularis	7	*Fontinalis squamosa*	10	*Eleocharis sp(p)*	7	*Mentha aquatica*	6
Lemanea fluviatilis	8	*Hygrophypnum ochraceum*	10	*Elodea canadensis*	5	*Myosotis sp(p)*	5
Sigeoclonium sp(p)	1	*Racomitrium aciculare*	10	*Elodea nuttallii*	4	*Myriophyllum alterniflorum*	10
Vaucheria sp(p)	2	*Rhynchostegium riparioides*	6	*Glyceria maxima*	3	*Myriophyllum spicatum*	7
Other filamentous algae	—	*Sphagnum sp(p)*	10	*Glyceria other sp(p)*	4	*Nasturtium officinale agg*	7
		Other mosses (each)	10	*Iris pseudacorus*	3	*Nuphar lutea*	6
LIVERWORTS				*Juncus acutiflorus*	6	*Oenanthe crocata*	3
Chiloscyphus polyanthos	10	VASCULAR CRYPTOGAMS		*Juncus bulbosus*	6	*Polygonum amphibium*	3
Scapania undulata	10	*Equisetum fluviatile*	3	*Juncus bufonius*	6	*Polygonum sp(p)*	2
Solenostoma sp(p)	10	*Equisetum palustre*	3	*Juncus effusus*	4	*Ranunculus calcareus*	5
Other foliose liverworts (each)	10			Other *Juncus sp(p)*	4	*Ranunculus fluitans*	5
Pellia epiphylla	6			*Lemna sp(p)*	4	*Ranunculus hederaceus*	5
Other thallose liverworts (each)	6			*Phalaris arundinacea*	2	*Ranunculus omiophyllus*	10
				Potamogeton alpinus	10	*Ranunculus peltatus*	8
				Potamogeton berchtoldii	2	*Ranunculus penicillatus*	6
				Potamogeton crispus	4	Other *Ranunculus spp* (each)	6
				Potamogeton natans	3	*Rorippa amphibia*	4
				Potamogeton pectinatus	1	*Solanum dulcamara*	2
				Potamogeton perfoliatus	7	*Veronica beccabunga*	5
				Potamogeton polygonifolius	10	Other Dicotyledons	—
				Other *Potamogeton spp* (each)	7		
				Sagittaria sagittifolia	4		
				Scirpus sp(p)	5		
				Sparganium emersum	3		
				Sparganium erectum	2		
				Typha latifolia	4		
				Zannichellia palustris	5		
				Other Monocotyledons	—		

Table B 5 Plant Community Description

PCD				
aa	Dominated by bryophytes (excl *Amblystegium* & *Fontinalis*)	at least 1°	>	other groups
ab	Bryophytes (excl *Amblystegium* & *Fontinalis*)	=		Rooted angiosperms (excl *Potamogeton pectinatus*)
ac	Bryophytes (excl *Amblystegium* & *Fontinalis*)	=		*Cladophora* spp
ad	Bryophytes (excl *Amblystegium* & *Fontinalis*)	=		Group d plants (see below)
ba	Dominated by rooted angiosperms (excl *Potamogeton pectinatus*)	1°	>	Bryophytes (excl *Amblystegium* & *Fontinalis*)
bb	Dominated by rooted angiosperms (excl *Potamogeton pectinatus*)	at least 1°	>	any other group
bc	Rooted angiosperms (excl *Potamogeton pectinatus*)	=		*Cladophora* spp
bd	Rooted angiosperms (excl *Potamogeton pectinatus*)	=		Group d plants (see below)
ca	Dominated by *Cladophora* spp	1°	>	Bryophytes (excl *Amblystegium* & *Fontinalis*)
cb	Dominated by *Cladophora* spp	1°	>	Rooted angiosperms (excl *Potamogeton pectinatus*)
cc	Dominated by *Cladophora* spp	at least 1°	>	any other group
cd	Cladophora spp	=		Group d plants (see below)
da	Dominated by group d plants (see below)	1°	>	Bryophytes (excl *Amblystegium* & *Fontinalis*)
db	Dominated by group d plants (see below)	1°	>	Rooted angiosperms (excl *Potamogeton pectinatus*)
dc	Dominated by group d plants (see below)	at least 1°	>	*Cladophora* spp
dd	Dominated by group d plants (see below)	at least 1°	>	Any other group; *Cladophora* spp absent

Where 1° = one division of the 1–5 percentage area scale A(A1 = < 0.1%, A2 = 01–1%, A3 = 1–5%, A4 = 5–10%, A5 = > 10%.

Group a: All bryophytes excluding *Amblystegium riparium* and *Fontinalis antipyretica*
Group b: Rooted angiosperms (eg *Ranunculus* etc) excluding *Potamogeton pectinatus*
Group c: *Cladophora* spp
Group d: *Potamogeton pectinatus*/Blue-Green mats/*Stigeoclonium*/*Amblystegium riparium*

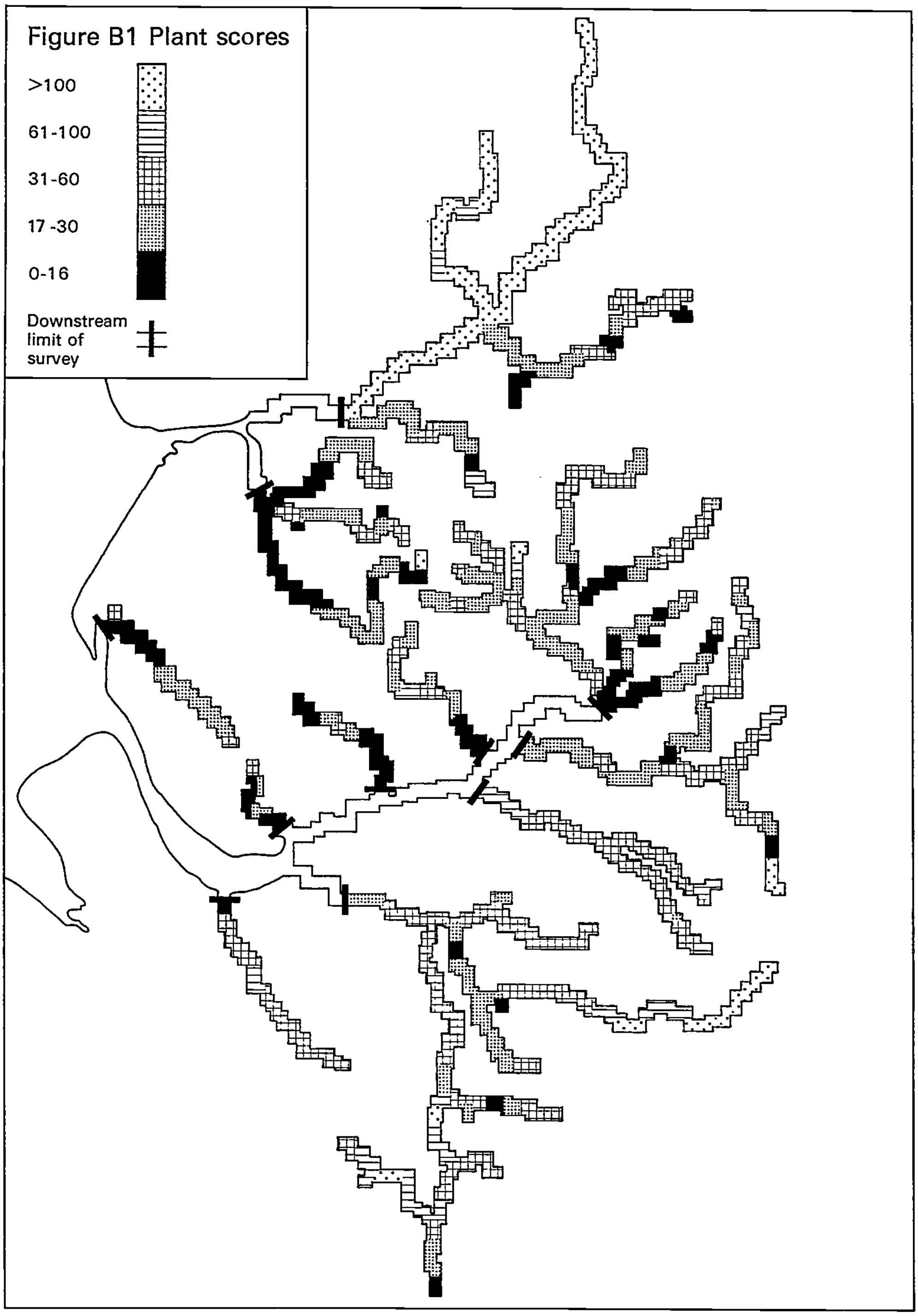


Figure B1. *Spatial variations in Plant Scores within the major rivers of the Southern North West Water Authority area*

(Derived from surveys of 0.5 km lengths between 1978 and 1980)

Values of Plant Scores recorded in the survey area ranged from 0 (on a grossly polluted tributary of the River Croal, Bolton) to more than 150 at several sites on the River Ribble. In general the spatial variations in Plant Scores corresponded closely with previous information on general river quality and habitat diversity, although a number of previously unknown pollution problems were revealed through the use of the score.

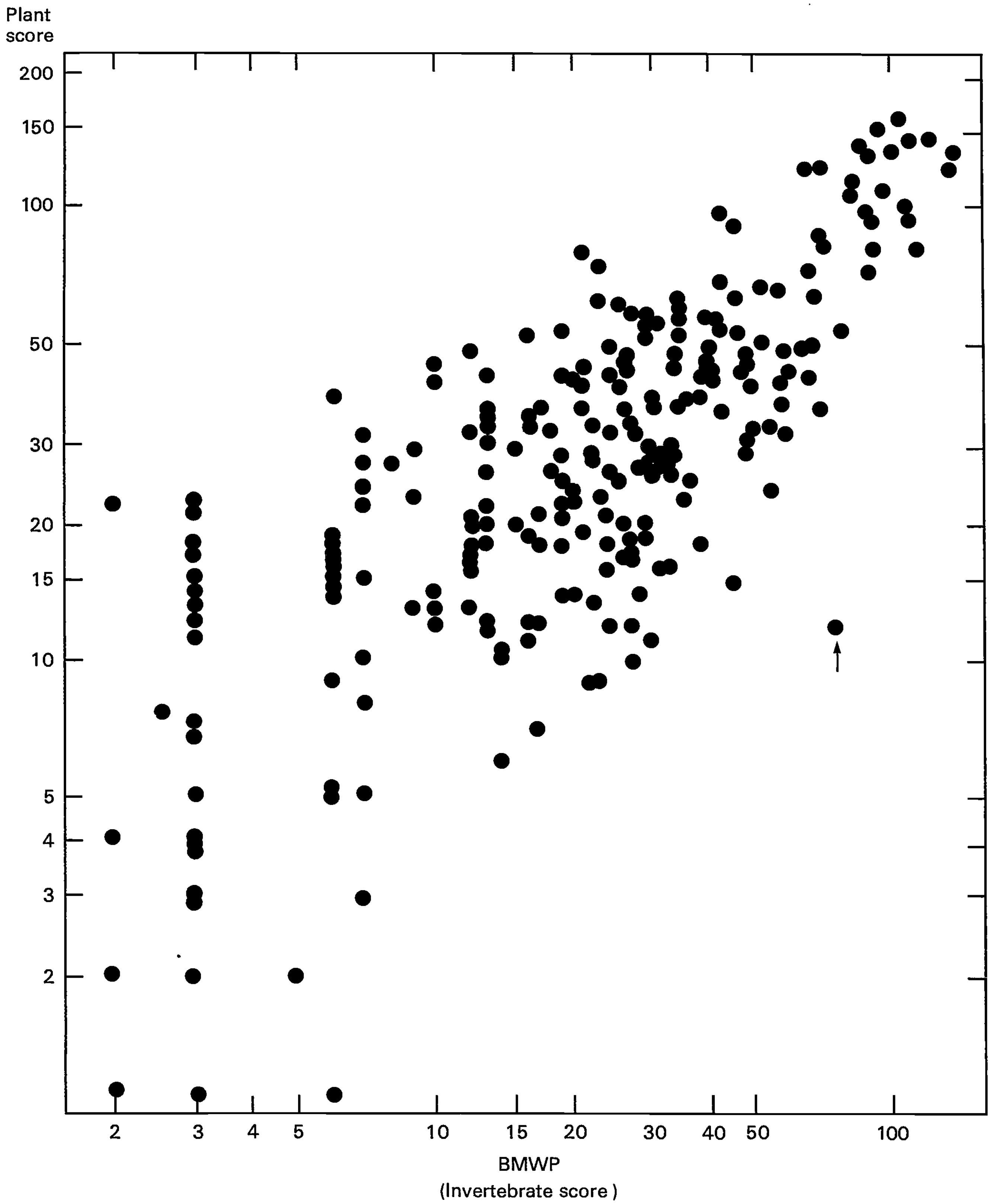
Figure B2. *Comparison of values of Plant Score with values of BMWP (invertebrate) score in the southern NWWA area*

This graph has been included to illustrate the marked similarities between variations in Plant Scores at sites in the southern NWWA area and variations in BMWP invertebrate scores (as used throughout the UK by Water Authority Biologists). The values of BMWP Score used in the construction of the graph were taken from the results of the last routine invertebrate survey before an adjacent 0.5 km length was surveyed for macrophytes in 1978, 1979 or 1980.

Clearly there was general agreement between the results of the 2 scores for different sites, with the range of recorded values being similar for both BMWP and Plant Score. However, it was the areas of disagreement between BMWP and Plant Scores which were of most interest for monitoring purposes, since these differences served to focus attention on sites where an unusually impoverished invertebrate community might have been overlooked had information not been available on plants and *vice versa*. For example sites on rivers contaminated by salt (eg Lower River Dane) tended to cluster in the lower part of the graph, suggesting that invertebrate monitoring alone may under-estimate the severity of the general effects of salt pollution. Conversely, points for sites on the part of the River Etherow affected by high levels of zinc cluster towards the upper half of the graph, adding weight to previous suspicions that several invertebrate taxa (especially leeches and molluscs) were unable to colonize the River Etherow because of the toxic effects of zinc.

The isolated point (arrowed) below the main cluster of points refers to data from Sabden Brook, an upland tributary of the river Calder. The anomalously low plant score served to focus attention on this stream, and it was subsequently discovered that a factory was allowing severe pollution of various types to enter the stream on one or two occasions per year. The effects of these incidents had not been detected by routine invertebrate sampling, probably because the invertebrates were recolonizing the site rapidly after each event.

Figure B2



Plant score
200
150
100
50
30
20
15
10
5
4
3
2
2
3
4
5
10
15
20
30
40
50
100
BMWP
(Invertebrate score)

C The Surveying of Macrophytes in Standing Waters

C Summary of Method

C1.1	Biota determined	Macrophytes: attributes listed in C1.5 (excluding biomass—for which see Methods 1985).
C1.2	Vegetation sampled	Emergent vegetation in marginal fens and swamps: floating-leaved vegetation and submerged vegetation.
C1.3	Type of sampler	Quadrats and grabs, or large areas delimited as belt transects along or down slopes.
C1.4	Basis of operation	Varies with type of plant cover, with water depth and with accuracy deemed necessary. Operator may wade, wade with underwater viewer or with snorkel, dive with snorkel or SCUBA, or use grab or viewer from boat. Attributes, or performance criteria, of vegetation are recorded *in situ,* or plants are collected and subsequently measured. If the provisions of the Wildlife and Countryside Act or local circumstances make collection out of the question, it may be possible to use photography instead. See Method A Sections A3.1 and A5.4.1 for information.
C1.5	Form of data	Qualitative, as species lists. Quantitative, precision depending on homogeneity of vegetation stands and on number of samples, % frequency, % cover, density, depth in lakes of zone colonized by macrophytes (z_c). (Attributes, defined in C2.2.)
C1.6	Range of application	One or more attributes can be recorded in vegetation on marshy or wet ground associated with lake margins and in the lakes themselves. Outside fens and the inner margins of swamps, wading may be impossible in rough weather when, also, sampling from a boat is haphazard. Generally, lack of time for adequate underwater sampling, lack of calm conditions and (underwater) visibility all reduce accuracy. Diving with SCUBA involves safety regulations.
C1.7	Errors	a. Errors of sampling technique, especially from use of inappropriate sampling devices (see C5.2). b. Errors of observation and identification, including overlooking individual species, such as one of a somewhat similar pair of species: leading to faulty data being recorded *in situ.*

C1.8 Logistics

a. Sampling. Depends on extent of marginal fens and swamps, access to water-body, its size, availability or not of a boat, and the depth of water colonized. On an accessible lake, Loch Borralie (35 ha in area), with z_c of 12 m but no fens or swamps, 10 dives and a 20-sample shore survey (50 m lengths) took 20 man-hours. In a nutrient-rich lake of the same size, complex fens and swamps partly compensate for shallow z_c and no SCUBA diving, reducing field-time to about 14 man-hours.

b. Identification of plant material. This depends on experience of operator with a wide range of taxonomic groups and how much he/she can rely on experts to identify plants rather than their checking his/her own determination.

c. Preserving of plant material: voucher collection. Time must be allowed for labelling, pressing and drying plant material (including paper-changing), for packeting bryophytes, for sorting and suitably preserving Charophyta and for sorting and preserving large algae. Depending on the floristic richness of the lake and the operator's knowledge, this phase may take from 2 to 5 man-hours per lake.

d. Tabulating of basic data, notes; allow about 3 man-hours per 5 man-hour field work.

C2 Introduction

C2.1 Macrophytes. Macrophytes are the larger plants of fresh water. Most are attached to the sediment or to rocks but a few may also be free-floating. Their shoots and leaves may grow out of the water, they may have leaves floating on the surface or they may be fully submerged plants. Some species have more than one kind of leaf, eg floating and submerged. Taxonomically, macrophytes include angiosperms (flowering plants), pteridophytes (ferns, horsetails and quillworts), bryophytes (mosses and liverworts), charophytes (stoneworts) and branched filamentous algae like *Cladophora* species and thalloid algae such as *Enteromorpha* species; *Cladophora* is dealt with in another issue of this series (Methods 1982).

In lakes these plants grow from the banks down to a maximum depth (z_c) which usually depends on the transparency of the water. In the UK, z_c may extend from less than one metre in turbid water to 15 m in very clear waters; the mean probably lies at about 3 m. z_c and the maximum biomass (B_{max}) found usually at some intermediate depth, are useful characteristics of lakes.

Since the extent of colonization in shallow standing water varied primarily with degree of exposure to waves and, related to this, with sediment type, sampling should include the full range of shore types in a lake. Both the potential range in exposure on relatively shallow shores and the potential extent of z_c in a lake should be borne in mind when choosing a sampling procedure (Fig C1).

C2.2 Criteria or attributes of macrophyte sampling. % **frequency:** percentage of the number of quadrats or stands in which a species occurs; % **cover:** area of quadrat or stand covered by a species or, as total plant cover, by all macrophytes; neither will exceed 100%; **mean % cover** of each species or of all macrophytes in all samples; **density:** number of individual shoots of species spreading by rhizomes or number of individual plants of non-creeping species per unit ground area; **depth of the zone colonized by macrophytes:** z_c(m).

C3 Equipment Needed

C3.1 Equipment in the field

a. Notebook or translucent, or white-surfaced plastic board with pencil.

b. Thigh-waders, wet or dry suit, face-mask and snorkel: fins, weight-belt, capillary depth gauge: SCUBA and 'Fenzy'-type buoyancy vest, or integral buoyancy suit.

c. Various quadrats: pegged lines, and dexion, painted, for permanent sites; weighted plumb-line, marked in m for soundings.

d. For plants attached below water, at depths beyond a wader's arm's-length: weighted plant grab, grapnel or rake-heads wired back to back and netted on long ropes (see Table C1).

e. Underwater 'viewer'. This is a simple square box, one foot wide and high, made of wood or block-board. The bottom is a sheet of perspex, set about one inch above the base of the sides. Two handles are attached at opposite sides of the box, near the top. The outside is treated with polyurethane and the inside painted matt black. Used in conjunction with waders or a dry or wet suit for scanning submerged vegetation in water up to chest deep (or from a boat in choppy water).

f. Miscellaneous sample bags (nylon shopping bags with stiff tops are useful underwater), metre sticks; flower press for angiosperms (see Section A3.1f for details) damp containers for Charophyta and other Algae if to be examined fresh; otherwise preserve in bottles. Labels.

g. Maps of the area.

h. If rare species are involved or there are likely to be problems over collecting, a good camera may be useful. See A3.1m and A5.4.1, also B5.6.1.

C3.2 Equipment in the laboratory. See Methods A and B for details.

C3.3 Identifications. The following keys or texts are recommended:

Vascular plants

—In general—Clapham, Tutin & Warburg (1962).

—Aquatic species—Haslam, Sinker & Wolseley (1982); Spencer-Jones & Wade (1986); not all species included.

—*Ranunculus* spp—Holmes 1979.

—Grasses—Hubbard (1968).

—Sedges—Jermy & Tutin (1968).

—Introduced spp—Stodola (1967).

Mosses

—Smith (1978).

Charophytes

—Allen (1950).

—Moore (1986).

For recording, the codes in Holmes, Whitton & Hargreaves (1978) should be used (Whitton, Holmes & Sinclair (1978) for charophytes). These manuals also give complete checklists and more information on identifications.

Note: useful identification keys are given in bold type in the reference section of this booklet.

Doubtful material should be mounted between blotting paper and pressed between newspaper, making several frequent changes over a few days until dry. It should then be labelled and filed for future reference. Mature, flowering specimens, including roots are most useful.

C4 Sampling

C4.1 Choice of technique. This is influenced by sampling objective, size and shape of lake and its water clarity, man hours available, and availability of equipment and expertise (particularly in snorkel or SCUBA diving). Table C1 outlines some of the major points needing decisions and some suggested (not unique) solutions.

C4.2 Access options. These are mainly influenced by water depth. Unless visibility is exceedingly poor and depth gauge is inaccurate, direct sampling by diving intrinsically achieves greater accuracy than any form of indirect remote sampling Wade and Bowles (1980). The appropriate safety precautions must be taken (WAA). Health and Safety Executive regulations **must** be adhered to when diving is used HSE (1981);

Fleming and Miles (1979) and a trained team **must** always be present. These are less stringent when work is limited to less than 1.5 m and certificates of exemption from certain regulations may be negotiated with HSE, for scientific purposes only, under specific conditions.

i. Thigh waders. Only suitable for banks and water less than 30 cm deep.

ii. Wet or dry suit. Very convenient for water down to about 60 cm and down to 1.5 m with the aid of a snorkel or UW viewer.

iii. Wet or dry suit and self-contained breathing apparatus (SCUBA). Used in water over 1.5 m.

iv. Boat and remotely operated grab. An inflatable boat is adequate.

C4.3 Minimal data.

a. If a full list of macrophyte species in a lake will suffice, without quantifying abundance etc, then a main need is adequate sampling to minimize the omission of species. A simple indication of sampling adequacy is obtained by plotting cumulative species number (y axis) upon cumulative sample areas (x axis) and ensuring that the flat part of the curve has been reached.

b. Where the entire lake shore is visible from one viewpoint, the investigator may be able to walk right round it, wearing thigh waders, and listing fen and swamp species, floating-leaves and submerged species. For irregular and larger lakes, a one inch map is needed, from which the investigator selects at least 3 stretches each of likely exposed and sheltered shores—eg headland and narrow bay respectively (Table C). If a boat is available, it allows quick access to any part of the shore and allows the map-based selection to be confirmed, or modified, eg by increasing the number of samples to include any shore types intermediate between a silted bay and exposed headland.

c. A note is taken of every macrophyte species present round a small lake or, in larger lakes, in each sample site. A note is also taken, at each site, of the predominant particles as determined by a range of sizes (Table C2); in these terms. The substrate is mainly rocky or composed of gravel, sand, silts or peat. Substrate notes are preferable to stating simply that a shore is 'exposed' or 'sheltered'. Dominant fen, swamp and floating-leaved species may also be recorded.

d. With a dry or wet suit and an underwater viewer, or snorkel and facemask, listing of sections of shore can be extended to about 1.5 m in clear water and, on soft substrata in dark water, by grab or rake. Grabs are useless as sampling tools on rocky stretches, becoming jammed when (as would be the case here) thrown from the shore towards deeper water. Diving with snorkel on selected sections can extend accurate listing to 3 m or, even, 4 m depth.

e. It is likely that a 'waded' shore survey or, better, a waded and snorkelled littoral survey will, with sufficient replication, provide a fairly complete macrophyte list of most British standing waters; in calm weather, boat and grab provide an adequate alternative method in most lakes to snorkelling and the other method, in the absence of SCUBA divers, in lakes where z_c extends beyond 2 to 3 m.

C4.4 Quantitative data. Quantitative data, involving any or all of the range of macrophyte attributes or performance criteria listed in C2.2, should only be collected from lakes where environmental change is known or suspected to be occurring, or is anticipated; in other words, where detailed information is needed on, say, an annual basis, of change in frequency etc, or in z_c. For these more detailed surveys, major sample sites are selected in a lake after a qualitative, primary survey. 'Major sites' are sheltered bays and exposed shores or headlands and, probably, some intermediate situation.

Each major site runs from marginal fen, swamp and dense or sparse vegetation in shallow water to the lower limits of macrophyte colonization. Sampling procedures for fens and swamps and submerged vegetation within wading depth are similar to those used for terrestrial vegetation (Greig-Smith 1983).

C5 Use of Quadrats and Records Obtained

C5.1 Species present/absent. The number of quadrats in which a species occurs in a given lake, expressed as a percentage of all quadrats sampled, may be used to provide a first assessment of its relative abundance in that lake, or % frequency. Frequency depends on quadrat size and this dependence can only be avoided by using a technique where each quadrat is a point (the point-quadrat method). However, while appropriate for, eg short grassland, this method is probably of doubtful value in most aquatic macrophyte vegetation.

C5.2 In most aquatic communities 1 m^2 will be a suitable quadrat size and comparisons between sites, or occasions, may be made as long as this size is used. Very large plants may necessitate smaller quadrats, but it must be remembered that data from different size quadrats are not comparable.

One problem with making quantitative comparisons of percentage frequency is that the statistics require large numbers of quadrats (Greig-Smith, 1983), at least 100 in most cases.

Variance of the mean percentage frequencies may be decreased by stratified random sampling. Random samples are taken within areas that are distinctly different (eg different depth zones, different dominant species). In the simplest form, equal numbers are taken in each area, with all areas the same size. In the most efficient form numbers in each area are related to the size of the area and to estimates of the variance in each area. The booklet on biomass (Methods (1985)) describes the application of stratification in more detail, including the calculation of the numbers of quadrats needed for the required level of precision and of the relevant statistics.

C5.3 Percentage cover. This method involves a visual estimate of the projected plant cover of individual species in a quadrat, expressed as a % of the total area of the quadrat; the sum of the % cover of individual species gives the total % plant cover. If the vegetation is tall, like much reedswamp, the method is unworkable by an observer on the ground. (It may be quite suitable as an estimate from, eg aerial photographs of emergent or floating-leaved vegetation.) For shorter vegetation, the less the plant cover is than 100% the more the accuracy of the method depends on the observer. In non-uniform vegetation which may or may not also be sparse, this accuracy is improved by using a gridded quadrat and estimating plant cover in each, or a random selection of, subsamples. % total plant cover may be useful in characterizing particular vegetation zones relative to extent of wave action (ie on exposed and sheltered shores, and in shallow and deeper water). Otherwise it is probably most appropriate to use % cover as a measure of plant performance on a seasonal or annual basis in marked permanent quadrat or sample areas: see, for example (Hoogers and van der Weij (1968), (1971)).

On a relatively small scale, in floating-leaved communities and in submerged plant communities in shallow, slow moving water which are readily visible from above the water surface, transect surveys at fixed points may be made (eg Ladle, Bass and Jenkins (1972)). Along each transect, at suitable intervals for example, every 0.4 m at the site studied by Ladle, Bass and Jenkins (1972), cover is estimated and from the result a map of the site, which presents the dominant species in terms of their projected cover, can be constructed.

C5.4 Density. In rosette species with no means of vegetative spread, the number of individual plants or, for the rest, of individual shoot per unit area is a good measure of the amount of species present. The method is particularly useful (Sheldon and Boylen (1978)) in rapid estimates of relative species abundance in underwater vegetation, especially in conjunction with SCUBA. (Sheldon and Boylen (1978) combines density measurements with those of biomass, outlined in a separate booklet in this series). The method has been successfully evaluated by plotting densities of individual species, estimated from random quadrat sampling, upon observed density indices and found to follow a log-normal density distribution (Sheldon and Boylen (1978)).

C5.5 Depth of zone colonized by macrophyte (z_c, in m). Unless z_c is less than c.1.5 m, where snorkelling may make an estimate possible, this criterion can only be accurately determined by diver, using SCUBA and a depth gauge (Spence, Barclay and Allen (1984); NZ54). By swimming down transects across depth contours on, say, a fixed compass bearing, measures of z_c can be combined with estimates of species' occurrence. Transects at fairly regular intervals around the lake shore then allow determination of mean $z_c \pm$ SE and provide a list of species present (together with their % frequency) at the simplest, number of transects in which species x is present (at % of all transects): (Spence, Barclay and Allen (1984)).

C5.6 Site records. In collecting data from quadrats of which the sites are selected at random on a transect across contours, or on a grid, always record the depth of water above the sediment surface at each sample site; it may also be useful, particularly in relatively shallow water, to record the predominant texture of the sediment (see above). If species' presence only is being recorded, some estimate of extent of total plant cover is also recommended.

C6 Calculations

Of the simple estimates described, only % cover needs any further comment. Plant cover may be expressed as % cover in each sample area of individual species, or as % total plant cover, which is the sum of the % cover of each species. Combination of data from sufficient transects allows the calculation of estimates of % plant cover over a range of water depths down to the lower limits of colonisation, z_c, and estimates of the total amount of lake sediment covered by submerged macrophytes: (% cover of floating-leaved and emergent vegetation being measured from further transects, or aerial photographs where available).

C7 Interpretation

This section describes general principles only; the detailed patterns and pollution indices provisionally available for rivers (see the other methods) have not yet been determined for lakes, though a four or five class division is possible.

Lake vegetation is determined by many variables, of which the most important are (see Figs C1–3):

a. Water depth, particularly in relation to the habit and potential size of the species and the available light (including water clarity). Different species have different depth ranges. Since macrophytes are restricted to shallow water, the potential area of vegetation is determined by the morphometry and so by depth and edge slope of the lake (Fig C1).

b. Circulation pattern within the lake. This acts largely through c.

c. Liability of the site, its water and bed, to:

1. disturbance and erosion by waves (wind) and current; and
2. conversely, deposition of different types of sediment (including the development of soil structure and texture).

These vary widely both between and within lakes, depending on wind regime, lake size etc.

d. Nutrient status of water and sediment, as determined by rock type, sediment type, dissolved gases and surrounding vegetation (see f. also) (see Fig C2).

e. Temperature regime and microclimates of, and within the lake.

f. Mans' activities*. Pollution (Fig C3) is not the only activity influencing macrophytes. Others include bank management; navigation; alteration of lake size, shape and depth; fisheries (fishing, stocking, over-grazing); embanking, disturbance, trampling and grazing of the edges; and swimming. The use, management and cultural history of the catchment and the lake (its bank, edges and centre) are also important.

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*Note that occasionally similar effects may be produced by natural causes and the activities of wild animals.

In undamaged places each habitat type bears a specific plant community. These communities vary in composition, diversity and quantity with, especially, a-e above. Where water depth, disturbance, sediment type and quantity etc permit the potential development of abundant vegetation, the type of this vegetation is further influenced by these and the other factors.

Nutrient status varies from dystrophic to eutrophic, with plant communities varying correspondingly. Undamaged communities are relatively species-rich, with high cover and of a species composition appropriate to the rock and (undamaged) soil types of the catchment. Where the nutrient range of the species present does not correspond to the latter, eutrophication or, less often, acidification can be diagnosed.

Other forms of pollution include organic, heavy metals and other industrial chemicals, biocides and other agricultural chemicals. Turbid but non-toxic pollutions (including phytoplankton) prevent the development of submerged macrophytes through lack of light. Lakes often receive more than one type of pollution, making interpretation difficult. Water, sediment or both may be rendered unsuitable. If in otherwise good conditions diversity is low, and the species are drawn from the list below, pollution (other than nutrient-related) is probably occurring.

Ceratophyllum demersum	*(P. lucens)*
(Elodea canadensis)	*P. pectinatus*
(Glyceria maxima)	*P. perfoliatus*
Myriophyllum spicatum	*Scirpus lacustris*
Nuphar lutea	*Typha latifolia*
(Nymphaea alba)	*Zannichellia palustris*
Phalaris arundinacea	*Enteromorpha sp*
Phragmites australis	*Filamentous algae*
(Polygonum amphibium)	*(Potamogeton crispus)*

Elodea nuttallii and *Lemna minor* agg are prominent in more limited habitat ranges.

Species in brackets are generally less tolerant than the others.

As in rivers, each macrophyte species occurs in undamaged and natural habitats, forming part of the species assemblage characteristic of each habitat. When the habitat is subjected to pollution, species sensitive to the relevant pollution decrease or disappear first, leaving the more tolerant species persisting longer. Species favoured by pollution may invade moderately polluted habitats. The most tolerant species in any site are determined by the conditions of the habitat, and the type of pollution.

Full pollution indices are not yet available. They could, however, be developed using an abundance index similar to that used by Lachavanne et al (1986),

(number of points) = (surface of area) × (relative % of species in relation to the other species) × (abundance modules for the weedbed zone) plus an assessment of diversity and pollution tolerance.

In a detailed study of Swiss Lakes, Lachavanne (1982) gives the following effects of pollution:

- decrease of diversity in the greater part of the lake, incoming species not compensating for losses;
- decrease, and subsequent loss of Charophyta;
- decrease in diversity of submerged species, rooted and free-living;
- decrease in diversity, and subsequent loss of free-floating species;
- slight decrease of rooted species with floating leaves (in Britain, this loss can equal the others).

Lachavanne et al (1986) can be consulted for further information, see also Figs C1–3.

Table C1. Summary of macrophyte sampling options and techniques in a lake

	water depth less than 2–3 m			water depth more than 2–3 m		
	0.6 m	0.6–1.5 m	1.5–3.0 m			
	thigh waders	wet or dry suit + u/w viewer or snorkel	diving with suit + snorkel, depth gauge, wt belt and fins	collection of plant debris on shore	boat and grab	full diving kit, with SCUBA
minimal data[1]						
overall species list	+	+	+	+	+	+
species list for exposed and sheltered shores **or** (underwater) on, say, gravel or mud	+	+	+	+	−	+
in defined sample areas[2, 3]						
% frequency	+	−	+	−	+	+
% cover	+	−	+	−	−	+
% density	+	−	−	−	−	+
z_c	−	−	+	−	−	+

[1]minimal data; good coverage still needed to minimize chance omissions; preferably indicate dominants of principal veg-types.
[2]better data but sampling intensity has to be determined; quadrats or transects.
[3]one, a few or all these variables adaptable for repetitive estimates, to follow seasonal or annual changes in vegetation; **either** in permanent quadrats, **or** with enough replication to make within-season variance less than between-season variance.

Table C2. Broad relationship between aspect of shore and predominant particle type

aspect of shore	plant cover (%)	predominant particles at least in shallow water (arbitrary dimensions)	
exposed headland and open shore	5 (locally −20)	rocks, boulders, stones	> 2 cm dia
		gravel	2 cm–2 mm
sheltered bay	up to 100	sands	2 mm–0.2 mm
		silts, peats	< 0.2 mm

In Figs 1–3, which follow, the species assemblage may differ to that found in Britain. For reason, see Introduction.

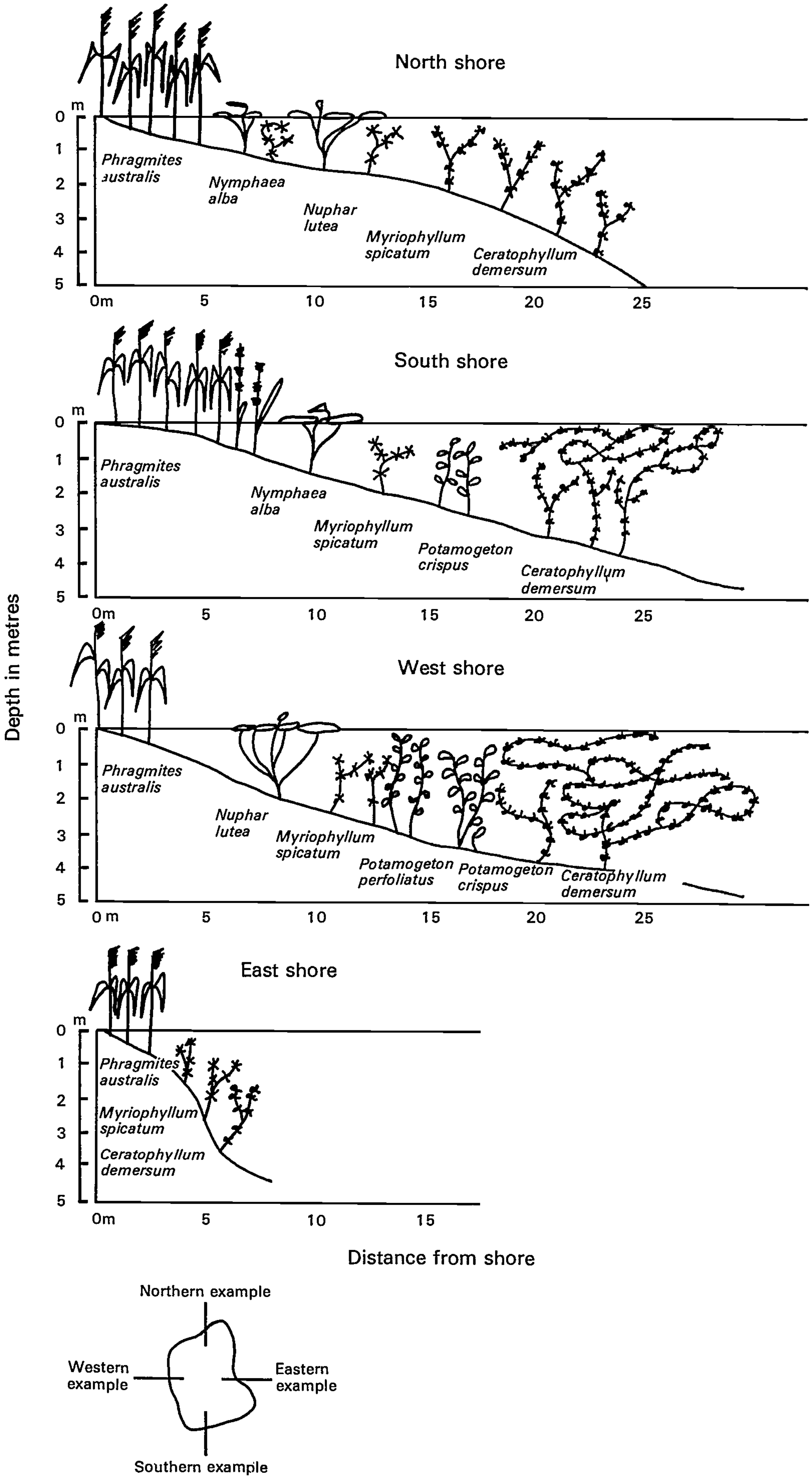


Figure C1. Vegetation transects in different habitats in a Swiss lake (Burgäschisee, 1976) *(Lachavanne, 1979)*

The following species are indicated above their approximate location.
(For further details see *Lachavanne, Jaquet, Juge, Perfetta et alia*).

Callitriche sp.	*Potamogeton x decipiens Nolte*
Ceratophyllum demersum L.	*P. filiformis Pers.*
Charophyte: Chara + Nitella	*P. gramineus L.*
Elodea canadensis	*P. lucens L.*
Myriophyllum spicatum L.	*P. pectinatus L.*
Najas marina L.	*P. perfoliatus L.*
Nitellopsis obtusa (Desv.) J. Groves	*P. pusillus L.*
Nuphar luteum (L.) Sibth	*Ranunculus sp.*
Nymphea alba L.	*Scirpus lacustris L.*
Phragmites australis (Cav.) Trin.	*Typha sp.*
Potamogeton crispus L.	*Zannichellia palustris L.*

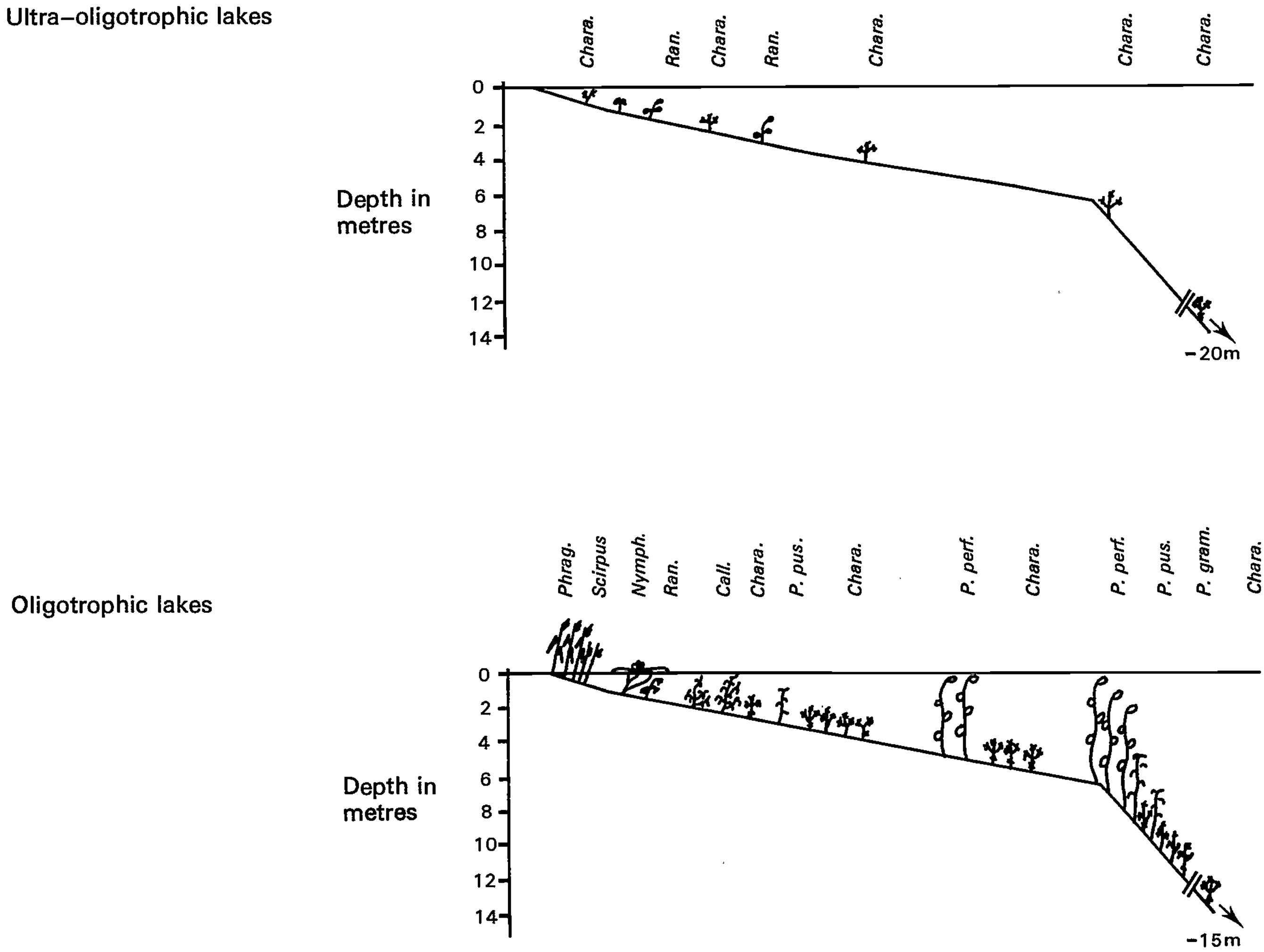


Figure C2. Characteristic vegetation of Swiss lakes of different trophic status (after *Lachavanne 1985*)

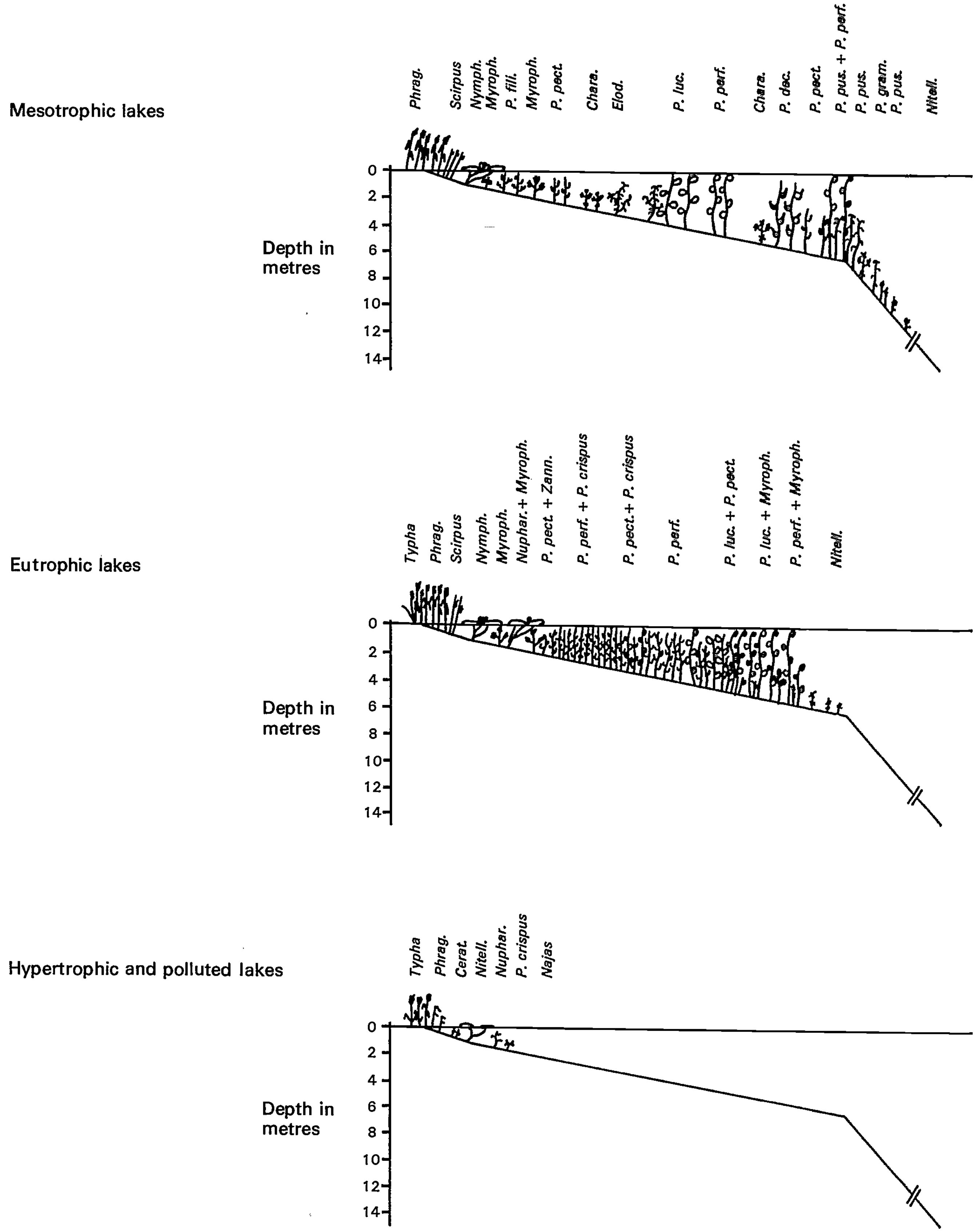


Figure C2. (cont'd)

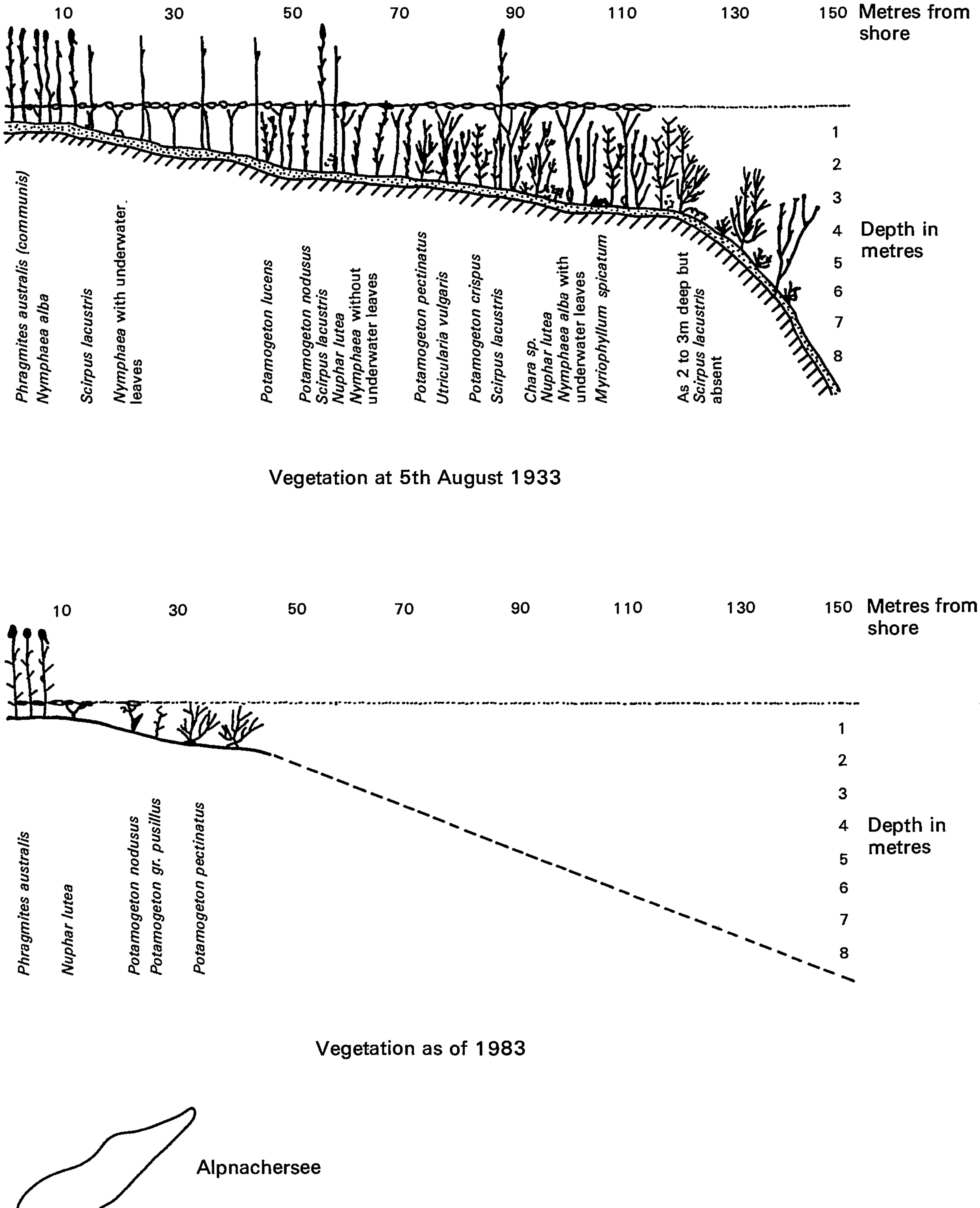


Figure C3. Change in vegetation along a transect of a Swiss lake (Alpnachersee) between 1933 and 1983 *(Lachavanne et al 1984, 1986)*

Navigational Aids

1 A Basic Guide to the Use of the Optical Square for Position Fixing

These notes are meant to be a simple guide to the use of the optical square for position fixing, with a view to facilitating vegetation survey. It is not a guide to its use in formal surveying practice; if such highly accurate results are required, then reference must be made to Ordnance Survey literature.

The optical square is a hand held device with 3 prisms which are set so as to give 3 images, one of an object straight ahead and the others of objects at 90 degrees to either side. The 3 images are formed one above the other so that alignment can be very rapidly checked. It is particularly useful in transect work, since it enables both end markers of a transect line to be viewed simultaneously, thus giving a check on any drifting off the line.

By reference to the appropriate OS map (of the largest available scale) a suitable transect line is defined between 2 markers which are obvious both on the map and on site. Suitable markers would be corners of buildings, boathouses, fence or wall ends etc, in fact any permanent structure unaffected by change in water level. (In this context a tangent to the shore of an island would be suitable if the shore sloped steeply, a gently sloping shore would be affected too much by fluctuations in water level.)

Having established a transect line, intermediate stations are then fixed at intervals along its length by means of intersections. Three intersecting lines are recommended, ie, 2 plus the transect line to establish an intermediate station. The intersections are produced in the same way as the transect line by alignment through permanent markers; to minimise errors in this operation, each intersection should ideally be about 45° from the transect line. When surveying a very large water body it may be necessary to use the facility of throwing a right angle from the intersection line to a shore mark to give the third point of reference.

Having established intermediate stations, it is necessary to mark them; poles are preferred for this, but in deep water buoys may have to be used. In this event it must be remembered that a buoy tends to drift about its theoretical position due to the influence of wind and water movement.

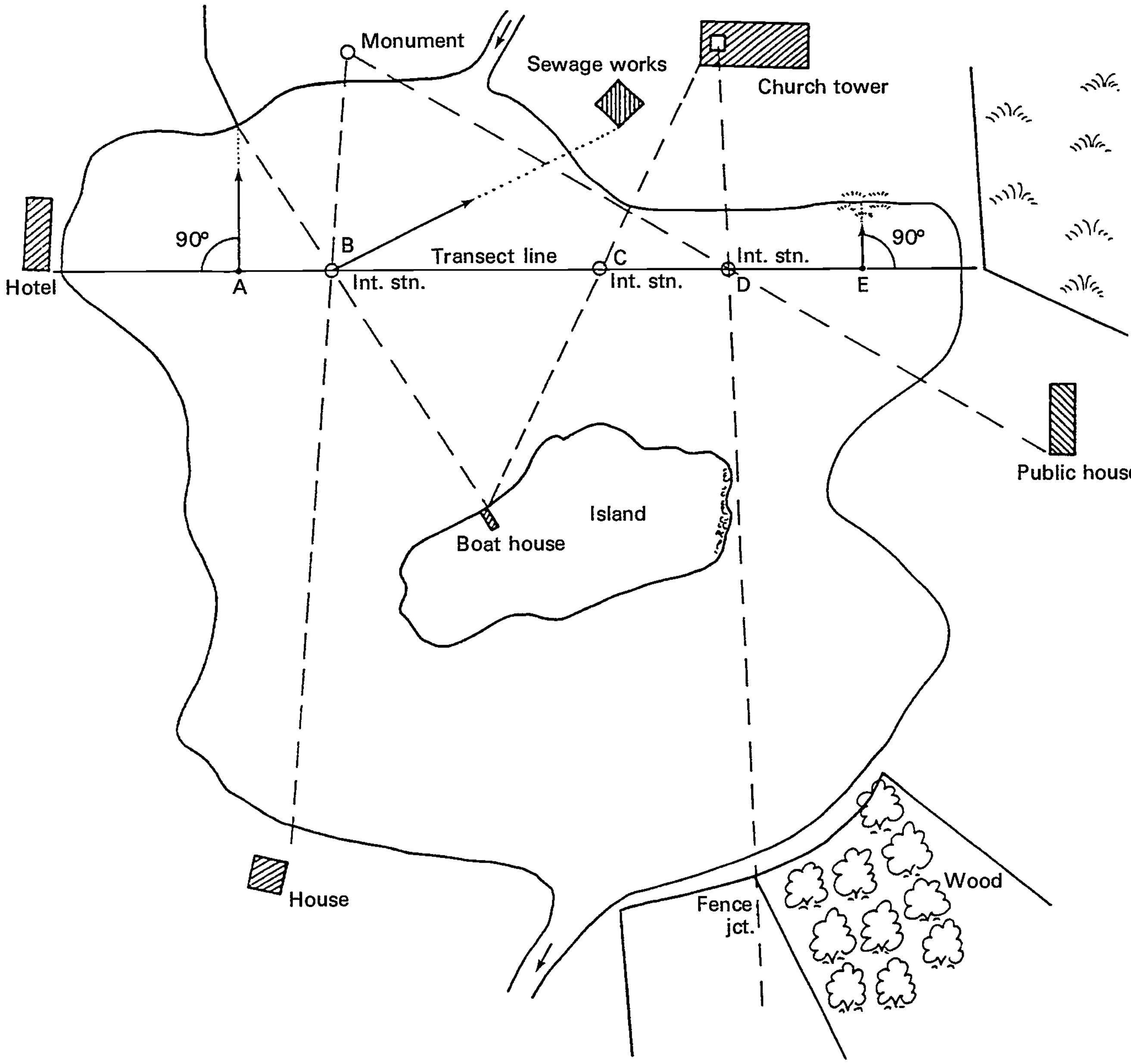
The intermediate stations are then regarded as fixed points, set at convenient distance (30–60 m) apart, and points along the transect line can then be located by reference to the fixed points either by direct measurement (tape or range finder) or by estimation.

An intermediate station can also be used as a centre for secondary transects consisting of a series of lines radiating from the station to shore marks.

Figure N1 demonstrates the methods in graphical form.

It is good practice to confirm that shore features being used as markers correspond to their positions as indicated on the map, since it occasionally happens that a building may have been rebuilt or a fence moved since the previous OS survey.

It must also be emphasised that good survey practice ideally requires 3 straight line intersections to establish an intermediate station, though 2 may be acceptable. The right angle facility should only be used as a check of say estimated distance along a transect line. Referring to the sketch map, points B and D are well established, C is acceptable and A is acceptable to confirm a measured or estimated distance from B.



Transect Line fixed by sighting from Hotel corner to fence corner.

A. Point fixed by 90° sighting from transect line to fence end.

B. Intermediate station fixed by intersections:-
   (i) Boathouse to fence end.
   (ii) Monument to house corner.
   (iii) Transect Line.

C. Intermediate station fixed by interjection:-
   (i) Boathouse to Church tower.
   (ii) Transect Line.

D. Intermediate station fixed by intersection:-
   (i) Church Tower to Fence Junction tangential to island shore.
   (ii) Monument to Public House.
   (iii) Transect Line.

E. Marginal vegetation clump located by 90° projection from point on transect line measured from Intermediate Station D.

F. Secondary Transect from Intermediate Station B. to shore mark (sewage works building).

Figure N1. Use of Optical Square

1.1 Makers of Optical Squares known to the authors

Clarkson & Co Ltd
1 Brixton Hill Place
London
SW2 1HL
Telephone 01–671 5454—Telex 947618

Hall & Watts Ltd
266 Hatfield Road
St Albans
Herts
AL1 4UN

Wild Heerbrugg (UK) Ltd
Revenge Road
Lordswood
Chatham
Kent
ME5 8TE
Telephone Medway 64471/5

W F Stanley & Co Ltd
33 Avery Hill Road
New Eltham
London
SE9 2BW
Telephone 01–850 5551—Telex 896414

2 Use of Radionavigational Aids

Provided good reception can be obtained, radio beacons are available for use with navigational devices such as the Decca Navigator which can locate position accurately on specially prepared charts. However, care is necessary in unfamiliar waters and interference effects are known due to hills and buildings which can cause serious errors for the unwary.

Similar but modified systems have also been used on waters where radio reception is restricted by the surrounding land or interference from electrical equipment or atmospheric effects. For reservoirs, lakes and estuaries where more positional accuracy is required, a similar radio system can be estimated locally and temporarily by the use of portable shore based stations. Radio waves continuously transmitted from two or more shore based stations can be detected by a receiver unit on board the survey vessel. This unit computes the distance to each shore station and displays the information on digital readout. Other electronics can be used to convert these distances to latitude and longitude or to some other position grid system desired by the user. The positional data from such equipment is in a form that can be retained continuously on a datalogger. An accuracy of 1.0 ± 0.1 m or better at ranges of up to 10–20 km from the beacons is attainable if interfering objects are avoided by careful sighting of the beacons.

Although the survey vessel's position can be determined quickly throughout the survey area, positioning the vessel at predefined points can be slow without the services of a well practiced operator. Typical close range equipment are the Del Norte Transponder and the Motorola Miniranger.

3 Use of a Laser Theodolite

For reservoirs and lakes where shore positions can be selected to observe the whole area of investigation an alternative shore based positioning technique can be employed. An electronic distance measuring device can be fitted to a conventional surveyors theodolite and aimed to view the survey vessel, which must be fitted with a prism reflector device. By reading the angle between the vessel and a prominent landmark its position can be plotted using the distance between the theodolite and the vessel.

More sophisticated electronic equipment is available which combines the electronic distance measuring device and the theodolite into one optical unit known as a 'Total Station'. The positional information from a Total Station can be interfaced directly to a datalogger for subsequent data processing on a computer.

An advantage of the shore based position system is that several vessels can operate simultaneously throughout the investigation area and each can be positioned in turn as desired.

The vessel only requires to be fitted with reflectors to enable the crew to devote their efforts to water and sediment sampling at the chosen position. Using the system it is also relatively easy to position a vessel at pre-defined points. For example, by instructing a vessel to move down a desired bearing and to stop at a selected distance.

Equipment of this nature which can cover considerable distances and enable vessels to be positioned very quickly and with great accuracy, is commercially available.

Information in this section is based on experience by:
North West Water Authority,
Forth River Purification Board, and
Northern Ireland Department of Development.

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Extracts From

Typing British Rivers According To Their Flora

by Nigel Holmes

July 1983

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1 Introduction

Between 1978 and 1982 botanical and habitat surveys of rivers were undertaken throughout mainland Britain. This document is intended to summarize some of the findings of these surveys and highlight their value in being able to classify rivers. A spin-off from such classifications is that it allows a more objective evaluation of the extent, range and variation of different river types which is a necessary pre-requisite for effective conservation.

The prime purpose of this publication is to relay some of the most basic information already available as well as indicate the scope for further work on the data set. For this reason the report concentrates on factual information which will enable anyone to survey a section of river, classify it, and assess its flora in relation to similar stretches of river in Britain. The contents are therefore for general application and will allow Water Authority biologists to identify the plant community resources of their rivers, enable students and naturalists to work with water plants in a practical way which can allow an immediate classification if desired, and aid in nature conservation by identifying the range of any particular river type within any geographical area.

The report is divided into three further sections. Firstly the methodology for survey and evaluation are described. Secondly the results are briefly presented with reference to the main body of data which are presented as figures and tables at the back. Thirdly the results are discussed in a general way and then each river vegetation type is described in detail.

The most important feature of the classification presented here is that it is derived solely from the computer assimilation of data from 1,055 sites. The computer programme has assigned sites with similar plant communities into discrete groups and it is these which are described in the report. The grouping of sites is therefore objective but the size of each group and the level at which no further divisions in the classification are regarded as meaningful have necessitated a subjective cut-off point being made by the author. The subsequent naming of the 56 derived groups is therefore intended as a guide to the characteristic features of each group.

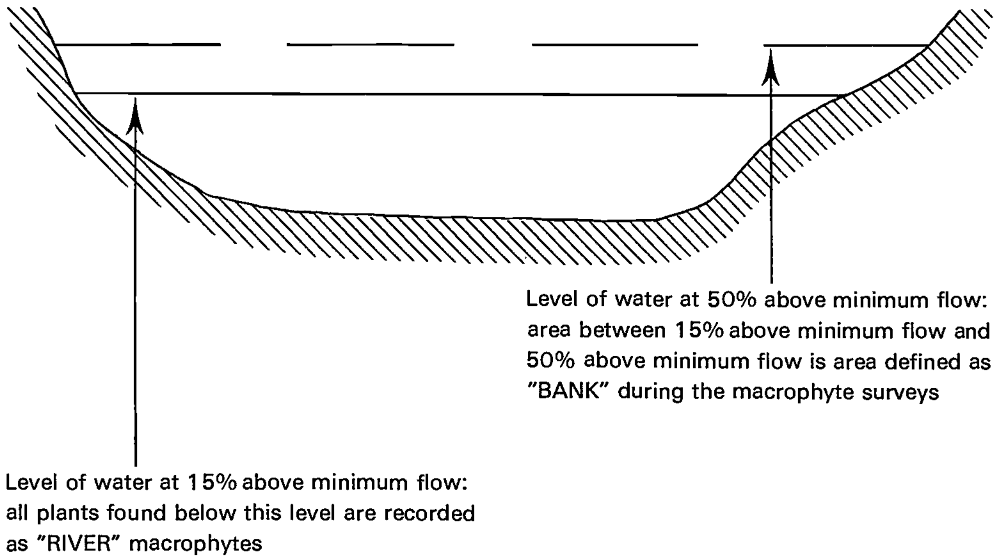
2 Methods

2.1a Survey of Plants

(M1) The methodology for survey has been outlined in CST Note 7 (Holmes, 1978). It involved 1 kilometre of river being surveyed at each individual site with each site being 5–10 km apart. The surveys were carried out by wading wherever possible but in some situations this was impossible. In such cases a 100 metre section would be intensively surveyed by use of either a grapnel and/or snorkling and the remaining 900 metres surveyed primarily from the banks of the river or by boat.

The survey at each site included the whole river and immediate banksides from one side to the other. There are, therefore, separate records for those macrophytes found in the river, and similarly for those found on the banks. Such a separation of records is an attempt to distinguish between those species which occur more or less permanently submerged, albeit their basal parts, and those that are subject to only periodic submergence. The former are referred to as 'river' records and the latter as 'bank' records.

To make the separation of these records objective, it was important to keep to the following guidelines when defining the limits of a river. At the sides of the river all parts of the substratum were included which are likely to be submerged for more than 85% of the time. The 'bank' can be usefully defined as those parts of the sides of the river (or boulders or islands in the middle of the river) which are submerged for more than 50% but less than 85% of the time. In general terms, therefore, 'river' records are reserved for those macrophytes which occur in the region of the river which is rarely uncovered, and those shallow sections which have an upper limit that may be exposed for a maximum of 50 days in any year. 'Bank' records are for those plants that occur above the limit of the 'river' plants, and are thus out of the water for more than 50 days in any one year, yet will be submerged, or partially so, during mean flow periods. The upper limit of the 'bank' excludes all the areas of the bank which are submerged during the 150 days of each year when river flows are at their highest. In most cases such estimates involve guesswork, but at least the adoption of a 'particular submergence level' does allow a greater flexibility in the interpretation of data and give a clearer insight into the ecology of individual species and communities in different types of river.



(M2) The adoption of such narrow limits for survey was necessitated by a need to collect information that would aid in classification rather than in describing every possible species present within the channel of a river. By extending the survey up to the lip of the bank to include all species that occurred within the bank *sensu stricto* would have probably increased survey time four-fold. The information gained would have probably trebled the species list for a site yet aided little in being able to classify it because the majority of species would not be specialised wetland plants.

To ease recording, data for species were recorded from two half kilometre lengths within the site. The actual abundance, and the abundance of each species in relation to other species, was recorded for 'river' and 'bank' using a five point scale. In practice inexperienced surveyors find this difficult and analyses have been based on a three point scale. The new simplified scale for relative abundance is: 1 = rare, 2 = frequent, 3 = co-dominant or dominant, and the scale for stream bed or bank covered by individual species is: 1 = <0.1% cover, 2 = 0.1–5% cover, 3 = >5% cover.

To enable anyone to carry out comparable surveys a specimen recording sheet is given in the appendix. It lists the species used in the site evaluations described in this document. For comparability, therefore, the use of this list and the same definition of 'river' and 'bank' will allow direct comparison with the data described here. If more detailed species lists are required then there is no reason why they cannot be included but they should not be used in the site assessment.

Visualizing the relative abundance of one species versus all the others present in a half kilometre length of river is relatively straightforward but estimating the actual cover value is more difficult. As a general guide it is valuable to envisage a dense stand of vegetation which stretches from bank to bank, and extends for 5 metres downstream, as covering 1% of the 500 metre stretch. Similarly an unbroken stand of 25 metres represents 5%. Bank cover may be best recorded from a single bank in very wide rivers. In such cases a continuous fringe of a single species stretching 5 metres represents 1%. If both banks are clearly visible and being recorded, then a continuous stand of 10 metres represents 1% cover. To record a species as having cover value 3 in the river therefore requires it for instance to completely cover the stream bed for 25 metres, cover half the bed for 50 metres, quarter of the bed in 100 metres or occur throughout the whole 500 metres but only sparsely. Bank taxa must be similarly abundant along both banks with a continuous fringe of 50 metres, a co-dominant fringe of 100 metres or 50 plants or colonies covering a metre each being required if it is to be recorded at value 3.

2.1b Survey of Habitats

Another important element in the classification of rivers according to their vegetation is to record the physical characteristics of the site. For each half kilometre site data were recorded for those features which are most likely to affect the floral communities. These included the range of substrates, water depth, water velocity, river width, bank slope, bank type, habitats within the river, shade, stability, and adjacent land use. In addition, information from maps such as geology, altitude, slope and hydrology are archived.

Habitat surveys in river corridors are now being regarded as a major requirement for effective conservation of river corridor resources. For this reason it is important that
(M3) future surveys collect habitat data in a consistent way which will assist in evaluating the relationship between habitats and all wildlife resources in river corridors. For this reason a new habitat recording sheet for river corridors is presented in the appendix. Recording of data in a standard way will enable consistency of recording in all parts of the country and assist in assessing the extent of various habitat resources.

Whereas the recording sheet for plants can be described as definitive in the sense of not requiring modification until there is a greater understanding of river vegetation and an update of the present classification, the proposed standard habitat recording sheet may require slight modification to satisfy the needs of different specialized interests. Essentially, however, there is a need to use a standard description for peripheral environments which has wide applicability. For this reason the codings used by the NCC for SSSI mappings have been used. For specific river corridor surveys it is possible to collect data for some habitats in greater detail and for this reason a standardized scheme for recording riverine and bank features is forwarded.

2.2 Analyses

Although this document concentrates solely on the results from a single analysis, the data have been subject to many analytical treatments.

Since this report wishes to concentrate on general aspects of river flora the information from both river and bank have been combined for whole sites. 1,055 sites were surveyed, 1,012 of these being an amalgamation of two 0.5 km lengths and the remaining 43 sites being represented by single 0.5 km lengths.

This community analysis has used data from both the river and the bank and used it quantitatively. To aid others in being able to evaluate their own data easily the complete list of species recorded originally has been truncated to include only those species listed in the appendix. Many algae, bryophytes, non-specialist wetland plants and rarely recorded aquatics have been omitted. The data are quantitative because the analyses use the highest relative abundance score (1–3) for each species in either the river or bank and in either 0.5 km length in the whole 1 km site. For this reason this analysis is referred to as RBSQ—River Bank, Selective, Quantative. The RBSQ data set was chosen as the subject for this report because it gave the most comprehensive account of each site and this in turn gave the closest similarity to the predictions made prior to analyses. In all, ten analyses were carried out and evaluated. These were:

i. river only, all species, presence/absence (RAP);
ii. river only, selected species, presence/absence (RSP);
iii. river only, selected species, quantitative (RSQ);
iv. bank only, all species, presence/absence (BAP);
v. bank only, selected species, presence/absence (BSP);
vi. bank only, selected species, quantitative (BSQ);
vii. river and bank, all species, presence/absence (RBAP);
viii. river and bank, selected species, presence/absence (RBSP);
ix. river and bank, selected species, quantitative (RBSQ);
x. dominant species only for river and bank (RBD);
xi. whole rivers or sections amalgamated, presence/absence (WRP).

The analyses were a standard TWINSPAN classification which has been developed by Hill (1979). The programme classifies similar communities into groups and also list the species which are indicative of that group. It also lists those species which occur in at least 20% of the sites represented in the group.

(M4) Since the analyses were carried out on quantitative data (1–3 scale) it is important to indicate how this is used by TWINSPAN. For example, if a species occurs at abundance level 1, it is represented in the analyses as a single species. If it is recorded at scale 2 it is represented twice in the analyses—once as a pseudospecies at abundance 2 and once in its own right at abundance 1. A species recorded at abundance 3 will therefore be represented three times in the analysis.

3 Results

One thousand and fifty-five sites were surveyed on over 200 rivers and tributaries. The (R1) number of sites surveyed on each river varied from 22 on the R. Tweed to only single sites on many tributaries. The rivers surveyed are listed in Appendix 1 and their distribution in Great Britain is shown in Fig 1. The latter shows that 126 catchments were investigated, with over 70 being in England and about half this number in Scotland and Wales. In more than half these systems only the main river was investigated but in others one or more tributaries were surveyed. These tributaries are listed in Appendix 1 below their recipient river and have computer codes in numerical sequence following that of their main river.

The information presented and discussed here relates only to the analysis of a single amalgamation of data—the whole site data for river and bank for 1,055 sites using quantitative data for selected species only (RBSQ).

The inclusion into this document of the other analyses would have been very complicated; the relationship between the different elements of the data set will be the subject of a later paper. However, all the analyses split the communities into broadly similar groups but inevitably the smallest end groups sometimes varied markedly. This was particularly so for river and bank analyses where one of the environments was typically stable and the other was not, and vice-versa. In many cases, however, all analyses places sites into the same end-groups. The TWINSPAN analysis first split the 1,055 sites into two unequal groups of 656 and 399, the former more lowland and rich group and the latter more upland and less rich (Appendix 2). The second split then divided these two groups into the four major groups described throughout this document. Group A with 386 sites is characteristic of lowland areas with a rich geology, Group B with 270 sites is associated with sandstone and hard limestone, Group C with 276 sites occurs where there is resistant geology and Group D with only 123 sites are upland acid and nutrient poor. The four major groups therefore have variable numbers of representatives with more than three times the number of sites in Group A than in Group D.

The final classification into 56 meaningful groups necessitated end-groups occurring at different levels in the dendrogram. Such a decision is arbitrary but unavoidable if the data set contains an imbalance in the number of representatives in different community types. The Tables give details of the community types identified by the analyses (Tables 1 and 2); an indication of the species assemblages for the sixteen main groups at a coarse level of classification (Table 3); the important species for Groups A–D (Tables 4–7); and the relative importance of difference taxa in the four main groups A–D (Table 8).

In Table 2 there is an analysis of the relative species richness of the 56 community types. Data are given for all species as well as the selected 223 species given on the recording card in the Appendix. The ratio of selected species in relation to the total gives a good idea of the relative importance of aquatic or marginal wetland plants because many algae, bryophytes and opportunistic non-wetland species are omitted from the former. The higher the figure, therefore, the more important the wetland higher plants are. Particularly species rich or species poor communities are highlighted also.

Table 3 lists all the species which occur in at least 20% of the sites in one or more of the 16 major Groups. Where a species occurs in more than 50% of the representative sites in each major Group it is highlighted. To illustrate the different behaviour of individual species in adjacent community groups the percentage values have been given for 'nearest neighbour groups' even if they are below 20%. As in Tables 4–7, truly aquatic taxa are highlighted.

(R2) In Tables 4–7 the important taxa in the four major Groups A–D are given separately. Data for species occurring in 20% or more of the representative sites in each of the community types are given. Where a particular species is a major and characteristic component of the community type its data are highlighted. The minimal requirement was to occur in at least two-thirds (67°) of the sites.

Figures 2–6 show pictorially the distribution of each community type throughout Great Britain. Figure 7 shows on a single page the dot distribution of sites within each community type throughout Great Britain, lists the rivers and sites and the total species complement for each site, and lists the indicator and common species which typify the community type. The most species rich, and least species rich, sites for each of the 56 community types are illustrated. Figure 8 pictorially represents the relative proportion of major taxa in each of 56 community types.

The Figures and Tables are therefore designed to convey the majority of the information for communities and species at the coarse level of classification at the 16 group level as well as the fine detail at the 56 end-group level. By reference to the limited discussion text and Table 1 it should therefore be possible for anyone to look at the Tables and Figures to find out the geographical range of a particular community type and the flora which characterises it.

One of the prime purposes of the survey was to erect a working classification of rivers in Britain which could be used for nature conservation evaluation. Previous investigations into the flora of rivers in Britain suggested that water velocity, substrate and trophic status had the greatest influence over community types. For this reason it was proposed by Holmes (1980) that rivers could be typed according to their height at source, since this frequently governs the velocity and substrate, and then by gross geology which has a bearing on both the substrate and the trophic status of the water. Each of these altitudinal and geological types can then be sub-divided on their trophic status. This latter category is the most difficult to define and should refer to a river in its lower reaches. (In some cases rivers may be eutrophic from source to mouth, others oligotrophic from source to mouth, whereas some may change from small ultra-obligotropic systems in their upper reaches to large eutrophic systems in their lower reaches).

Accordingly, Table 9 is a classification of rivers based on their height at source, geology and trophic status in their lower reaches. Appended to the classification are the community types of each of the 1,055 surveyed sites.

During the individual descriptions of community types reference will be made to the use of the Indicator Species Key. Although individual sites are assigned to a particular community type using its total species complement, TWINSPAN also erects a key which enables selected species to be used to classify sites. The key erected by the programme is duplicated in the appendix. It cannot be expected to work perfectly because several sites will be classified correctly using their total species assemblage but be incorrectly assigned by the Indicator Species Key if one or more of the indicator species behave in an atypical way. The more divisions in the classification dendrogram the more the chances of errors occurring.

Despite the above reservations, the Indicator Species Key performs exceedingly well and correctly assigns more than 75% of the sites. By carrying out surveys using the
(R3) recording checklist in the appendix, where the indicator species are highlighted, it should be possible to increase the efficiency of the key by double-checking the presence or absence of these species. Using this key and the method of survey and recording sheet given here it is possible for anyone to make their own evaluation of a stream they may wish to survey.

In 1982 five sites on five of the original rivers surveyed in 1978 were resurveyed. The total of 1,055 sites therefore contains 25 duplicate sites. The five rivers selected aimed to represent a geological and geographical cross-section with the R Itchen in Hampshire representing a Chalk river, the R Lark in East Anglia representing a fen river, the R Torridge in Devon representing a lowland mudstone river, the R Conway in North Wales representing a mountaineous, base-poor river and the R Eden in Cumbria representing a calcareous sandstone river.

Of the 25 replicate sites, 19 (76%) were classified into exactly the same community types. The remaining six sites were all classified into the same major groups and usually in adjacent community types. Both the Rivers Itchen and Conway had all their duplicate sites classified identically whereas on the R Lark only one site was classified differently. On the R Torridge and R Eden three and two sites respectively were classified differently.

4 Discussion and Description of Community Types

(D1)

4.1 General Discussion

Exactly 50 years ago a classification of British rivers based upon macrophytes was published (Butcher, 1933). This pioneering work was a descriptive account which classified rivers according to their substrates and water chemistry. The characteristic plant communities were then described for various examples of each type. This publication provided a far greater understanding of the relationship between plants in rivers and their environmental constraints yet almost fifty years on from its publication there still lacked a comprehensive account of the vegetation in British rivers which had been subject to rigorous analytical study. The presentation here of results from over 1,000 kilometres of British rivers which have been objectively classified using 'Twinspan' is aimed to be the start of more objective, and statistically valid, riverine plant community evaluations.

The community descriptions which can be derived from computer studies such as 'Twinspan' are regarded as greatly advancing the objectivity in evaluations compared to recent publications by the author Holmes (1975, 1977 a, b, 1980) and Haslam (1978, 1981) the two people most involved with macrophyte surveys in Britain in the last decade. The former has provided a much greater understanding of the flora of rivers in a discrete geographical area (NE England) whereas the latter has immeasurably increased the knowledge of the flora of rivers throughout Great Britain. Both have used only a limited statistical treatment of their data and therefore their publications are essentially descriptive.

Haslam has been able to use much greater objectivity in relating the preference of individual species for such parameters as flow, depth, shade, substrate, nutrients etc than she has been able to for community evaluations. The present account therefore compliments her publications of 1978 and 1981 by classifying rivers according to their actual flora and not by their expected flora. The 56 community types identified and described here compare with over 70 stream types described in Haslam (1978). The main difference is that the data presented here relates to distinct communities identified by computer analyses whereas Haslam first identifies the range of river types based on size, landscape and rock type and then describes the expected flora.

By comparing the two different approaches it is possible to draw some tentative conclusions. Firstly, the key species for Chalk streams are essentially the same in both systems. Secondly, the key species for lowland clay rivers are relatively compatible but not as clearly comparable as they are for Chalk streams. Thirdly, the limited species complement identified by Haslam results in highland and resistant rock communities having few species in common with those identified as being key indicators in this report. Clearly there is a need to investigate further the relationship between the two systems.

There is also a need to investigate how data collected by other individuals and organisations compare with those presented here. These should include the work initiated by NCC Regions (ie Goriup 1979, 1981; Hobbs *et al* 1979, Arnott *et al* 1979) and the multidisciplinary approach adopted in the R Teifi Survey (Brooker, 1982).

Three other facets need careful consideration and further investigation. Firstly there is a need to assess accurately the optimum survey length. Secondly there is a need to (D2) evaluate how the 25 sites for which there are duplicate data can assist in assessing seasonal or annual changes in flora and how representative single records for individual sites are. Thirdly there is a need to accept the problems of operator error but at the same time steps must be taken to minimise these.

Results from using the Indicator Key suggests that the most efficient length for typing a river is 1 km. For the 1,012 sites for which there are data for an amalgamated 1 km length and two-half kilometre lengths, the key correctly assigns more than 75% of the 1 km sites but only about 65% of the 0.5 km lengths. For the 43 sites for which there is only a single 0.5 km length, 28 sites, or 65%, are correctly assigned. Although these sites were used in the original classification they still keyed significantly worse than the 1 km data.

In 1978, the original survey year, more than 100 sites had a 100 metre length surveyed within the total 1 km length. Although it has not been possible to key out all the sites, the accuracy of the key is reduced further by using only 100 metres. However it still correctly assigns almost 60% of the sites and rarely assigns sites into incorrect major groups.

In 1982 the England Field Survey Unit of NCC surveyed a number of rivers in the south of England. Some of their data have been evaluated using the key. Initial results suggest that using data collected by other surveyors at least a 70% relationship between keyed sites and predicted sites can be achieved. Using 1 km data provides a slightly higher figure than that for 0.5 km lengths.

The above figures will all be significantly increased using the standard recording sheet. By using this method a quick check of the indicator species records can be made at the end of recording. The key will therefore be more accurate than the present data suggests and it is almost certainly likely to be most accurate for a survey length of river of 1 km.

The duplicate data for five sites on five rivers collected five years apart are valuable in assessing both the methodology of data collection and its evaluation. The data also provide a means of assessing how stable the floral communities of rivers are and how meaningful it is to rely on single site visits.

The results from the R Itchen and the R Conway suggest that the floras of a classic Chalk river and a classic, rapidly flowing oligotrophic river are very stable communities. This is perhaps what should be expected because the flora of the former is a result of ancient management practices which are altered very little today. The latter, on the other hand, have very little management and should also not change unless drastic changes occur in the river basin or management of the channel takes place. Their identical floral communities recorded five years apart suggests that rivers which retain traditional management or have no management at all can be assessed well by just a single visit.

The six sites in which changes were evident are attributable much more to human error than actual changes which might have occurred in the five year period. The greatest error occurred on the R Torridge in which three of the five sites were classified differently. This is a result of additional species being recorded in the second survey which were omitted in the first survey because experience had not been gained in identifying plants early in the season when they are not in flower. What is surprising is that these additional species resulted in duplicate data for three sites being placed (D3) in different community types using the full species complement but the Indicator Species Key assigned them to similar community types. The assemblage was therefore richer in the latter but the indicator species remained the same.

No river was re-surveyed which had had major management in the intervening years so the effect of channel manipulation cannot be assessed.

The above data suggest that a single site visit can establish the major features of the flora of a river. This, however, can only be regarded as satisfactory for rivers which have not had recent management (unless this management is a routine one which is of a traditional nature). The errors evident within this data set suggest that the use of a standard recording sheet should minimise problems but it must always be accepted that experience will aid collection of accurate data. Another feature of the duplicate data is its ability to illustrate that 1 km lengths surveyed every 6–7 km gives an accurate picture of downstream succession in a system. Both sets of data from the R Eden illustrate this by showing that the community in the upper reaches is an oligotrophic (D) community which changes downstream rapidly to a mesotrophic (C) community and then into an extensive system of a meso-eutrophic (B) community in its lower reaches. The two sets of data for the R Itchen on the other hand show that this river has the same community characteristics from top to bottom. The duplicate data therefore confirm that the method can be used to identify accurately the different plant community resources in an area as well as an appreciation of their spatial distribution in different catchments.

4.2 Plant Communities

Before describing in detail the characteristics of each of the 56 community types identified, a few points warrant comment. The detailed descriptions are arranged in four sections since the analyses separated sites into the four distinct major groups described in the results section.

The altitudinal, geographical and geological characteristics of the four major Groups A–D have been described earlier but how this is reflected in their flora has not been discussed fully. In a very coarse way a great deal can be learnt from referring to Table 8 which summarizes the relative importance of groups such as bryophytes and flowering plants in each of the four groups. This clearly shows that algae and lichens are relatively uniformly represented, albeit with different taxa being important in different groups. The bryophytes on the other hand are far less common in Group A, more common in B and even more important in Groups C and D respectively. There are three times the number of species recorded for Group D than Group A, yet their importance is even greater than this because in the former group they are often the primary producers and represent the majority of permanent plant standing crop. This is also often true for the algae. Flowering plants have an inverse relationship, being most important in Group A where they account for 81% of the recorded taxa, and least important in Group D where they account for only 61% of the taxa. Again, these figures are related to numbers of species and not their standing crop or contribution to the productivity of the rivers.

The importance of bryophytes and algae in Groups C and D is even greater than the above data suggests because these figures are based on the reduced species list. The original records show an even greater prevalence of these species. Another interesting feature of the data shown in Table 8 is that monocotyledons, in which all pondweeds are to be found, are far more important in Group A than the other three groups whereas dicotyledons are important components in all but Group D. Being predominantly broad-leaved these are not generally adapted to upland rivers where abrasive floods are frequent.

(D4) The importance of these groups of taxa in each of the 56 community types is shown in Fig 9. The figure shows quite clearly the relative importance of each of the taxa in the major groups as well as illustrating that great differences are apparent for individual communities within each group. The numbers of species closely associated with a particular community may vary by as much as 40 species with the most species diverse community found in Group D and the least diverse found in Group A.

Although the trend towards a more bryophyte rich community is clearly evident from A–D a number of sites are visibly very different from their neighbours. This is particularly clear for C3v which is species poor overall but has more dicotyledon species than any other community in Group C or D. It also has both few liverworts and mosses than any other community in Group C or D. The uniqueness of flora is because it is the community type associated with the New Forest streams, a lowland oligotropic community isolated geographically from similar river habitats in the remainder of the British Isles. The community also shows that the geology is very important in determining the community type, even though its non-westerly position is responsible for the absence of many important bryophytes.

The relative importance of aquatic taxa in the four major groups is highlighted in Tables 4–7. In Group A, 43 aquatic higher plants are important in at least one of the community types identified whereas the comparable figures for Groups B, C and D are 24, 23 and 11. This clearly explains why previous accounts of British rivers have described the richness of the flora of lowland rivers in comparison with those flowing in uplands. The present data support this fully when related to purely aquatic species but this is not true if the total species complement is considered.

Reference to Table 2, which shows the mean number of species found for all sites in each of the 56 community types, illustrates how great the variation is for each major Group. If the total species assemblage is considered, Group A has 67% of its sites below average even though for aquatic taxa it has twice the average. The mean species complement is greatest for Group B and least for Group A, with Groups C and D being about average. If the selected species complement is considered (which has had many bryophytes and non-wetland taxa removed) then the average for Group A communities almost reaches average whereas the communities of Group C are well below average. This is because Group C is predominantly an oceanic community type where shading is important. Many taxa are therefore more characteristic of shade adaption than being typical wetland species.

The number of selected species expressed as a percentage of the total recorded assemblage frequently illustrates the nature of the community. If the percentage is high then the community contains relatively more aquatic or wetland taxa than rare bryophytes or species not particularly associated with rivers. The percentages are therefore higher for Group A communities; here too however it is possible to derive that the ditch-like communities of A4 have less aquatic taxa than their more downstream counterparts. In Group B, B1 has the highest average because it is associated with lowland, river reaches of rivers which rise at higher altitudes. Within Group C highest ratios are found in C3i–iii which are communities or rivers associated with upland fens, bogs, reservoirs and lakes. The stability, richer substrates, lack of shade and higher water tables favour aquatic flowering plants and marginal wetland species whereas bryophytes and invasive species are rarer. In Group D the highest ratio is again associated with slower water velocity and richer substrates but the percentage is not comparable to that associated with lowland rivers.

(D5) The mean values for species richness for each of the 56 community types given in Table 2 allows individual site diversity to be compared with comparable sites. In any conservation evaluations it is imperative that like communities are compared with each other and not with different community types. If species richness is to be regarded as an important criterion then it is amply illustrated by these data that the aquatic flora of an upland system should not be compared with a lowland system. In addition, many of the 56 community types are intrinsically more species rich than others whereas others have been impoverished through management.

For example, within Group A mean community values range from 28 species per site in Group A1i to 52 in Group A3i. In most cases the richest site in each community type has twice the number of species found in the poorest site but in the three most highly managed community types there is a five-fold difference. These great variations illustrate the importance of comparing for instance only Chalk stream floras with each other, clay stream floras with each other, and so on. By so doing it is then possible to identify examples which most typify a community type as well as identify those which are particularly species rich or species poor. Having identified their relationship with other similar rivers it is then possible to evaluate the reasons why individual rivers are atypical, be it good or poor.

For nature conservation evaluation it is important to have a working classification which enables national and regional differences to be considered. The combination of the hierarchical system of classification based on altitude, geology and trophic status (Table 9) and the communities identified by the 'Twinspan' analyses achieves this. The former clearly shows the relationship of the four major community groups in relation to altitude, geology and trophic status but the regional differences are only evidence with reference to Figs 3–6.

In the classification, it is clear that Group A communities are associated with rivers rising at low altitudes and with rich geological strata, whereas Group D is associated with high altitudes or where the geological strata are poor and the water low in nutrients. Similarly, it is possible to deduce that Group A3 communities are associated with Chalk and varied trophic status whereas Group A2 communities are associated with non-limestone geologies and eutrophic water: where the trophic status is lower, any Group A communities are very rare, even at low altitudes.

Geographical variations of otherwise similar communities can be illustrated by reference to the distribution of individual sub-groups of Group A3 and the distribution of the four main types in Group B.

In the first example all A3 communities are associated with Chalk yet there are four distinct examples which are geographically discrete. The first example is the classic Chalk rivers of the R Itchen and R Test which have exceptionally stable flow regimes and very rich communities of plants within the channel and on the banks. On average, sites surveyed on these rivers contain at least 15% more species than other Chalk rivers. Secondly, there are smaller Chalk streams and those which rise on Oolite. Their flow regimes are less stable and they contain less species. Examples occur throughout the soft limestone areas of England, typical examples being the Chalk fed aquifers of rivers in East Anglia, small Chalk streams of Berkshire and smaller Chalk streams in Hampshire. Thirdly, there are a group of modified Chalk streams where siltation has become a major problem. These are even less species rich. Typical examples are the Chalk streams of Berkshire and Hertfordshire where the streams traverse clay, and the
(D6) rivers on the Chalk of Humberside. Fourthly there is a distinct group which have typical Chalk stream species in the channel but on the banks are found species more associated with neutral clay or peat. These are typically found in Dorset where the Chalk fed rivers flow over clay and are influenced by the Dorset Heaths.

Although Group B is strongly correlated with sandstones, grits, mudstones and hard limestone, each of the four major types tend to be geographically discrete. This is not evident from the classification but is very clearly illustrated in Fig 4. It shows that B1 is associated with rich strata in north-east Scotland, B2 is associated with the borders of England and Scotland, B3 is most clearly evident on the England/Wales border and B4 occur throughout western Britain where the combination of high rainfall and rich strata are found.

• The classification and community types should now be used as a basis for aiding the designation of riverine SSSIs. It is important to note that the NCC would always wish to attempt to use a whole ecosystem approach in its evaluation—ie plants, invertebrates, fish, mammals, birds etc. However, since plants are by far the easiest and quickest to evaluate (and now that we have a framework for standard comparisons) it is intended that they should become the skeleton of the evaluation scheme onto which other wildlife features can be added. In reality this has been the practice in the past because most authorities are agreed that a diverse and semi-natural plant assemblage will benefit animal communities. A river of exceptional botanical interest could therefore stand in its own right and may form the basis of an SSSI designation even if other wildlife attributes were poorly understood; it would not necessarily be downgraded if they turned out to be poor. On the other hand, a run-of-the-mill botanical site may be upgraded if other wildlife aspects are outstanding.

The classification into community types is site specific and allows the thorny problem of site boundaries and downstream succession to be neatly short-circuited. Upstream sites at a particular altitudinal source and geology can be compared with other sites with similar floras. Similarly this is possible for middle reaches and lowland reaches on different geological formations and at different trophic levels.

SSSI selection should therefore attempt to encompass the national variation in river types which exists for a particular broad category of rivers. For example, four types of Chalk stream have been identified and at the very least one representative of each requires designation. Similarly the full range of types identified in the other sub-groups should be considered yet it is doubtful whether ditch-like communities identified in Group A4 would warrant protection. On the other hand, it may be argued that the very atypical communities associated with upland bogs and fens (C3i) require greater attention because they are a very limited resource which remain in a semi-natural state but could be easily destroyed.

The classification allows therefore a national series to evolve which illustrates the best examples of river types found throughout Great Britain. Reference to two lowland examples illustrates this.

The R Eye in Leicestershire has been designated as one of the finest examples of a clay river. It is a particularly good example because although its source is highly managed with its upper two sites classified in the ditch A4ii community, the remainder of the river has consistently the same clay community of A2iv. It therefore shows no suc-
(D7) cessional change from source to mouth and is an example of a purely clay river. The middle section above Melton Mowbray was designated because it fulfils the NCR criteria; it is truly representative, typical, species rich, and contains the right rarities for its type, and it is in a semi-natural state. The R Nar is another good example because it typifies a lowland river which shows a classic downstream successional change. It is in the same category as the R Lark in the NCR, being a Chalk stream feeding into fenland. It rises as a managed drain before passing into a Chalk stream community which is typical, is semi-natural and more species rich than others like it. It then flows into fenland. It is probably the best of its type and shows diversity in catchment characteristics, representing four distinct community types.

In lowland England any river which is in a semi-natural state—ie it has the expected (or better) flora, has few obstructions to flow, has a high and original water table and has had minimal dredging, should warrant consideration for SSSI status. This is because the semi-natural resource is now so limited in lowland rivers. Unlike natural woodlands, where the destruction of the interest is obvious, in rivers they still flow and appear to some as being semi-natural even though they have had considerable reductions in their physical and biological variations.

In some river types—such as smaller rivers which still have a natural channel and native, natural tree-lined margins the flora may be particularly poor. This is natural and species poor natural examples should, and can be, catered for by comparing like sites with like sites.

Semi-naturalness must therefore be the most important criterion in site selection in lowland rivers.

The use of comparing 1 km lengths and relating these data to the overall national resource allows the semi-natural, representative, richness etc criteria to be applied to the smallest stretch of river as well as whole systems. A small stretch of river as small as 1 km may be worthy of consideration if it has had minimal management, has great diversity of natural features, has a representative flora and lacks impermanence or fragility. The concern for the smallest units is that they are part of a dynamic system with a major throughput of water, sediments, plants and animals. The natural features present must be regarded as being as stable as can be expected for an evolving habitat.

The consideration of very small units is often also important when the river is an important component of a composite wetland site which may include marsh, fen, carr or osier. The peripheral habitats might be rendered fragile if changes to the river occur.

Site evaluation and a consideration of downstream successional changes, the integrity of large or small sections, appears to be well catered for in the typing system. What is less easy to quantify is the resource of the corridor and where to draw the lateral boundaries of the SSSI. The importance of the river for many invertebrates, mammals and birds may be dependent on the existence of large tracts of semi-natural habitats along the margins of the river. If the river schedule is not merely peripheral environments, particularly if they are wetlands. If the channel of the river is the only interest then the lateral extent of the SSSI should be where the slope of the river flattens out and has become cultivated or developed.

(D8) Although in terms of the national resource, lowland England only represents a little over a quarter of the known river types, selection procedure should be relatively simple because of the limited number of systems warranting SSSI status. Only the smallest streams could be described as semi-natural throughout their length, and these are likely to be found as tiny trickles in native woodlands. Sectional SSSI designations are therefore most appropriate except for those larger rivers which have traditionally, and slowly developed, management practices. This applies to Chalk streams. Clay rivers, on the other hand, have had major management in recent decades which has been so rapid that populations have not had chance to evolve gradually.

Each District should have representative lengths of all its river types, however small, providing they fulfil NCR criteria. In some Regions (ie East Midlands) only a few river types may be expected where others (South Region) a whole range from clay, Chalk and oligotrophic acid rivers of the New Forest are encountered. In this latter case, because this District contains the majority of examples of lowland, acid heath streams more than the average number of examples should be scheduled.

The same arguments apply for SW England, Wales, N England and Scotland where totally different plant communities of rivers occur. Each District should schedule the best examples of the river types which occur within their confines. If a particular river type is a very common resource, then variations in trophic status from source to mouth, size variations, and the importance of peripheral environments should be considered so that the variation of this river type is adequately covered.

If each district adhered to these principles a series of rivers would be scheduled which would adequately protect the lowland rich examples, the sandstone and Carboniferous Limestone rivers, the oligo-mesotrophic, Silurian and Ordivician rivers and the upland and highland oligotrophic rivers and streams. The scheduling of the best examples in each District would ensure that the geographical variation was catered for, each District having their own series of river types which are important in a GB context because they will be different from a similar river type in another part of Britain. The actual number of a particular river type to be scheduled in a particular District will depend most on how widespread that particular type is and how limited the resource is. If the river type is limited to single Districts then more examples should be scheduled than if the type exists in many districts.

Group A Communities (RBSQ)

(RBSQ.A1) This group is the largest of the four major groups and contains 386 sites. All of these sites are either base-rich or nutrient rich, and usually both. They occur exclusively at low altitudes and usually where the slope of the river is very shallow. They can, therefore, be described as lowland and nutrient rich communities.

Geographical distribution

This group is typified by communities in central, southern and eastern England south-east of a line drawn roughly from Scarborough to Exeter. A narrow flange in the midlands fans west from this line to include the rivers in the lowland plains of Cheshire and Staffordshire. Further north, the flood plains of central Yorkshire also contain lowland communities.

The rivers of the New Forest are the only examples in southern England of rivers with communities which are consistently not classified within this group. Apart from these rivers, the R Teise, and the WS Rother are the only examples of rivers which have two of their sites not within Group A. The uppermost sites of the ES Rother, Lambourne, Moors, Uddens and B Avon are the only other examples of sites within this geographical area which are not classified as Group A communities.

Of the 386 sites in Group A, 10 occur in Wales remote from the centre of its range (4 on Anglesey, 1 on the W Cleddau, 1 on the Lougher, 2 on the Nicholaston Pill and

2 on the Thaw). Seven occur similarly in Scotland (1 on the Wick, 2 on the Ythan, 2 on the Dean, 1 on the Teith and 1 on the Tweed). There is only one example in England (R Inny) distant from the representative geographical area. The remaining 368 sites (95%) occur within, or on the edge of, the defined geographical area. Within this area, 94% of the sites are classified as having Group A communities and the streams of the New Forest account for half of the atypical classifications.

Excluding the New Forest, therefore, 97% of rivers in central, southern and eastern England have a distinct Group A plant community. The area of Group A can therefore be defined as lowland England, excluding the streams of acid heaths and sands. Almost all the area is below 200 m with only the summits of named Wolds, Downs and Hills exceeding this height.

Geology

The geology is characterised by the lack of any resistant rock. The Chalk of Great Britain is confined to this area, as are the majority of the harder and less pure Oolites. Clays account for almost 50% of the area with alluvium and peat important on the east coast and in East Anglia. Soft sands are important components in the Cheshire Plain, in the Vales of the Yorkshire Ouse and Trent, in East Anglia, the edges of the Weald and in the New Forest area.

In general, the geology of this central, southern and eastern region of England is characterised by rocks which are rich in either nutrients or bases, or rich in both. The sands of the New Forest and on the edge of the Weald are the major exceptions, both having few nutrients and being poor in bases.

Physical characteristics and variations

Rivers in central England are typified by fine substrates of clay or silt over which the water flows with only slow or moderate velocity. These two characteristics of the rivers are a function of their sources being at low altitudes and their channels passing over soft deposits which are easily eroded into fine substrates.

(RBSQ.A2) There are three clearly distinct substrates which result from the very different parent rock types.

The most distinct is the coarse gravels, pebbles and even cobbles which are a feature of the streams and rivers flowing over Chalk. Because these rivers receive the majority of water from underground sources, their flow capacity varies little through the seasons. The water is characteristically crystal clear with siltation confined to their lowermost reaches or in backwaters or sheltered alcoves at the edges of the water courses. The Rivers Test and Itchen in Hampshire epitomise the characteristics of Chalk rivers whereas the middle reaches of the R Nar in Norfolk and the Upper Kelk Beck and R Hull in Humberside are typical of small Chalk streams. Rivers flowing over Oolite have some features akin to those which flow over Chalk yet they generally rise at much higher altitudes and then carry inflated volumes of water after heavy rain. The Rivers Coln and Windrush in the Cotswold are typical examples, both of which have much coarser substrates in their upper reaches.

Fine sandy substrates, occasionally accompanied by gravels, are a characteristic feature of rivers flowing over the soft sandstones of Cheshire, the Vales of the Yorkshire Ouse and Trent and the smaller rivers in Norfolk. The sandstones in southern England, and especially those of the New Forest, are generally base poor. Because of their open texture water flows rapidly through these rocks and the rivers which they produce frequently rise and fall rapidly and have coarse gravels and pebbles as typical substrates. They are frequently erosive channels.

The rivers which flow over clay are characterised by very fine sediments or clay itself. Flow velocity is generally slow during low flows. A major feature of clay rivers is their behaviour after heavy rain. Since clay is impervious, rain drains rapidly into drainage channels and river levels may rise dramatically, a 5 m rise in the largest rivers being possible. In contrast, during very dry weather the levels drop very low.

Vegetation characteristics of Group A communities

Lowland rivers are dominated by flowering plants and these communities also contain many more aquatic species than other river types. For instance Tables 4–7 show the relative importance of aquatic taxa in Groups A, B, C and D with Group A having 43 representatives, almost double the number found in Group B and C and quadruple the number found in Group D. Table 3 shows the important taxa for the 16 major subgroups and this also illustrates the importance of Group A for aquatic higher plants. Sixteen aquatic species are confined to being important components of Group A whereas the comparable number for Group B, C and D are 2, 0 and 2 respectively.

Concomitant with the greatest importance of aquatic flowering plants in Group A is the least importance of lower plants such as liverworts and mosses. This too is amply illustrated in Table 3 which lists 35 bryophytes, 75% of which are not represented in Group A. Table 8 further highlights this by showing that the combined bryophyte total for Group A river communities represents only 10% of the total species complement whereas the flowering plants represent 81%. The former is much lower than in any of the other three major groups and the latter is much higher.

The characteristic species of lowland rivers is most easily illustrated by reference to the top of Table 3. This shows the species confined to being important components of lowland rivers only.

Since Group A contains 21 community types it is important to discriminate between the four main sub-groups A1 to A4.

(RBSQ.A3) Group A1 is characteristic of rivers with calcareous water, often partially derived from Chalk aquifers, which flow through very flat country which ensures a slow water velocity. Substrates usually comprise of silts, sands and very fine gravels. The catchments are usually intensively farmed and there is considerable nutrient enrichment. The characteristic species are therefore submerged taxa which prefer sluggish water and a high level of nutrients. Shallow rooted or free floating species, as well as those taxa which prefer to receive nutrients from the water rather than the sediments, reach their greatest importance in this group.

Group A2 are clay rivers. Wherever clay is the major geological constituent of a catchment the flora will be dominated by species characteristic of Group A. Clay catchments usually provide an abundance of nutrients and fine sediments to a river. However, because the rivers rise and fall rapidly siltation is confined to stretches of water protected from the full force of flood water. An unmanaged clay river will thus provide a combination of firm rich substrates into which plants can root as well as more unstable fine silts in sheltered backwaters.

Group A3 are Chalk or Oolite rivers. All rivers with this community type share two important characteristics which are not found in other lowland rivers. Firstly, their primary source of water is from aquifers which provide a very stable flow regime, differences between minimum flows and peak floods being small. This provides a stable flow regime which assists colonization on the stream bed as well as maintaining a high water table on the bank. Secondly, gravels and other coarse substrates prevail.

Group A4 is a strange community which is dominated by the most upstream sites on lowland rivers which have ditch-like characteristics. They are highly managed, narrow rivers with steep sides and impoverished physical diversity. They differ, of course, from the true 'ditch' in having a large fluctuation in water level and an almost continuous, uni-directional flow of water through them.

Table 9 shows the distribution of Group A communities in the classification of rivers. The majority of sites are centred at the top of the Table which describes rivers which rise at altitudes lower than 200 metres. However, a striking feature of the communities associated with lowland rivers is that Group A communities are only associated with calcareous, eutrophic waters. The lowland rivers with non-calcareous rocks and oligotrophic or mesotrophic water rarely have these community types.

The sites surveyed in the rivers classified in the uppermost five boxes in Table 9 ie lowland, meso-eutrophic and/or calcareous have 97% of their sites classified as Group A communities. On the other hand, lowland rivers classified as less calcareous and having less nutrient and base-rich water have less than 15% of their sites classified as having Group A communities.

Throughout the remainder of the classification which deals with rivers with altitudinal sources greater than 200 metres, Group A communities are rare. Throughout this part of the classification Group A communities represent a mere 5% of the total. In all but one example the sites are confined to the lower, more enriched sections of rivers. Moreover, almost 50% of the examples are confined to two rivers, the R Coln and R Windrush. These two rivers are the most calcareous examples because they drain the Oolite of the Cotswolds.

The classification also highlights several other points. Firstly, Group A3 communities are associated almost entirely with catchments dominated by Chalk or other soft limestones. Secondly, Group A4 communities invariably occur in the upper reaches of the river where the greatest effects of channel modification manifest themselves in the flora. Thirdly, Group A2 communities prevail in eutrophic, lowland rivers with no soft limestone in their catchments. These are usually dominated by clay. These points are further illustrated by reference to Fig 3 but all serve to show that the classification of rivers based primarily on geology, altitude and trophic status is a valuable aid in elucidating the patterns of river plant communities.

(RBSQ.A4)

Group A1 Rivers

Group A1 rivers are confined almost entirely to lowland England with the greatest concentration of these river types being found in East Anglia.

The two main features which characterize these river types are a calcareous water chemistry and a substrate of sands, gravels and occasionally silt and clay. Their presence is therefore very highly correlated with geological characters which ensure that the river is fed by Chalk aquifers but the river itself flows over other substrates. The geology of much of East Anglia therefore epitomises this group because much of the Chalk bed rock is overlain by more recent Quaternary deposits.

Fifteen species occur more commonly in Group A1 communities than in any other of the 15 main community types. These include the eight species at the top of Table 3 and *Lemna minor* (Common Duckweed), *Zannichellia palustris* (Horned Pondweed), *Potamogeton natans* (Broad-leaved Pondweed), *P. perfoliatus* (Perfoliate Pondweed), *Myriophyllum spicatim* (Spiked Water-milfoil), and the two algae *Enteromorpha* and *Vaucheria*. Most of these species are characteristic of enriched and sluggishly flowing water and all are truly aquatic species.

There is great variation within the seven subgroups of Group A, the greatest variation being due to flow rate and associated substrates.

Community A1i—Man-made Channels in Tidal Reaches

This community type is particularly associated with the lower reaches of rivers which are man-made channels. Although there may be little or no salt intrusion, most rivers with this community type will be affected by tidal influences. The community is found particularly frequently in the East Anglian fens where the substrates often contain a mixture of fine sands and other fine particles. Rivers with this community type are usually at least 1 m deep and 15 m wide. If the water is not polluted, it is at least considerably enriched. No other community type has such an impoverished flora.

A1i communities are characterised by aquatic higher plants dominating the flora. Of the 44 taxa present in at least 20% of the sites, 17 (39%) are either submerged, floating or emergent species, three are algae of enriched or sluggish water (*Cladophora,* and *Vaucheria* and *Enteromorpha*) and three are predominantly amphibious. Because the substrates are so fine this is the only community type in which no bryophyte species are represented in at least 20% of the sites. The flora is thus characterised by more than 50% of the taxa being aquatic plants, and many of these are very poorly anchored.

The main indicator species (Fig 7) are all submerged higher plants with three species being uniquely common to this community type (Table 4). The two *Potamogeton* species are both common in deep water whilst *Scirpus maritimus* (Sea Club-rush) is indicative of the tidal influence on the flora. The dominance of *Ceratophyllum demersum* (Rigid Hornwort) and *Potamogeton pectinatus* (Fennel Pondweed) in the channel are indicative of sluggish, polluted water. In A1i these species are at their greatest abundance.

The banks of A1i rivers are usually steep and high sided since all are a result of ancient channel construction. On such banks *Agrostis stolonifera* (Creeping Bent) and *Phalaris arundinacea* (Reed Canary-grass) are always to be found alongside many species which have no special affinity to water. Thus they may be just as common along a roadside (RBSQ.A5) verge. Where silt accumulates rafts of amphibious species spread into the water, *Glyceria maxima* (Reed Sweet-grass) and *Polygonium amphibium* (Amphibious Bistort) being the most characteristic.

Only 58% of the sites are correctly assigned to this community type using the indicator species key. This is very low but typical for a particularly species impoverished group.

Community A1ii—Canalised Fenland Rivers on Clay and Sand

This community is most characteristic of fenlands in East Anglia and on the Somerset Levels. Both the water chemistry and physical features are similar to those of Group A1i communities but the major difference is that Group A1ii communities are rarely found in tidal stretches. They are associated with much more stable substrates which invariably contain clay, and occasionally gravels also. Both community types are associated with sluggish flow velocities.

The large number of indicator species listed in Fig 7 shows that A1ii communities have a combintion of species typical of sluggish fenland rivers as well as species more common on clay. This community type is therefore not species poor. Only three species, *Carex otrubae* (False Fox-sedge), *Elodea nuttallii* (Nuttall's Pondweed) and *Sagittaria sagittifolia* (Arrowhead) are most prevalent in Group A1ii communities. A further indication of the lack of a truly obvious identity of the group is shown by no species occurring commonly in A1ii communities but in no others.

Because water velocity is so slow, water-supported aquatic taxa are a major component of the flora. Twenty five (37%) of the 67 taxa which occur in 20% or more of the sites are either submerged, emergent or floating species. The range of aquatic plants is greater than in A1i because sections of river are likely too be shallower which also creates an increase in velocity. The presence of Water Crowfoots and *Berula erecta* (Lesser Water-parsnip) is characteristic of the increase in morphological variation in the plant community.

The species richness of the community which results from a combination of fenland and clay characteristics enables 91% of the sites to be assigned correctly using the indicator species key.

Community A1iii—Highly Managed Unstable Sand Rivers

This group is characteristic of central and eastern England where highly managed rivers flow over fine sandy substrates. The water is generally calcareous because water is derived from ground water before the river flows over sand. Because management has reduced habitat diversity and because sand is intrinsically an unstable substrate, the community is typically species poor.

The Rivers Devon and Smite in Nottinghamshire are typical, being less than 10 m wide and having enriched water due to the intense arable land within the catchment. They are an example of calcareous clay rivers giving way downstream to sand whereas the R Stour in Essex is an example of a river partly derived from Chalk aquifers which then flows over fine sands.

(RBSQ.A6) Group A1iii communities are similar to those of Alii but lack the diversity of species. Despite being represented by more sites, there are far fewer taxa represented. Of the 55 taxa present in 20% or more sites (Table 4), 19 (34%) are floating, submerged or emergent species. The absence of species common in Group A1ii such as *Potamogeton lucens* (Shining Pondweed), *Phragmites australis* (Reed), *Elodea nuttallii, Ceratophyllum demersum, Ranunculus circinatus* (Fan-leaved Water-crowfoot), *Butomus umbellatus* (Flowering Rush) and many more, all indicate shallower water, lack of clay and general bed instability. On the other hand, the importance of a species such as *Zannichellia palustris* shows how characteristic unstable sands are. Indeed, this species and the pollution tolerant *Amblystegium riparium* are the only common indicator species of the group. Other important species include not only those of polluted, unstable rivers, but those which can withstand constant management and a lowering of the water table.

The flora of A1iii is characteristic and despite being so impoverished, the indicator species are capable of assigning 96% of the sites correctly.

Community A1iv—Sluggish Mixed Sand/Clay Rivers

This Group is very small and characteristic of the Suffolk R Deben. Such a small group, based primarily on a single river system, is undesirable in a national river classification. However, because so many taxa are common indicators which separate these six sites from 29 other sites in Group A1v it has been retained. It is also possible that other river systems may be equally characteristic.

The main features which characterise Group A1iv are mixed sand, clay and fenland peat substrates within a channel about 10 m wide. Water quality is good, derived partly from calcareous ground water.

The most characteristic indicator species (Fig 7) are *Potamogeton alpinus* (Reddish Pondweed), *Hippurus vulgaris* (Mare's tail), *Petasites hybridus* (Butter-bur) and *Scutellaria galericulata* (Skull-cap), all these species being confined to Group A1iv in Group A1. Seven other species occur more commonly in Group A1iv than in any other Group, these species ranging from the submerged calcareous water lover *Oenanthe fluviatilis* (River Water-dropwort), the floating *Lemna minor*, and the emergent fenland reed *Phragmites australis*. The dominance of *Nuphar lutea* (Yellow Water-lily) indicates the importance of clay.

Because of the diversity of habitat and clean water, this sub-group is characteristically species rich.

Five out of the six sites are assigned to the correct community type using the indicator species key and no other sites are incorrectly assigned to it.

Community A1v—East Anglian Fen Rivers Fed by Calcareous Water

This large Group typifies rivers in very flat country in East Anglia. The main physical characteristics are a sluggish flow over fine gravels and sands but small amounts of clay are also usually present. Banks are usually steep and the rivers are usually greater than 10 metres wide. The water is always calcareous, typically the rivers rising from small springs and then being augmented by surface water lower downstream.

Rivers such as the Wensum, Yare and Waveney in their non-tidal lower reaches are typical. All these rivers rise in catchments where Chalk is thickly overlain by clay but then pass onto Tertiary sands and gravels in their lower reaches. The R Waveney is an unusual example because in its upper reaches clay and fine sediments predominate (with classic A2 clay communities) but in the lower reaches on the Tertiary sands the substrate becomes coarser and A1v communities dominate. The communities found in the R Stour in Kent below Wye indicate that where less calcareous water flows over chalk this A1v community may also be found.

The flora associated with A1v communities is of average richness but truly aquatic species are important. Twenty five of the 66 common species (38%) are submerged, (RBSQ.A7) floating or emergent with *Sparganium emersum* (Unbranched Bur-reed) being particularly characteristic. There are only two species uniquely common to this lowland community (Table 4), and both occur only sparsely. The occurrence of the moss *Fontinalis antipyretica*, which is absent from Groups A1i-iv, indicates that coarse substrates are important even though the flow remains sluggish.

The indicator species (Fig 7) show that the characteristic aquatic species are all typical of sands and gravels (eg *Myriophyllum spicatum*, *Ranunculus calcareus*—Brook Water-crowfoot and *Zannichellia palustris*) whereas the importance of *Glyceria maxima* on the banks indicates a sluggish water velocity. The sluggish velocity is also reflected in the importance of the alga *Enteromorpha*.

90% of the sites are correctly assigned using the indicator species key. In addition, several other sites are incorrectly assigned to the group.

Community A1vi—Fast-flowing Calcareous Small Rivers on Mixed Substrates

Almost all rivers having this plant community have considerable Chalk or Oolite in their catchment. This ensures both a calcareous water chemistry and a stable flow regime. Although Chalk may dominate the catchments, Quaternary deposits ranging from clay, alluvium, gravel and peat are common. There is, therefore, usually a stable flow regime over diverse substrates. Because of the stability of flow, banks are normally shallow and the water table on these banks is high. These rivers rarely exceed a width of 15 metres.

A1vi communities are widely distributed in England from the Chalk rivers of Kent, Hampshire and Norfolk in the south and east to the rivers draining the Cotswold in the centre. The most characteristic rivers are the R Wissey in East Anglia and the R Avon above Salisbury, both of which superficially resemble typical Chalk streams.

Because A1vi communities are associated with diverse substrates the plant assemblages are generally species rich. Although the flow regime is stable, both the narrowness of channel and increased velocity ensures that aquatic plants are relatively less important than they are in other A1 communities although the actual number of taxa found is comparable. Of the 68 common species in A1vi, 22 species (33%) are submerged, floating or emergent species.

The absence of submerged species of sluggish, deep water is particularly obvious with *Ceratophyllum demersum*, *Ranunculus circinatus* and *Potamogeton lucens* being typical examples. On the other hand the occurrence of plants such as the alga *Hildenbrandia rivularis*, the lichen *Verrucaria*, the liverwort *Pellia endiviifolia* and the mosses *Amblystegium fluviatile*, *Fontinalis antipyretica* and *Rhynchostegium riparioides* all illustrate the presence of coarse substrates. Species typical of shallow Chalk streams are aslo common, *Berula erecta*, *Callitriche obtusangula* (Blunt-fruited Water-starwort) and *Veronica anagallis-aquatica* (Blue Water-speedwell) being important indicator species.

The flora of A1vi communities is truly diverse with submerged fine-leaved species such as *Ranunculus fluitans*, *R. calcareus*, *Myriophyllum spicatum* and *Zannichellia palustris* occurring alongside broad-leaved species such as *Potamogeton perfoliatus*, *Berula erecta* and *Callitriche* species. Although A1vi communities contain many species typical of Chalk streams, their floras reflect the enriched water and substrates which are a result of the Quaternary deposits. The moss *Amblystegium riparium* and the pondweed *Potamogeton pectinatus* illustrate the nutrient enriched expression of the flora. Because of this enrichment the floras are more related to a fenland flora than the flora of typical Chalk streams.

(RBSQ.A8) Only 59% of the sites are assigned to the correct community type using the indicator species key. This is because the fenland rivers such as the R Nar and R Wissey do not key correctly.

Community A1vii—Large Rivers with Calcareous Water Flowing over Tertiary Sands

This community is characterised by the lower reaches of the R Avon in Hampshire. The upper reaches of this famous river flow in a Chalk catchment which has considerable Quaternary deposits but below Salisbury it traverses Tertiary sands. It is in this section of the river, which is deep and large, the flow regime very stable, the water chemistry alkaline and rich, but the substrate relatively poor, that A1vii communities are typical. Although the substrate within the channel is often nutrient poor, the alluvium which forms the banks is rich. The same geological and hydrological conditions prevail in the lower reaches of the R Frome in Dorset and the same community is present.

The flora of A1vii communities is very similar to that found in A1vi, being an admix of typical Chalk stream species and sluggish river species. The indicator species (Fig 7) reflect the more sluggish nature of this community with the Floating Water-fern (*Azolla filiculoides*) the Fat Duckweed (*Lemna gibba*), the Shining Pondweed and its hybrid *Potamobeton*×*salicifolius* illustrating this clearly. Conversely, bryophytes are very rare, only *Fontinalis antipyretica*, a species tolerant of both deep and sluggish water, being common. The richness and high water table of the banks is illustrated by the presence in abundance of *Carex acutiformis* (Lesser Pond Sedge) *Glyceria maxima*, *G. Fluitans* (Floating Sweet-grass), *Angelica sylvestris* (Wild Angelica) and *Rorippa palustris* (Marsh Yellow-cress). The influence of the more acid Tertiary sands is illustrated by *Oenanthe crocata* (Hemlock Water-dropwort) and *Eleocharis palustris* (Common Spike-rush).

Although Communities A1vi and A1vii differ in the presence or absence of the key species mentioned, they share much in common. They are similarly species rich and almost half the species to occur in either group, occur in 75% of the sites in both groups. All dominant species in Group A1vii also occur as dominants in Group A1vi.

The majority of A1vii communities are correctly assigned using the indicator species key.

Group A2 Clay Rivers

Clay river communities are most characteristic of rivers in central Britain but may rarely outcrop in other parts of Britain where clay, slow water velocity and enriched water occur together.

Although Table 3 indicates which taxa are most associated with clay rivers, this belies the variation in communities associated with clay. The six major variations are listed in Table 1 and the differences in the flora are shown in Table 4. Different communities may thus be expected where clay is associated with mudstones, coarse gravels, Chalk ground water or acid sands.

The most universally characteristic species of clay are shown in Table 3 and from this Table it can be seen that about a dozen species are more common in clay rivers than in any other river type. The most characteristic are *Nuphar lutea* (Yellow Water-lily). *Scirpus lacustris* (Common Club-rush) and *Sparganium emersum* (Unbranched Bur-reed) within the channel and *Rorippa amphibia* (Great Yellow-cress) and *Ranunculus sceleratus* (Celery-leaved Buttercup) on the rich and water-retentive margins. In common with sluggish rivers of fenlands, *Sagittaria sagittifolia* is characteristic.

(RBSQ.A9) The six variations of clay river communities are frequently discretely distributed with a clear association of allied geological strata. Subgroup A2i therefore occurs predominantly in the lower, managed reaches of clay rivers rising from the Cotswolds, subgroup A2ii in the Cheshire Plain, subgroup A2iii to the west of central England where soft sandstones are prevalent, subgroup A2iv in central England where only clay is obvious, subgroup A2v from Hampshire to Norfolk along the line of Chalk overlain by clay and subgroup A2vi in southern England where clay combines with acid Tertiary sands.

The majority of clay river communities occur in the river classification (Table 9) in the upper part of the Table which describes lowland river systems. However the Table allows a much more positive identification of the distribution of these community types.

In lowland rivers with Chalk as their main geological substrate, only one river has A2 communities. This is the R Kennet which has abundant Clay on its lower reaches. In the limestone admix section, less than 15% of the sites are classified as A2. However more than 90% of these atypical sites in this section flow over clay, the Rivers such as the Loddon and Hart in Hampshire being good examples. In the section of the Table which classifies eutrophic lowland rivers flowing over non-calcareous rocks together, over 60% of the sites are classified as having type A2 communities. The majority of the exceptions are the upper reaches of the rivers which have ditch-like communities (A4) and the Rivers such as the Devon and Smite which flow almost entirely on sand (A1). Throughout the remainder of the classification Group A2 communities are rare. They do, however, occur sporadically in several catchments where Boulder Clay is important. Examples include the lower R Dee in Wales, the R Derwent in Yorkshire and the R Windrush in Oxfordshire.

Community A2i—Highly Managed Clay Rivers with Soft Limestone in Catchment

This river type is characteristic of slow-flowing rivers in catchments dominated by clay but where the underlying bedrock is limestone. This limestone is usually Oolite. The R Welland in the East Midlands is the typical example, being the only river surveyed which traverses such extensive areas of the geological features described above. Apart from the R Welland, this community type is found in six other catchments, the R Dean and R Leam being examples of lowland river where soft, rich sandstone is important in the catchment.

All the sites in A2i have been considerably managed, the banks usually being steep and high sided. Because the impervious nature of the clay overrides the stabilizing influence of the Oolite, the rivers are subject to marked fluctuations in flow. In addition, the rivers flow through intensively farmed land which enriches the nutrient status of the relatively calcareous water.

The indicator species for the community (Fig 7) show that some species typical of clay rivers are common but these are accompanied by species most associated with Chalk streams. In the former category is *Scirpus lacustris* and in the latter category are *Veronica anagallis-aquatica* and *Rorippa nasturtium-aquaticum* (Watercress).

Because of the degree of management the flora in A2i communities is impoverished. Only 13 truly aquatic species (22%) occur in at least 20% of the sites, the most characteristic being the pollution tolerant *Potamogeton pectinatus* and the emergent associated with Group B communities, is confined to being commonly represented in A2i in the 21 subgroups of A. Six other species are more common in A2i than in any other A subgroups, these being *Rorippa palustris, Myosoton aquaticum* (Water Chickweed), *Ranunculus sceleratus, Alopecurus geniculatus* (Creeping Bent), *Juncus*
(RBSQ.A10) *acutiflorus* (Sharp-flowered Rush) and *Potamogeton crispus* (Curly Pondweed). All but the last mentioned are species of water-logged river margins and the Pondweed is a classic colonizer of disturbed substrates. It is also pollution tolerant. The impoverished physical diversity of this community is further illustrated by the paucity of bryophyte records.

In common with groups A2ii/iii, which also flow over clay admixes, Group A2i has many species commonly associated with unstable sandy substrates (Fig 7).

The indicator species key correctly assigns 69% of the sites to this community.

Community A2ii—Large, Sluggish, Polluted Rivers on Mudstone and Clay

This community is widely distributed throughout lowland England, with the rivers flowing over the flat Cheshire Plain being typical. These rivers, like the majority in this Group, flow very slowly over Permian or Triassic Sandstone and Mudstone. These geological formations are very characteristic of this community, and when such large Rivers as the Wharfe, Dove and Teme flow onto these sandstones the plant communities change to A2ii.

A2ii communities are most commonly associated with wide rivers which are always nutrient rich and often polluted. Banks are usually steep and the substrate is naturally very unstable because of the extent of fine sands present. Although the banks may be composed of stable earth, there is little or no clay present on the stream bed.

Because of the intrinsic instability of the sandy substrates the plant communities of Group A2ii are very species poor. Only 13 submerged, floating or emergent species (23%) are represented in at least 20% of the sites, the *Sparganium erectum* and *S. emersum* are the only widespread and common examples. The combination of unstable substrates and poor water quality results in this Group having one of the most impoverished floras, a mean number of 30 species being expected for a 1 km length of river.

Reference to Fig 7 shows that the floras of Groups S2ii/iii are very similar, the main distinguishing feature being the lack of a large number of species in this Group which are widespread in Group A2iii. *Bidens tripartitus* (Trifid Bur-marigold) is the only species confined to being well represented in Group A2ii and no other species are more widely distributed in this group than in any other. On the other hand, many species so typical of clay rivers are absent or rare, with *Sagittaria sagittifolia*, *Nuphar lutea* and *Scirpus lacustris* being obvious examples. Bryophytes are also very poorly represented, the pollution tolerant *Amblystegium riparium* being the only widespread species.

Because the flora is so impoverished, only 52% of the sites can be assigned correctly using the indicator species key.

Community A2iii—Clay Rivers with Additional Coarse Substrates

This community type is associated with much greater physical diversity than the last group. Almost all sites have a combination of clay, sand, gravels and cobbles. Occasionally boulders are also present. The water quality is generally better than in the previous Group and it is also more calcareous.

The Bristol Avon and the R Lugg are characteristic examples, the former flowing over a mixture of soft limestones and clays and the latter flowing over rich Old Red Sandstone and clays. It is also noteworthy that the R Coln and R Windrush, which
(RBSQ.A11) traverse the extensive Oolite of the Cotswolds, both have Group A2iii communities in their lowermost reaches when they flow over Oxford Clay.

The indicator species shown in Fig 7 indicate the diversity of flora in Group A2iii. There are 12 indicator taxa which occur in 50% or more of the sites, and these include one alga, one liverwort, four mosses and six flowering plants. More than 25% more species can be expected in Group A2iii than in A2ii, and 15 truly aquatic species occur in more than 20% of the sites. This however only represents 2% of the total, the low percentage being indicative of the effect of the coarse substrates.

The sluggish water velocity is reflected in the presence of several species which are much more common in the fenland rivers of Group A1. Examples include *Ceratophyllum demersum*, *Ranunculus circinatus*, *Enteromorpha* and *Myriophyllum spicatum*. However, Group A2iii communities have these species growing alongside species typical of clay rivers as well as *Ranunculus* species and many bryophytes.

Only 62% of the sites are correctly assigned using the indicator species key and several other sites are mis-classified into this group.

Community A2iv—Central England Clay Rivers

This Group contains the largest number of sites from the data set yet almost all flow on the same geological formation—clay. They thus share a spatey flow regime which may result in the river changing from being a stagnant trickle to a flooded torrent in a short period. Almost all are managed to some degree, the banks usually being high sided and steep.

All species described as being typical of clay rivers are present in this Group with *Nuphar lutea*, *Sagittaria sagittifolia* and *Scirpus lacustris* being most frequent. Groups A2iv and A2v have very similar floras, the main indicator species being few. The main differences relate to the absence in the former of species which occur on rocks and gravels. The rarity of *Ranunculus* species and bryophytes further illustrates this. On the other hand, 19 species (26%) are true aquatic taxa.

The presence of a stable, rich substrate into which aquatic plants can root enables *Potamogeton lucens*, *Butomus umbellatus* and the species mentioned above to reach their greatest abundance in this subgroup of Group A. The rich banks also provide the ideal habitat for amphibious species such as *Rorippa amphibia*, *Glyceria maxima* and *Polygonum amphibium*. However, although the banks may be subject to flood scour, they are stable enough to also enable a rich emergent fringe to develop. Three species of sedge are common at the water's edge and on the landward side are found a rich array of colourful flowering plants of rivers which have been subjected to minimal or sympathetic management only.

Group A2iv communities are intrinsically species rich

Despite being such a large subgroup, 87% of sites in A2iv are correctly assigned using the indicator species key.

Community A2v—Clay Rivers Fed from Chalk Aquifers

This too has a large assemblage of sites dominated by clay. They differ from the previous Group however in being much more calcareous. The calcareous influences are derived either from the rivers rising on Chalk and then flowing on clay, or the rivers flowing upon clay but being fed principally by Chalk aquifers.

(RBSQ.A12) The greatest concentration of this community type is found in Suffolk and Hampshire. In the former case the upper half of the River Wavenye flows on clay which thickly covers the Chalk bedrock, and the R Brett rises on Chalk but then flows over London Clay. In Hampshire, the R Kennet and R Loddon are typical examples. Both rivers rise on Chalk but in their lower reaches they flow over more impervious substrates, including substantial London Clay. Most rivers in this group are therefore likely to have a more stable flow regime than those of Group A2iv and extremely low flows in summer are unlikely because surface run-off is augmented by ground water.

The substrates in Group A2v are more varied than those found in Group A2iv, with gravels more prevalent. Banks are also shallower because they are less subject to marked fluctuations in flow.

The floras of Groups A2iv/v have much in common (Fig 7) with very few species being common indicators. However, the key indicator species which most clearly distinguish A2v communities from other clay rivers is the importance of species common in Chalk streams. Apart from the indicator species listed, *Berula erecta* also indicates the presence of Chalk stream species which thrive on gravel. Alongside these, however are most of the species associated with clay.

Although most of these lowland river types are subject to at least periodic management, the diversity of physical features derived from their geology ensures that most sites are species rich. Added to this, the stability of substrate and flow regime ensures that 22 truly aquatic species (32% of the total) may be expected to be found.

81% of the sites are correctly assigned using the indicator species key.

Community A2vi—Lowland Clay Rivers Fed by Acid Sands or Heathlands

This community type is always associated with clay substrates but rarely are typical species of clay rivers the most important taxa. Invariably this type is found where the river which flows on clay is fed, either laterally or from upstream, with acid water derived from heathlands or acid Tertiary sands.

The classic examples of this community type are found in Dorset and Hampshire. In the former case the lower reaches of the R Lymington flow over mixed substrates, including clay, but it is fed by the acid drainage of the New Forest through the Highland Water, Black Water and Ober Water. In Hampshire, the lower Hart and Whitewater flow over clay but within their catchment there are considerable deposits of Tertiary sands which give rise to acid heaths.

The flora associated with these rivers is very different from that found in other clay rivers. Firstly, true aquatic plants are less frequent, with 15 (25%) present in at least 20% of the sites. Secondly, although some typical clay species are common (*Nuphar lutea*), species such as *Sagittaria sagittifolia* and *Scirpus lacustris* are very rare or absent. Thirdly, the acid element is reflected in the presence in abundance of species such as *Juncus effusus* (Soft Rush) and *Callitriche hamulata*. Fourthly, bryophytes are more important in this group than in any sub-group of A2.

A noteworthy feature of the aquatic species found in this group is that the majority of the most common species are those which thrive also in sluggish upland rivers which have an acid and nutrient poor water chemistry and peat or clay substrates. The most noteworthy are: *Nuphar lutea*, *Ranunculus peltatus* (Pond Water-crowfoot), *Callitriche stagnalis* (Common Water-starwort), *Sparganium emersum*, *Potamogeton natans*, *Callitriche hamulata*. They are, therefore, the widespread taxa with a wide base tolerance or a preference for neutral water.

(RBSQ.A13) 73% of the sites in this unusual community type can be assigned using the indicator species key.

Group A3 Chalk Rivers

Wherever streams and rivers derive the majority of their flow from Chalk aquifers the Chalk stream flora of Group A3 will be found. The flora may also be found on rivers flowing on the purest Oolite.

Chalk in Britain is confined to south and east England. In Berkshire and Hampshire, for instance, Quaternary deposits are much rarer than they are in Norfolk. In the former therefore a much purer expression of the Chalk flora is found compared with the admix of the latter.

The main features which characterise good Chalk rivers and streams are: a sparkling clarity of base-rich water; a very stable flow regime; high water table maintained on the banks at all time; gravel as the major substrate; silt deposition in sheltered alcoves and areas of stream sheltered by reed beds; good water quality.

This combination of features is not duplicated in any other river type and very few of the individual features are found in other lowland rivers.

Only five species (Table 3) are confined to being important components of Chalk streams. Of these five species, *Hippurus vulgaris*, *Carex paniculata* (Great Tussock Sedge) and *Groenlandia densa* (Opposite-leaved Pondweed) are important throughout the geographical range of Chalk streams but *Impatiens capensis* (Orange Balsam) is confined to being important in Hamphire. Table 3 also shows that 24 other taxa are more prevalent in Chalk streams than in any of the other 15 major community types. Particularly characteristic species within the channel are *Berula erecta*, *Callitriche obtusangula*, *Veronica anagallis-aquatica*, *Callitriche platycarpa* (Various-leaved Water-Starwort) and *Ranunculus calcareus*. The stable and high water table of the banks is responsible for the importance of fenland species such as *Phragmites australis* and *Typha latifolia*, with *Rumex hydrolapathum* (Water Dock), *Carex riparia* and *C. acutiformis* also being more common in this Group than in any other.

Both Tables 3 and 4 show how rarely are *Potamogeton* (Pondweeds) found in Chalk rivers. These Tables also show that the species so characteristic of sluggish water and rich substrates (Groups A1 and A2 are also absent. The Common lowland species which are notably absent are *Potamogeton perfoliatus*, *P. pectinatus*, *Sagittaria sagittifolia* and *Nuphar lutea*. On the other hand bryophytes are more prevalent on the rocky substrates.

The distribution of Chalk stream communities within the overall classification of rivers is shown in Table 9. A3 communities are very strongly correlated with calcareous, lowland rivers, and 75% of the sites on Chalk rivers have such a community type. The exceptions are entirely due to the characteristic calcareous ditch community found in the upper reaches or the clay community associated with the R Kennet. In rivers where soft limestones are mixed with other geological strata the extend of A3 communities varies according to the extent of the soft limestone. In most cases the distribution of Chalk or soft limestone in the catchment can be determined by the changes in plant communities. Thus in the R Hull, Chalk is important throughout the catchment yet in the R Nar it is only found in the upper reaches before the river traverses fenland. In many cases, such as the majority of East-Anglian rivers, the Chalk is so thickly overlain that the limestone influence on the flora is totally masked. These rivers generally thus only have a Chalk ditch flora at their sources before passing into fenland communities downstream.

(RBSQ.A14) In the lower two-thirds of the classification A3 communities are very rare and almost confined to the Rivers Coln and Windrush which drain the Oolite of the Cotswolds. The only exception is a single site on the lower R Lugg in Herefordshire which flows on a rich admix of superficial deposits and Old Red Sandstone.

Community A3i—Classic Chalk Rivers

The classic Chalk rivers are the R Itchen and R Test in Hampshire. These rivers are characterised by a very stable flow regime which ensures that maximum flows exceed mean flows less than three-fold yet minimum flows are approximately half of the mean flow. These features ensure that at no time of the year are the river levels so low as to create a serious reduction in water quality. The maintenance of flow also ensures that gravel is the main substrate but silt accumulates in backwaters and bays protected by vegetation. Clay may also be present, but this is limited and the rivers are about 10–15 metres wide.

Chalk rivers have been managed for centuries yet their low banks, which are subject to a high water table, still remain a unique feature of this type of lowland river. Summer plant cutting is undertaken to reduce the risk of flooding and to enhance the fishing but this limits the natural seasonal succession of the various species of the plant community. In general, water quality is exceptionally high because of the natural purification rendered by the Chalk and the lack of intensive arable farming in the valleys. Water quality has deteriorated, and siltation increased, in some stretches of the R Test because of the inputs of effluent from fish farms.

The flora of classic Chalk streams and rivers will contain all the characteristic species described earlier. Within the channel *Ranunculus calcareus* and *Berula erecta* are characteristic where velocity is fastest and the substratum coarsest, whereas *Elodea canadensis*, *Hippurus vulgaris*, *Oenanthe fluviatilis*, *Zannichellia palustris*, *Callitriche obtusangula* and *Groenlandia densa* often predominate on finer substrates. *Lemna trisulca* (Ivy-leaved Duckweed) is a characteristic species in this river type only. Because of the stability of flow, it is able to thrive submerged among other plants, even though it is not rooted.

Perhaps the most characteristic species of Chalk rivers are those which are found at the water/bank interface. It is on these stable margins where the plants can be guaranteed a constant supply of water throughout the year that *Rumex hydrolapathum*, *Phragmites australis*, *Carex acutiformis* and *Carex paniculata* will occur. Table 4 also shows the very wide range of flowering plants to occur commonly along the banks of Chalk rivers with the introduced *Impatiens capensis* uniquely abundant in this river type.

The classic Chalk river is one of the most species rich lowland river types. This river type also compares favourably with more upland, species rich community types, especially if the selected species list is chosen as a base-line. Chalk rivers also have a relatively high number of true aquatic species present (20 species—27% of the total number of common species) even though fewer *Potamogeton* species can be expected than in clay or fenland rivers. However, the main feature of the Chalk river and bank plant assemblage is the very high proportion of wetland species which require either submergence or a permanently high water table.

All sites are assigned correctly using the indicator species key.

Community A3ii—Small Chalk Streams

This community type is scattered throughout the central England Chalk belt which stretches from Hampshire to Norfolk. The only outliers are the R Glen and R Coln which flow over Oolite.

(RBSQ.A15) In general these streams are narrower than those of A3i, have coarser substrates which often include cobbles, and have slightly less stable flow regimes.

The flora of A3ii communities are distinguished from A3i more by the species they lack. They therefore share most of the typical Chalk stream species but in A3ii some important species are much less common. These are all species which prefer finer substrates and/or deeper, stable flow regimes. The coarser substrates of A3ii are reflected in the importance of *Myriophyllum spicatum* and the genus *Potamogeton* is represented only by *P. crispus*. In all, 17 truly aquatic species are present in 20% of the sites.

Although of above average richness, the species diversity of A3ii communities does not compare with that found in A3i.

Because of the very few indicator species (Fig 7) it is understandable why only 40% of the sites can be assigned using the indicator species alone. Of the nine sites misclassified, all the sites on the R Test were classified as B3iii (sandstone + limestone) and the remaining six were classified into five different community types. All these data further illustrate that the small Chalk streams are difficult to classify according to any consistent indicator species.

Community A3iii—Small, Silted, Enriched Chalk Streams

This community type is consistently associated with Chalk streams and rivers where considerable silt is present on the river bed. In general these rivers rarely exceed 10 metres in width and have less rapid flow velocities than A3i communities. No examples of this community are found in catchments which are not dominated by Chalk yet the communities occur from Hampshire to Humberside.

Reference to Table 4 shows that A3iii communities contain many species characteristic of all Chalk streams. However, in general they have a more impoverished flora and the indicator species shown in Fig 7 illustrate both the physical and eutrophic effects that siltation have on the flora. Siltation has the most effect on truly aquatic species and only 13 species (22%) of the 59 common taxa are aquatic. Perhaps more revealing is that no *Potamogeton* species occur in at least 20% of the sites and the three *Callitriche* species, which thrive on unstable silt, are the most important submerged species.

Only three of the 21 sites in A3iii cannot be classified solely by the indicator species. The community therefore contains sufficiently widespread taxa which can characterize the combination of Chalk and silt. Several additional sites are assigned to this community type using the indicator key; the most notable are the sites on the Moors River which flow over Chalk and clay in Dorset.

Community A3iv—Chalk Rivers with Clay Influence

This community type is associated primarily with rivers in Dorset which rise on Chalk but then traverse substantial areas of clay and other geological strata. These rivers characteristically have substrates dominated by gravels and pebbles but the banks are primarily clay or heavy soil. Because of the impervious nature of substrates such as clay, these rivers rise and fall substantially more than is typical with other Chalk stream communities.

The R Piddle and the middle reaches of the R Frome are characteristic examples of this community type.

(RBSQ.A16) Like the previous community, A3iv has an impoverished Chalk stream element in its flora which is combined with several other species which are more typical in other community types. Because the gravel substrata are not associated with a constant flow regime the rivers are not capable of supporting many truly submerged species. Indeed, only nine (17%) of the species present in at least 20% of the sites are truly aquatic and none of these include *Potamogeton* species.

Few species are characteristic of the community yet 92% of the sites can be assigned correctly using only the indicator species. This is because sufficient Chalk stream species are present to allow the initial key to designate sites into the major Group A3. However, the indicator species shown in Fig 7 illustrate great differences in this community compared with other Chalk stream communities. Perhaps the clearest indicators are the marginal species which encroach from the bank-sides into the water, many of which occur in rivers which have marked fluctuations in water level. *Alopecurus geniculatus, Glyceria fluitans, Oenanthe crocata, Catabrosa aquatica* and

Juncus effusus are all species which are most common in this type of Chalk stream and all thrive where water levels fluctuate. On the other hand, species such as *Rumex hydrolapattim, Carex riparia, Carex acutiformis* and *Carex paniculata*, which prefer a constantly high water table, are absent or rarer.

Group A4 Ditch Communities in Lowlands

Group A4 communities are characteristic of ditches with sites scattered throughout lowland England and occasionally in lowland Wales and Scotland. The communities are thus normally associated with man-made narrow channels.

There are four distinct communities which are associated with different geological features. Calcareous ditches, clay ditches, fenland streams and neutral or acid ditches thus have distinct communities. The separation of typical ditch communities from normal river communities is thus a valuable elucidation by 'Twinspan'. However, it is even more remarkable that the programme has the ability to distinguish between different types of lowland ditch.

Very few species are characteristic of Group A4 alone, the main feature of the Group being an impoverished flora which contains fewer species, especially aquatic taxa.

In Table 9 Group A4 sites are seen to be evenly distributed in the lowland section of the classification. A4i communities are invariably found where Chalk or Oolite rivers and streams rise, A4ii above clay rivers, A4iii in fenlands where calcareous aquifers feed sandy and clay substrates and A4iv where less basic rocks are found. Most sites are confined to the upper reaches of rivers. However in the case of the R Darent, which has been cruelly manipulated, the ditch-like communities are found throughout the system.

Community A4i—Calcareous Ditches

Almost all rivers which rise on Chalk or soft limestone and have had unsympathetic management will have an A4i community. Most of the examples in this community are the most upstream sites of limestone catchments. Typical examples include the Dorset R Frome and Wiltshire R Kennet which both rise on Chalk, and the Rivers Coln and Windrush which rise on the Oolite of the Cotswolds. The Gypsey Race in Humberside and R Darent in Kent are examples of Chalk rivers which have been so manipulated that even in their lower reaches they have impoverished floras which resemble that found in calcareous ditches.

(RBSQ.A17) Although the flora of calcareous ditches are very species poor, the indicator species shown in Fig 7 show that there are only a few characteristic indicators but these are typical of the stable flow regimes of Chalk rivers and streams. As is typical for managed narrow rivers, aquatic species are rare with only 11 species occurring in 20% or more sites and *Callitriche stagnalis* is the only submerged species to occur in 50% or more sites.

Because there are few clear cut indicator species only 57% of the 28 sites are assigned to their correct group using the indicator species key. The group is thus an indistinct amalgam of many calcareous species, none of which are characteristic enough to be good indicators.

In addition to 53% of sites not being correctly assigned to A4i using the key, an additional 16 sites (66%) have been incorrectly assigned to the community. In general, these too have an impoverished flora.

Community A4ii—Clay Ditches

This community is associated almost entirely with clay catchments. All but one of the 19 sites are in the extreme upstream reaches of clay rivers where the general characteristics are a narrow channel not exceeding 5 m, and very steep, high sided banks which are physically uniform. These river communities thus result from intense management which rarely does not include deep dredging and a total re-profiling of the channel.

Although scattered throughout England, A4ii communities are typically found in the centre of the country. Here they occur upstream of classic clay communities (A2iv). Typical examples include the R Thame, R Leam, R Tove and R Eye. The only atypical site in this community is the lowermost reaches surveyed on the R Bure. Here the flora is impoverished by the constant erosion caused by the heavy boat traffic; this has the same effect of eliminating species as dredging.

Like the previous ditch community, the typical clay ditch community has few characteristic indicator species and in general the flora is very impoverished. There are only six truly aquatic species which may be expected and the emergent *Sparganium erectum* is the only widespread example. The most common species are those which are generally widespread, particularly on clay. In addition, opportunistic species such as the two filamentous algae *Cladophora glomerata* and *Baucheria sessilis* as well as annuals such as *Ranunculus sceleratus* invade quickly into the unstable, disturbed environment.

The ditch communities found on clay illustrate very clearly how intense management not only impoverishes flora generally, but this acts selectively. For instance, virtually all the species which typify the community are very widespread species and tolerant of a very wide range of habitats in addition to rivers. Not only are truly aquatic species rare, but nationally uncommon species are also rare. The combined effects of disturbance and reduced physical diversity are therefore admirably illustrated.

Unlike other ditch-like communities, the community for clay rivers has sufficiently stable indicator species to allow a high number of sites to be keyed correctly.

Community A4iii—Spring Fed Streams in Clay Catchments

This community is associated with steep and high-sided narrow streams which resemble ditches. All examples are from catchments where Chalk is overlain thickly by clay. The streams are therefore often fed by very small springs but in general their levels rise and fall rapidly due to the effects of the impervious clay. The catchments are always intensively farmed and the community is almost entirely confined to the extreme upper reaches of fenland rivers in East Anglia.

(RBSQ.A18) Disturbance tolerant and widespread species again dominate this community type. The most common species are similar to those of typical ditch-like clay rivers (A4ii) but in addition to these taxa are some species which prefer the gravels, clear water or more stable flow regime, typical of streams fed by Chalk aquifers. In addition to the indicator species shown in Fig 7 which illustrate this, the alga *Batrachospermum,* and *Berula erecta* and *Callitriche obtusangula* are all common species of Chalk streams which may also be expected.

Only 64% of the sites can be correctly assigned using the indicator species key alone. Three of the four sites not correctly assigned were assigned to other very impoverished community types with two being placed into a community type typical of Winterbournes (B3iv).

Community A4iv—Neutral and Acid Ditches

This is a widely distributed lowland community type which is usually associated with highly managed streams on neutral geological strata.

Because the community type may be found on such a variety of rivers it is difficult to describe a typical example. In general, however, rivers in southern England which rise on a combination of acid Tertiary sands and clay will have this community type. Typical examples are the W S Rother and Beaulieu. On the other hand are rivers such as the Inny in Cornwall, the Western Cleddau in Pembrokeshire, the Cefni and Ffraw in Anglesey and the Ythan in northern Scotland. All these rivers have in common stretches of upland flood plain where alluvium and clay are traversed. In these areas the farming potential is high and the rivers have thus been managed to accommodate improved drainage.

The A4iv community associated with neutral ditch-like rivers shares many of the features of other ditch-like community types but the species assemblage is often less impoverished. The common indicator species shown on Fig 7 illustrate the strange admix of the community as well as showing that some of the common species are also common in Chalk streams. However, combined with these are taxa such as *Pellia epiphylla*, ferns, *Chiloscyphus polyanthos*, *Carex remota* (Remote Sedge) and *Callitriche hamulata* which are typical of base poor soils and water. None of these latter taxa are sufficiently widespread in the group however to be good indicator species.

Because the community is such a strange admix, only 25% of the sites can be correctly assigned using indicator species alone. This is to be expected considering that the community is species poor, widely distributed and with no clear indicator species.

Group B Communities (RBSQ) (RBSQ.B1)

This Group of 270 sites can be described as having meso-eutrophic plant communities which are primarily associated with sandstone and Carboniferous Limestone. The trophic status, and the community, of Group B is intermediate between the truly mesotrophic communities of Group C and the substantially more enriched communities of Group A.

Geographical distribution

Group B communities are highly correlated with the distribution in the British Isles of Devonian, Carboniferous, Permian and Triassic sediments. Where rivers rise at high altitudes, or where peat nullifies the richer elements of the sandstones and limestones, Group C communities are more likely to be found as both the sediments and the water are more oligotrophic. On the other hand, in the very eutrophicated rivers which flow over flat areas of New Red Sandstone, the expected community type will be Group A.

Group B communities thus range from south-west England where Devonian, Carboniferous and Permian deposits occur, to north-east Scotland where Old Red Sandstone and sandy metamorphic substrates with rich drift deposits predominate. Between these two geographical extremes are the extensive areas of Lower Old Red Sandstone of South Wales, Herefordshire and Worcestershire, the extensive New Red Sandstone and Carboniferous deposits of the Pennines and Lancashire, the Carboniferous Limestone and New Red Sandstone of north-east Lakeland, and the combination of these formations which stretch from Northumberland to Aberdeenshire in eastern Scotland. The distribution of these geological features in Britain is mirrored by the distribution of Group B communities shown in Fig 4.

Perhaps more noteworthy are the occurrences of Group B communities on rivers which traverse isolated pockets of Carboniferous Limestone or sandstone. For instance, the Rivers Esk, Annan and Girvan in south-west Scotland traverse sandstone in their lowermost reaches and when they do their community changes from Group C to Group B. No other major community Group is so closely allied to two geological formations as Group B is.

The four main sub-groups of B are both geographically and geologically discrete. Group B1 is characteristic of Scotland, Group B2 is characteristic of northern England and southern Scotland, Group B3 is closely correlated with very rich and soft sandstones and limestones and Group B4 communities occur most commonly in west Wales, south-west England and north-west England where high rainfall and less calcium rich substrates occur. Group A is the most geographically distinct and therefore its relationship between other Group B communities is impossible to assess. On the other hand there is a clear relationship between Groups B2–B4 in relation to stream size and trophic status. Group B4 is the most mesotrophic and invariably occurs upstream of Group B3. Only in extremely nutrient poor sandstone rivers is this community found in the lower reaches. Group B2 communities are associated with very large rivers and are likely to occur downstream of B3 or B4 communities.

National Variation

The classification of rivers (Table 9) shows that the majority of Group B communities occur on rivers which rise above 200 m. However, within this broad category, Group B communities occur most frequently in catchments where sandstone and limestone are present. Only rarely are Group B communities found in catchments where resistant rock prevails.

(RBSQ.B2) These points are illustrated best by reference to specific points in the classification. For example, rivers included in the category-source 500 m, resistant rock, oligotrophic, have only a single site (2% of the total) classified in Group B. On the other hand rivers which rise at similar altitudes but flowing over limestone or sandstone and with eutrophic water have 25 sites (57% of the total) in Group B.

Because Group B communities are more enriched than those of Group C, but less so than Group A, these communities may be expected to occur in the middle reaches of large rivers which show classic downstream successional changes. There are, however, few good examples, the R Dee, in Wales and the R Wharfe in Yorkshire being two of the best. What normally happens is that Group B communities do occur downstream of Group C communities but these communities remain throughout the length of the river. It is only when the river traverses extensive lowland flood plains or becomes polluted that Group A communities are found.

Vegetation characteristics of Group B communities

Table 3 shows which taxa are most important in Group B in relation to the other three major Groups of vegetation types and Table 5 shows the characteristic species of the sub-group communities of Groups B1–4.

The former Table clearly shows the affinity of Group B to Group A with the presence of many species characteristic of lowlands and enriched water. Typical aquatic examples include *Lemna minor* (Common Duckweed), *Zannichellia palustris* (Horned Pondweed) and *Potamogeton pectinatus* (Fennel Pondweed) which occur in Groups B1 and B2 and *Ranunculus calcareus* (Brook Water-crowfoot), *Elodea canadensis* (Canadian Pondweed) and *Pontamogeton crispus* (Curly Pondweed) which occur in all B1–B4 Groups. The pollution tolerant moss *Amblystegium riparium* and the algae *Enteromorpha* and *Cladophora glomerata* are either confined to Groups A and B or only abundant in them.

Few taxa are confined to Group B alone but many are characteristic of the sandstones and limestones associated with the Group. Apart from the seven species shown in Table 3 to be allied solely to Group B, the red encrusting alga *Hildenbrandia rivularis*, the River Water-crowfoot (*Ranunculus fluitans*) and the Perfoliate Pondweed (*Potamogeton perfoliatus*) are aquatic species most associated with, but not confined to, Group B. On the banks, *Rorippa palustris* (Marsh Yellow-cress), *R sylvestris* (Creeping Yellow-cress), *Petasites hybridus* (Butterbur), *Impatiens glandulifera* (Indian Balsam) and *Mimulus guttatus* (Monkey-flower) thrive on the sandy well drained banks.

The closely associated *Collema fluviatile*, Britain's largest purely aquatic lichen, and *Cladophora aegagropila*, a tough pelt-forming alga, are confined to Group B and are most characteristic of large sandstone or hard limestone pavements. The former was previously thought to be a nationally rare species confined to Tayside and the latter is an interesting species because it also grows in Tarns where wave-action causes it to grow into balls.

Group B1 Rivers

This major Group of more than 60 sites is characteristic of the rich geological regions of Scotland where more than 75% of the sites occur. Although sandstone is a major geological formation in many catchments with B1 communities, well weathered Silurian, Ordivician, Igneous and Metamorphic catchments are also important. In NE Scotland drift deposits add significantly to the richness of the geology. In common with Group B4, B1 communities rarely occur where substantial limestone is present.

(RBSQ.B3) Rarely are B1 communities found in rivers smaller than 10 metres wide and almost invariably they are much wider and in the lower reaches of a catchment. Unstable gravel substrates dominate but the banks are generally more stable.

B1 communities contain several species which are most associated with the rich lowland communities of Groups A1–4. However there are few species which are typical of B1 communities alone, *Ranunculus peltatus* (Pond Water-crowfoot) being the sole example because it is the most common Water-crowfoot of rivers in Scotland. In addition, only five other species are more commonly found in B1 communities than in any of the other 15 major Groups (Table 3). The major distinguishing features are a combination of a few aquatic species from A1–4 which also occur alongside many bryophytes. However only 10 truly aquatic species occur in at least 20% of the sites in B1, the most successful species being *Elodea canadensis* and *Potamogeton crispus*, both species of very wide distribution and capable of growing in sheltered backwaters or on unstable gravels. On the other hand, *Callitriche hamulata* (Intermediate Water-starwort) and *Myriophyllum alterniflorum* (Alternate-flowered Water-milfoil), species typical of unstable river gravels where the water is not calcareous, are more common in Group B1 than in the other B Group communities. B1 communities are therefore characteristically enriched by nutrients but not bases.

Community B1i—Enriched Rivers of Scotland

This community type is typical of the lower reaches of meso-eutrophic rivers in Banff and Cuchan. The three main Rivers there, the Ugie, Ythan and Don, all flow through flat, rich farming land which enriches a naturally mesotrophic water. The natural mesotrophy is attributable to the finely weathered metamorphic rocks and glacial drift.

The main features of these channels are a mixed substrate ranging from silt in sheltered backwaters to boulders where flow velocity is rapid. The banks are usually distinct and contain the river within a clearly defined channel. Most banks are very stable and composed primarily of earth, a high water table being maintained where natural obstructions within the channel cause the water to be retained upstream.

Some management is a feature of the narrower examples of B1i communities but this rarely affects the river bed. Considerable management is normally associated with the feeder streams and often upstream on the main rivers also.

Group B1i communities are unique among other sub-groups of B in having *Equisetum fluviatile* (Water Horsetail), *Potamogeton alphinus* (Reddish Pondweed) and *Glyceria maxima* (Reed Sweetgrass) occurring in at least 40% of the sites. Four other *Potamogeton* species are common components of the community, as are *Callitriche hamulata* and *Myriophyllum alterniflorum*. On the other hand, species typical of eutrophic water are absent or rare, *Cladophora glomerata*, *Vaucheria sessilis*, *Amblystegium riparium* and *Brachythecium rutabulum* being taxa which are much more abundant in other subgroups of B.

Table 5 shows that 11 truly aquatic species occur in at least 20% of the sites in B1i. Most sites are of only average species richness.

Despite being a very characteristic assemblage, the sub-group B1i is difficult to classify solely by indicator species; only 33% of the sites were correctly assigned using the indicator species key. The key is not capable of showing the unusual nature of this community. Essentially it is a rich lowland community but because it occurs so far north, the species typical of lowland rivers in England do not occur there.

(RBSQ.B4) **Community B1ii—Small Sandstone Rivers with Limited Basic Influence**

This community is strongly correlated with sandstone catchments in Scotland. The majority of sites occur on rivers which flow over the narrow belt of sandstone which stretches from Glasgow to Stonehaven, typical examples being the Dean Water, Lunan Water and River Bervie. Rivers which have B1ii communities, but do not occur in this belt of sandstone, all occur in catchments with Old Red Sandstone. The most striking examples are the isolated sites on the R Teme, R Esk (Scotland), R Girvan and R Garnock which occur where the rivers flow over sandstone.

In common with most rivers flowing on soft sandstone, B1ii communities are associated with sandy substrates and eroding banks of soft sandy soil. Rocks, either in the river or on the bank are rare.

Fig 7 shows that there are very few indicator species which epitomise this community type, most of the common species being shared with B1iii. The main differences between the two is however the prevalence of species in B1ii which are associated with soft sandy substrates both within the channel and on the banks. In B1ii a mixed community of the above species together with those preferring course boulders or sandstone pavements is a common feature.

The finer, more enriched substrates of B1ii is illustrated by the greater importance of species such as *Potamogeton pectinatus* and *Zannichellia palustris* and the reduced importance of *Myriophyllum alterniflorum*. A striking difference is also the absence of many bryophytes and algae which require solid rocks to become established. Because of the instability of the stream bed only nine truly aquatic species commonly occur.

Despite few indicator species, the B1ii community is sufficiently distinct to be correctly assigned using the key in 70% of the examples. Those incorrectly assigned are randomly mistakenly classified.

Community B1iii—Rivers on Sandstone and Basic Silurians

This community is more widely distributed than the previous two types, being commonly associated with sandstone and more basic Silurian/ordovician deposits. An example of the former is the lower reaches of the R Earn and examples of the latter are the middle reaches of the R Tweed and the lower reaches of the R Ithon.

All examples have in common a channel which is at least 10 metres wide and stable banks which rarely erode to allow the river to change course within the river valley. Because most of the rivers bite into the alluvium deposited in the valley bottom, the banks are often steep. In the channel exposed bedrock is often adjacent to course cobbles and fine sandy deposits.

B1iii is the most species rich community type recorded for sandstone rivers. The combination of stable banks and diverse substrates is responsible for this.

Despite the rich community, truly aquatic species are very limited because of frequent erosive floods. The indicator species shown in Fig 7 illustrates the diversity of flora, encrusting algae (*Hildenbrandia rivularis*), filamentous algae (*Lemanea fluviatilis*), liverworts (*Chiloscyphus polyanthos*), mosses (*Fontinalis squamosa*), ferns and flowering plants (*Myriophyllum alterniflorum*) all being represented. Apart from *Myriophyllum*, *Potamogeton crispus* and *Elodea canadensis* are the only very common submerged species.

(RBSQ.B5) The stability of banks is illustrated by the diversity of forms present. *Polygonum amphibium* (Amphibious Bistort), *Alopecurus geniculatus* (Marsh Foxtail) and *Glyceria fluitans* (Floating Sweet-grass) are typical straggling species which commonly invade from the banks into the water; *Eleocharis palustris* (Common Spiked-rush), *Sparganium erectum* (Branched Bur-reed) and *Phalaris arundinacea* (Reed Canary-grass) are examples of common emergent species; Broad-leaved wetland species are represented by *Caltha palustris* (Marsh Marigold), *Mentha aquatica* (Water Mint), *Myosotis scorpioides* (Water Forget-me-not) and many willows and other tree genera. In addition, both liverworts and mosses are common in the river and on the banks. Almost all of these species are indicative of clean, clear water flowing over richer substrates.

Enrichment of the water is illustrated by the importance of *Cladophora glomerata* but this enrichment is limited and allows clean water species to thrive. The combination of rocks and silt, shade and open water, rapids and slacks, all contribute to the diversity of flora.

An 81% accuracy in assigning sites to their correct community type is achieved using the indicator species key.

Group B2 Rivers

There are two examples of Group B2 rivers, both of which are associated with large rivers. Group B2i is epitomised by the lower half of the R Tweed which flows over Old Red Sandstone and Carboniferous Limestone. Other examples of this community type are found in the large rivers which traverse the sandstones, limestones and Millstone Grit of Lancashire. Group B2ii is characteristic of the sandstones of the R Eden valley in Cumbria.

All the examples of sites in each of the two sub-groups have a combination of fine sandy substrates and slack water. Both community types are associated with enrichment of the water resulting from agriculture but B2i is more associated with urban influences also.

The water and/or sediments of B2 communities are more enriched than in other Group B communities. This is clearly illustrated in Table 3 which shows 10 of the aquatic species characteristic of the enriched Groups A1–4 being most common in Group B2. Typical examples are *Zannichellia palustris, Potamogeton pectinatus, Butomus umbellatus* (Flowering Rush), *Ranunculus calcareus, Elodea canadensis, Potamogeton crispus, P perfoliatus, Ranunculus fluitans* and *Myriophyllum spicatum* (Spiked Watermilfoil). The enriched water and sluggish velocity is also illustrated by the presence of the alga *Enteromorpha* and occasionally the Common Duckweed, *Lemna minor.*

Community B2i—Large Rivers on Old Red Sandstone, Carboniferous Limestone and Millstone Grit

This community is associated with very large rivers in their lower reaches as they traverse rich substrates of sandstones, limestones or grits. Apart from their large size, the other main feature of Group B2i is that the community is downstream of a much more oligotrophic catchment in which peat is often important. The water therefore becomes gradually enriched on passing downstream and is naturally much less basic than the substrates over which it flows.

Nine truly aquatic species are common in Group B2i. *Potamogeton crispus, Ranunculus calcareus, R fluitans* and *Elodea canadenis* are the most common with *Potamogeton pectinatus* indicating eutrophication. The naturally less basic nature of the water compared with Group B2ii is illustrated by the greater importance of *Myriophyllum alterniflorum* in Group B2i and the greater importance of *Myriophyllum spicatum* in Group B2ii.

(RBSQ.B6) Using the indicator species key 89% of the B2i sites are assigned to the correct community type.

Community B2ii—Rapid Rivers on Old Red Sandstone and Limestone

This community is associated almost entirely with the lower reaches of the R Eden in Cumbria. This is not surprising because the geological characteristics are unique. The river flows over New Red Sandstone but the sandstone is flanked by substantial areas of Carboniferous Limestone. Because the river and its tributaries rise at high altitudes the river is subject to rapid water velocities. In the lower reaches, therefore, a combination of boulders and shallow rapids are interspersed with slack sections where water depth and fine sediments increase.

The indicator species listed in Fig 7 illustrate the more base-rich expression of the flora which results from the surrounding limestones as well as the greater extent of rapid water velocity and boulders. The base-rich expression is perhaps best illustrated by the presence of *Butomus umbellatus* which is not common in any rivers north of the R Eden. Other base-rich indicators include *Zannichellia palustris* and *Rorippa nasturtium-aquaticum* (Watercress). Indicators of the importance of boulders and fast water velocities include the alga *Lemanea fluviatilis* and the moss *Fontinalis squamosa.*

Table 5 also shows that the banks are composed primarily of stable and rich soils with several species associated with lowland Groups A1–4 common. Examples include *Solanum dulcamara* (Woody nightshade) and *Epilobium hirsutum* (Great Willowherb). Amongst these plants which occur between boulders are found many bryophytes typical of clean water. Because of the combination of boulders and fine substrates, in both the river and on the bank, Group B2ii is characteristically a species rich community with a wide range of morphologically different species.

Using the indicator species key only eight of the 12 sites are assigned correctly with an additional two sites assigned incorrectly to the group. However, the two sites are on the R Lune and R Ribble which are on similarly rich geological strata.

Group B3 Rivers

This major Group of over 80 sites is most prevalent in the lower reaches of rivers which rise at moderate to high altitudes but then flow more slowly in their lower reaches over geologically rich strata. The group is therefore characteristic of rivers which rise in the moorlands but then flow in their lower reaches on limestone, sandstone, grits and mudstones.

Examples of B3 communities are most typical of rivers in the foothills of the Pennines, most of which rise in peat-clad hills or mountains before flowing through rich farmland. They therefore start as oligotrophic, slightly acid streams but become gradually more basic and nutrient rich. Examples include the Rivers Ure and Wharfe which drain east over Millstone Grit and sandstone, the R Ribble which drains west over a combination of Carboniferous Limestone and Millstone Grit, and the R Lathkill and R Dove which drain south predominantly over Carboniferous Limestone.

Reference to Table 3 shows that aquatic species are less important in B3 than they are in the previous two major B Groups. Only seven submerged species occur in at least 20% of the sites with *Ranunculus fluitans* and *R calcareus* the most common; *Potamogeton* species are very rarely encountered. These two genera therefore illustrate a major shift to taxa preferring fast water velocity and substrates of gravel and cobbles. The increased water velocity and limited areas of slack water are further illustrated by
(RBSQ.B7) the absence of free-floating species and rarity of amphibious species. On the other hand, a rich array of bryophyte species colonize the rocks over which water flows rapidly.

The richness of the substrate is illustrated by the frequent occurrence of the liverwort *Pellia endiviifolia* and several marginal species more common in the lowland communities associated with Group A. These include *Myosoton aquaticum* (Water Chickweed), *Juncus inflexus* (Hard Rush), *Glyceria plicata* (Plicate Sweet-grass) and *Rorippa nasturtium-aquaticum*.

Aquatic species also reflect that the substrates and water are relatively basic but not as nutrient rich as those of Groups B1 and B2. The basic nature is illustrated by the greater importance of *Myriophyllum spicatum* than *M alterniflorum* and the rarity of *Callitriche hamulata*.

Community B3i—Larger Rivers in their Lower Reaches on Old Red Sandstone

This community is most typically associated with the rivers in Gwent, Worcestershire and Herefordshire as they traverse the great expanse of Old Red Sandstone. The River Teme in the north and the R Monnow in the south are the most typical examples. Both cut deeply into the soft sandy substrate and the banks are often steep. The river bed is usually a combination of unstable sands, gravels and pebbles with bank material often crumbling into the river to form temporary ledges. Where the banks slope is less steep they are often stabilized by willow scrub and tall herbs.

Although the largest rivers on the sandstone centred in Herefordshire typify Group B3i, examples of the community type are also found in Derbyshire where the R Dove cuts through Triassic Mudstone, and in other isolated localities where rivers cross rich sandstone.

B3i communities are most associated with rivers in their lower, slower reaches.

It is noteworthy that the R Lugg, a large tributary of the R Wye, which also flows over Old Red Sandstone, has only a single site with a B3i community assemblage. The reason for the remaining sites being typical of the richer Group A is that this is the only catchment in Herefordshire where drift Boulder Clay and Glacial Gravels are important.

The plant communities of B3i reflect the softness of the substrate which produces a fine rich substrate for higher plants to root into. Fig 7 illustrates this most clearly with a list of indicator species which differ markedly from those of B3ii in which solid rock substrates are more important.

Because solid rocks are rare, B3i communities do not have any bryophytes which are indicator species. On the other hand, because sand, which may often be unstable, is important, the alga *Vaucheria* is an important component of the flora. The sluggish and rich nature of the water is reflected in the presence of the alga *Enteromorpha* as well as the importance of the submerged *Potamogeton perfoliatus,* the amphibious *Polygonum amphibium* and the emergent *Sparganium erectum. Ranunculus fluitans,* most typical of large clean rivers, is a dominant species in all the sites in which it occurs. In few other communities in this species so characteristic.

Reference to table 5 also shows the importance of higher plants and the relatively less prevalence of bryophytes. For example, the fine substrates support *Potamogeton pectinatus* and *Zannichellia palustris*, both species with very limited distributions outside Group A. In addition to species already noted, *Rorippa palustris, Symphytum officinalis* (Comfrey), *Alisma plantago-aquatica* (Water plantain), *Scrophularia* (RBSQ.B8) *auriculata* (Water Figwort) and *Ranunculus sceleratus* (Celery-leaved Buttercup) are all more common in Group B3i than in any other sub-group of B. These are all more common in Group A and illustrate the richness of the substrates derived from the soft sandstone. Conversely, algae and bryophytes associated with rocks and rapid water velocity are less common. Examples of the former include *Lemanea fluviatilis* and *Hildenbrandia rivularis* and examples of the latter include *Thamnobryum alopecurum* and *Chiloscyphus polyanthos.*

Group B3i communities are usually of above average species richness. This results from a high number of flowering plants which are augmented by less commonly occurring bryophytes which colonize the limited areas of rock.

Using the indicator species key, 81% of the sites are correctly assigned; in addition seven other sites, including two from the R Lugg catchment, are incorrectly assigned to it.

Community B3ii—Rapid Sandstone Rivers

This community is associated with similarly rich substrates as the previous Group but the water velocity is normally much faster. Substrates are therefore correspondingly much coarser with boulders and sheet bedrock often common.

The greatest concentration of sites within this Group occur in the Pennines where rivers flow over Carboniferous Limestone and Millstone Grit. Examples include the R Ure, R Wharfe and R Ribble. The same community also occurs in the lower reaches of the R Usk in South Wales where the river flows over sandstone which is much harder than that which occurs further north in Herefordshire.

All these rivers rise at high altitudes and therefore have rapid water velocity except in their lowest reaches. B3ii communities are associated with the intermediate physical characteristics where some deposition of fine material is integrated with the presence of larger boulders and gravel substrates.

Fig 7 shows that the indicator species of the sub-group are predominantly algae and bryophytes of solid rock substrates. The only two exceptions are *Caltha palustris* and *Rorippa sylvetris.* The former is an indicator species because it occurs very rarely on the fine sandy margins of Group B3i and the latter is an indicator because it has a positive preference for the margins of rapidly flowing rivers with loose shingle margins.

Reference to Table 5 shows that only eight truly aquatic species occur in at least 20% of the sites. *Ranunculus fluitans* and *R calcareus* are the most common submerged species. The absence of *Myriophyllum alterniflorum* and the frequent occurrence of

M spicatum illustrates the base richness of the water attributable to the Carboniferous Limestone. The common bryophytes are all species which have a wide trophic range or a positive preference for calcareous rocks. The algal communities associated with large boulders and sheet rock are also typical of sandstone or meso-eutrophic water with *Cladophora aegagropila* and *Hildenbrandia rivularis* typical.

93% of the 27 sites in B3ii are correctly assigned using the indicator species key. In addition, eight other sites are incorrectly assigned.

Community B3iii—Small Rivers on Mixed Sandstone and Limestone

This community is not confined to a discrete geographical area but occurs in hilly districts where small streams traverse alkaline rocks. The 30 sites occur in 18 river systems but almost all share similar physical characteristics. These include a channel less than 10 m wide, base rich water derived from a variety of calcareous substrates, (RBSQ.B9) moderate to rapid water velocity and substrates comprising of rock, pebbles and fine silt or clay. The banks rarely exceed 1 m in height because some stability of flow regime results from the underlying limestone.

B3iii communities are thus found flowing on the geologically rich substrata of the lowland areas of the Gower or Anglesey in Wales and in the similarly rich lowland areas of Fife in Scotland. More upland examples occur commonly on the Carboniferous Limestone of the Pennines with the R Lathkill, R Manifold and R Dove prime examples. The importance of calcareous substrates is best illustrated by the R Teme in Herefordshire. Here the community type of the river changes to B3iii as it traverses a geological admix above Lentwardine which contains Silurian Limestone.

Reference to Fig 7 shows that all the indicator species are aquatic lower plants or higher plants associated with river margins and banks. The algae indicate a rich, calcareous water chemistry and the bryophytes indicate an abundance of large calcareous rocks. The indicator higher plant species on the other hand illustrate a high water table resulting in the occurrence of many species typical of lowland rivers.

Despite B3iii representing prime examples of limestone streams, aquatic higher plants are rare, only five species being present. *Callitriche stagnalis* and *Sparganium erectum* are the only common species. Limestone streams differ fundamentally from their more lowland counterparts, the Chalk streams, which typically have many truly aquatic higher plants. The reason for the difference is that the substrate of hard limestone streams is much coarser and the fluctuation in flow is greater. In common with Chalk streams, the hard limestone streams have stable banks with high water tables which encourages many bank species which thrive when their roots are supplied with a constant supply of water.

Using the indicator species key, 80% of the sites are correctly assigned to B3iii. However, an additional 16 sites are incorrectly assigned to it.

Community B3iv—Winterbournes

This very small group of only three sites is associated with small calcareous rivers which have an intermittent flow of water at their sources. Although only three examples are present in the data set, many examples occur throughout the Oolite and Chalk range of England. The reason so few examples are present is that the survey was intended to concentrate entirely on watercourses with a permanent flow of water.

Reference to Fig 7 shows that the indicator species are all higher plants and these can be divided into two distinct groups. *Lemna minor* and *Ranunculus peltatus* are examples of species which behave as annuals and exploit the habitat when water is available. The majority of the remaining species are examples of taxa which thrive in shallow water but can survive solely on water held by the soil.

Species such as *Veronica anagallis-aquatica* (Blue Water-speedwell) and *Rorippa nasturtium-aquaticum* are examples of species characteristic of Chalk streams but they too can survive without standing water. Both can respond either by growing in a terrestrial form or regeneration as annuals. Apart from these two species and *Apium* *nodiflorum* (Fools Water-cress), Winterbournes are dominated by straggling and erect monocotyledons. Winterbournes are very species poor.

Using the indicator species key all the sites are correctly assigned. Three other impoverished small Chalk stream sites are also incorrectly assigned to it.

Group B4 Rivers

(RBSQ.B10)

This Group of communities comprises four sub-groups, all of which are less nutrient rich and less basic than all other sub-groups of Group B. Group B4 sites therefore almost always occur either in different catchment to those of B1–B3 or occur upstream of these other groups. Groups B1–B3 are therefore usually genuine meso-eutrophic communities but B4 has only a mesotrophic expression.

Group B4 rivers are most often associated with small streams at moderate altitude as they first traverse rich substrates. Examples range therefore from Devon and Cornwall in the south where many rivers flow over sandstone and Carboniferous deposits, to Cumbria and Lancashire in the north where many rivers flow from peat-clad mountains onto similarly rich substrates. In the Pennines, Gwent and Herefordshire B4 communities are rarely not encountered upstream of B3 communities.

Reference to Table 3 shows that aquatic species are rarely encountered in B4 communities. Only nine species occur in 20% or more of the sites but only *Sparganium erectum* occurs in more than 40%. Compared with the other three major groups of B, only *Sparganium emersum* (Unbranched Bur-reed), is most common in Group B4. Conversely, more bryophytes are important compared with other B Groups with the liverworts *Pellia endiviifolia, Lunularia cruciata* and *Conocephalum conicum* more common than in any of the other 15 main community Groups.

Community B4i—Small Sandstone Rivers with Shaded Margins

This community is common on rich and soft geological substrates around 200 m OD. The 29 examples of the community occur on 18 different rivers and more than 80% of these occur downstream from the more oligotrophic communities of Group C. The major concentration of this community is centred in the upper reaches of rivers which flow onto the soft Old Red Sandstone of the southern English/Welsh border. Typical rivers include the R Lugg, R Arrow, R Monnow and R Trothy.

The physical characteristics associated with B4i communities are a channel not exceeding 10 metres which has a combination of soft sandy substrates and gravels and pebbles. The banks are usually soft and steep with trees very common. These produce moderate to dense shade within the channel as well as on the bank.

The flora of B4i communities is characteristically species poor. This results primarily because soft sandy substrates and rapid fluctuations in flow velocity are not conducive to plant colonization. In addition, the flora is impoverished by shade.

Reference to Fig 7 shows that the indicator species are primarily shade tolerant species. Liverworts and mosses predominate but *Carex remota* (Remote Sedge) is a good example of a shade tolerant flowering plant. In no other community type do trees appear as the dominant bank taxa in 85% of the sites recorded.

Table 5 shows that the instability of bed and shade limits to just two the number of truly aquatic species. These are *Ranunculus calcareus* and *Sparganium erectum,* neither of which occur in more than 40% of the sites. Bryophytes on the other hand are more frequent but never common. In both the river and on the banks the typical species encountered are generalist, widespread taxa. This is typical for an impoverished flora due to natural substrate instability.

The indicator species key correctly assigns 73% of the sites to B4i and incorrectly assigns to it almost 40% more sites. The impoverished, and perhaps impermanent, nature of the flora is responsible for this.

(RBSQ.B11) **Community B4ii—Rivers on Calciferous Millstone Grit Series**

The distribution of the B4ii community is strongly correlated with more solid rock substrata than the previous community type. The community is also strongly associated with much larger rivers. For these two reasons the flora is different, being less shade impoverished and also having less affinity to unstable sandy substrates.

The most typical examples are found on the calcareous Millstone Grit of the western Pennines with the Rivers Eden, Lune, Ribble and Hodder providing good examples. The community is also found in the middle reaches of the R Usk in south Wales, a fast-flowing river which traverses resistant sandstone and receives many tributaries which drain Carboniferous Limestone.

The few indicator species listed in Fig 7 show that despite the very different size of rivers commonly associated with B4i and B4ii communities, the communities are very similar. The coarser substrates of B4ii are indicated by the greater importance of *Ranunculus calcareus* and the presence of solid calcareus rocks is indicated by the abundance of the moss *Cinclidotus fontinaloides*. The less shaded nature of the banks is illustrated by *Phalaris arundinacea* being dominant in 80% of the sites.

The large size, and less shade impoverished nature, of rivers with B4ii communities is illustrated in Table 7 which shows that five aquatic taxa are present in 20% or more of the examples. Although this is more than double that found in B4i, submerged taxa remain rare. Emergent species benefit greatest from the lack of shading.

In general, however, the impoverished community type is dominated by generalist species.

The indicator species key assigns 79% of the sites correctly as well assigning to it 50% more additional sites incorrectly.

Community B4iii—Small Lowland Rivers on Mixed Sands

This community occurs sporadically in lowland areas of southern England and Wales where neutral or acid sands are traversed. Examples are prevalent on rivers which rise at about 200 m OD. Although sand is the dominant substrate, clay is usually present on the valley floor but this is not evident from geological maps.

The community type is most common on the Devon/Cornwall border but the community is also associated with the acid Tertiary sands of southern England which stretch from Dorset to Kent.

The flora of B4iii has the least basic expression of all B4 communities. The indicator species listed in Fig 7 show that *Myriophyllum alterniflorum* is occasionally a dominant species and *Pellia epiphylla* and *Juncus effusus* (Soft Rush) are common. None of these three species occur commonly in base-rich rivers. The absence of basic rocks is illustrated by the absence of *Cinclidotus fontinaloides* yet *Pellia endiviifolia* may occur on the more calcareous clay. It is on this substrate too that *Apium nodiflorum* occurs.

The plant community of B4iii is an unusual admix of species with bryophytes being the most important group. However, large rocks and sheet rock are absent and the bryophyte flora is restricted to occurring on cobbles embedded on the stream floor. Eight truly aquatic species occur in 20% or more sites with a mixture of typical lowland species such as *Sparganium emersum* (Unbranched Bur-reed) and *Callitriche obtusangula* (Blunt-fruited Water-starwort) occurring in the same community type as
(RBSQ.B12) the more typical upland *Callitriche hamulata* and *Myriophyllum alterniflorum*. These two extremes rarely occur in the same site but they occur in the same community type with many species which occur in all the sites.

The indicator species key correctly assigns only 58% of the sites to B4iii.

Community B4iv—Large Mesotrophic Sandstone Rivers

This community type is associated entirely with rivers in western England and Wales with the community centred in Devon. The lower reaches of the R Teifi in west Wales is the only river outside Devon which typically has this community type.

Compared with the previous Group, B4iv communities are associated with much larger rivers which also have more rocks and gravels as substrates. Like B4iii, the margins are usually tree-lined.

The indicator species listed in Fig 7 show that the community of B4iv is morphologically more diverse than that of B4iii with algae, liverworts, mosses, vascular cryptogams and submerged and riparian flowering plants being indicator species. Table 5 also shows this with 10 aquatic species listed as occurring in more than 20% of the sites. The presence of the floating *Lemna minor* and the shallow rooted *Elodea canadensis* indicates that water velocity is generally less rapid yet *Myriophyllum alterniflorum* and *Callitriche hamulata* thrive because the water is not calcareous. The stream Water-crowfoot (*Ranunculus penicillatus*) is more characteristic of this community as it prefers nutrient poor water and occurs only in western Britain.

On the banks a more diverse higher plant flora also occurs with *Lythrum salicaria* (Purple loosestrife) and *Lycopus europaeus* (Gypsey wort) characteristic. These occur alongside *Phalaris arundinacea* which is the dominant bank species in 95% of the sites.

Bryophytes are most common within the channel but the majority of the taxa are ubiquitous species which require simply a rocky substrate and relatively clean water.

The indicator species key correctly assigns 71% of the sites and does not assign any other sites to the community type incorrectly.

Group C Communities (RBSQ)

(RBSQ.C1)

This Group of 276 sites can be described as having an oligo-mesotrophic/mesotrophic status due to flowing over resistant rocks. Old rocks of the Silurian and Ordivician, together with the extensive areas with intrusive or extrusive rocks, are typical. In areas where sandstone is particularly hard and where high rainfall is combined with rocks low in nutrients and bases, Group C communities will also be found. Group C communities are not found above 300 m (1,000 ft) but it would be very unusual if any rivers rising above this height did not have one or more Group C communities in its downstream succession.

Geographical distribution

Group C communities will be found most typically in south-west England, throughout Wales except in the south-east, the Lake District, North York Moors and throughout Scotland except in the geologically rich east or in the north-west where blanket bogs create true oligotrophic conditions. Group C communities are also common on the acid Tertiary sands of the New Forest and in some Pennines rivers where blanket bog in the catchment neutralizes the richness of the underlying geology.

National variation

Table 9 shows that all the rivers surveyed which have their sources above 500 m have Group C communities present. Oligotrophic rivers which flow on resistant rock usually have up to 50 km of their upper reaches as Group D but downstream succession results in Group C communities being present as the river approaches the sea. On sandstone or limestone rivers rising at high altitudes, only the uppermost few kilometres are sufficiently oligotrophic for Group D communities to occur. These are quickly succeeded downstream by Group C communities which are in turn succeeded by Group B communities in their lower reaches. Even rivers which rise at much lower altitudes, but flow entirely on resistant rock, have only Group D and then Group C communities. On limestone or sandstone however, or where rivers on resistant rock become eutrophic, Group C communities give way downstream to Group B, or even Group A, communities.

The R Findhorn and the R Dee in Scotland are thus prime examples of oligo-mesotrophic large rivers rising at high altitudes, the R Conway in Wales, or the Brathay in England or the R Cree and R Spey in Scotland being similar examples for rivers rising at intermediate altitudes, whilst the R Forss in Scotland is the best example in the lowland category. In the naturally mesotrophic to meso-eutrophic category the R Teifi in Wales, the R Ure in England and the R Don in Scotland are good examples of rivers rising at high altitudes; the R Ithon in Wales, the R Exe in England and the

R Tweed in Scotland are good examples of rivers rising at intermediate altitudes whereas rivers rising at lower altitudes are represented by the R North Ugie in Scotland, the Western Cleddau in Wales and the R Torride in England.

All the above examples have significant sections of river with Group C communities. At high altitudes the Group C sections of rivers are generally downstream of Group D communities. However at lower altitudes many of the rivers rise having Group C communities and downstream there is a succession to Group B communities. The Western Cleddau in Wales is a very unusual example because it becomes progressively more oligotrophic on passing downstream. This is because it rises on a flat river flood plain on clay and then traverses progressively coarser substrates. The river communities therefore rise as Group A, pass to Group B and remain consistently in Group C in the lower reaches.

Vegetation characteristics of Group C communities (RBSQ.C2)

Table 8 shows that the 141 taxa represented commonly in at least one sub-group of Group C spans a wide variety of plant types with 9 algae, 3 lichens, 8 liverworts, 23 mosses, 4 vascular cryptogams, 57 dicotyledons and 37 monocotyledons represented. The high numbers of dicotyledons is similar to the numbers in Group B but mosses are almost twice as important in Group C as they are in Group B.

The decrease in trophic status from Group B to Group C is best illustrated in Table 3. This shows that many taxa which are more typical of nutrient or base rich water are much less abundant in Group C than Group B, or absent from Group C altogether. Examples include *Cladophora glomerata, Enteromorpha* spp, *Pellia endiviifolia, Amblystegium riparium, Apium nodiflorum* (Fool's Water-cress), *Callitriche platycarpa* (Various leaved Water-starwort), *Epilobium hirsutum* (Great Willowherb), *Myriophyllum spicatum* (Spiked Water-milfoil), *Ranunculus calcareus* (Brook Water-crowfoot), *Scrophularia auriculata* (Water Figwort), *Symphytum officinale* (Comfrey), *Elodea canadensis* (Canadian Pondweed), *Potamogeton crispus* (Curly Pondweed), and many more. Conversely many taxa are more common in Group C than in Group B, or are listed in the Table for the first time because of the decrease in trophic status. *Pellia epiphylla, Scapania undulata* and *Solenostoma triste* are three such liverworts, *Brachythecium plumosum, Dichodontium pellucidium, Hygrohypnum ochraceum* and *Racomitrium aciculare* are four of many such mosses and *Achillea ptarmica* (Sneezewort), *Ranunculus flammula* (Lesser Spearwort) and *Myriophyllum alterniflorum* (Alternate-flowered Water-milfoil) are examples of higher plants.

Since there are 16 community types within Group C it is important to discriminate between the four main sub-groups C1 to C4.

In broad terms C1 is the most enriched sub-group with *Cladophora glomerata* occurring frequently which indicates nutrient enrichment, and *Amblystegium fluviatile* and *Cinclidotus fontinaloides* also occurring most frequently due to the higher base content of the rock. Reference to Fig 5 thus shows that Group C sub-groups are prevalent where moderate to high altitude is combined with hard limestone, sandstone or Millstone Grit, as indicated by their presence in north-east Scotland, the Pennines and the North Yorks Moors. Because the majority of Group C communities are in upland localities the rivers are typically fast flowing, dominated by byrophytes and with very few true aquatic species. *Myriophyllum alterniflorum* and *Callitriche hamulata* (Intermediate Water-starwort) are the only truly aquatic species represented in at least 20% of one or more of the three community types in Group C1.

Group C2 is a large group of oceanic river sites, usually on shales of the Ordivician and Silurian period. Although scattered throughout Britain, west Wales and south-west England are typical areas with rivers of high and moderate altitudinal sources being equally important. Although communities of Group C2 share some of the mesoeutrophic species of Group C1, they are all less important whereas more oligotrophic species are more important. Many of the rivers have densely shaded margins which favour bryophytes yet nine truly aquatic taxa occur in more than 20% of the sites of at least one of the five community types. *Ranunculus penicillatus* (Stream Water-crowfoot) and *Oenanthe crocata* (Hemlock Water-dropwort) are characteristic.

Group C2 communities therefore show a reduction in both nutrient and base status, and a reduced current velocity which allows more aquatic species to occur.

Group C3 is widely distributed throughout Britain with some sub-groups being very characteristic of a particular geographical location whilst others reflect the habitat. In general all community types reflect stability, either in terms of substrate or in flow (RBSQ.C3) regime. For instance, some communities reflect the presence of substantial upland bogs, lakes or reservoirs, all of which stablize flow, whereas others indicate stable earth banks or clay in the substrate. Distinct communities are found in the New Forest of Hampshire. Although bryophytes are still important, higher plants become of greater significance with 16 truly aquatic species represented in more than 20% of at least one site. Many of these species are common and includes five species not similarly represented in other sub-groups of Group C.

Group C4 are typical of oligo-mesotrophic rivers in Scotland which rise at high altitudes. Occasionally, however, rivers in the uplands of Wales or England and the less alpine rivers in northern Scotland may also be represented by these communities. Most have in common a wide margin of shingle which if stabilised will be species rich. Nine truly aquatic plants are represented with an equally rich emergent and bank flora. Bryophytes are also common but the shade loving species are less important and the species of unstable river beds and exposed shingle prevail.

Community C1i—Upland, Rapid Rivers on Carboniferous Limestone

This community type is restricted to northern Britain where rivers with relatively high altitudinal sources flow rapidly over geologically rich strata. Almost all the sites are on Carboniferous Limestone. The presence of extensive blanket bogs in the catchments may counterbalance the richness of the rock to some degree, but in general the flora exhibits a nutrient enriched element more typical of communities in Group B. However, the lack of many flowering plants, particularly truly aquatic ones, results in bryophytes being the most important major taxon.

Species which most typify the richness of the geology are the presence in abundance of *Cladophora glomerata, Cinclidotus fontinaloides, Amblystegium fluviatile* and *Schistidium alpicola* and the absence of the following species which prefer neutral or acid rocks: *Pellia epiphylla, Scapania undulata, Racomitrium aciculare.*

Communities C1i and C1ii are similar but the former communities are generally less shaded than the latter with the marginal flora commonly containing several species indicative of mixed boulders and gravels.

Only 63% of the sites are correctly assigned using the indicator species key. This poor correlation is due to the lack of many flowering plants and the presence of bryophytes which are also common in other community types.

Community C1ii—Upland, Shaded Rivers on Rich Geological Strata

This community type is much more widely distributed throughout the uplands of Britain than C1i communities: it is also less restricted to hard limestones, preferring equally the rich sandstones too. Although rivers may vary from less than 5 metres to more than 20 metres wide, the character which typifies C1ii communities is shading. Nutrient and base status of the water are probably similar to those of C1i communities but mesoeutrophic species are limited, or excluded, by shading. Clay on the banks is not uncommon.

Shade impoverished flora is typical, with Fig 7 showing that all the 50% indicator species are those which thrive most on moist, shaded banks. True aquatic plants are very rare, only *Myriophyllum alterniflorum* occurring in 20% or more of the sites. Bryophytes are the most important group with species favouring shaded and basic rocks being prevalent. The red alga, *Hildenbrandia rivularis* also favours shaded conditions and this is at least co-dominant in 25% of the sites. Although trees dominate the banks (75% of sites have trees as at least co-dominant) open areas on the banks are stabilized by the Reed Canary-grass (*Phalaris arundinacea*) and Creeping Bent (*Agrostis stolonifera*).

(RBSQ.C4) 74% of the sites are correctly assigned using the indicator species key.

Community C1iii—Upland, Rapid Rivers with Acid Water but Rich Substrates

Wherever C1iii and C1ii communities occur in the same river system, the former always occur upstream of the latter. This indicates that the peat-clad mountains within the catchment makes the water more acid and less nutrient rich, yet the substrata are often as rich as those in C1i and C1ii. Examples of C1iii communities occur throughout Britain from where Exmoor peat overlies Devonian sandstone, through south Wales where coal measures are overlain by peat, through the Pennines and the North York Moors where in the latter peat overlies Oolitic limestone, and into Scotland where the sandstone around Inverness provides an atypically rich geology over which peat-stained rivers flow from adjacent high land.

The plants of group C1iii are therefore a strange admix of species of acid peatlands and a few others which can occur in more basic or enriched habitats. Bryophytes dominate with the indicator species of the sub-group comprising 80% liverworts and mosses, most being typical of Group D communities too. Interspersed with these indicator species are sparse occurrences of the species so typical of basic rocks found more commonly in sub-groups C1i-ii. The rapid current velocities and unstable substrates limits to just two the number of truly aquatic higher plants which occur in 20% or more of the sites.

The atypicality of the species assemblage enables the indicator species key to correctly assign 84% of the sites.

Community C2i—Oceanic Rivers Dominated by Bryophytes

This community is characteristic of western Britain from south-west England north to the Lake District. Like all the communities of C1, C2i communities are associated with relatively rich geological substrates. However, C2i communities are rarely on Carboniferous Limestone but more generally found on sandstones and Ludlow Silurian strata. All C2i communities are found downstream of moorlands but never on the moorlands themselves and no sites occur above 250 m. The Rivers Exe, Barle and Horner which drain from Exmoor are typical. All carry peat-stained, acid water during floods but during low flows the neutral water flows over richer sandstones. The valleys are wooded and the banks shallow and relatively stable.

Because C2i communities are associated with shade and fast-flowing water, bryophytes are very important. The red alga *Hildenbrandia rivularis* is also characteristic—a feature not shared by any of the other four sub-groups of C2. Only three truly aquatic higher plants are likely to be encountered, with *Ranunculus penicillatus* characteristic of the less shade occluded rivers in west Wales. Floras are generally impoverished by shade but on the stable unshaded banks *Oenanthe crocata* and *Phalaris arundinacea* are very characteristic.

82% of the sites are correctly assigned using the indicator species key. However, the key also assigns many other communities to this group incorrectly.

Community C2ii—South-west England Rivers at Low Altitudes

This community type is unusual because it is confined to the discrete area of south-west England. In addition, over 90% of the sites rise between 190–290 m OD. The geology is characteristically of the Silesian Carboniferous period or sandstone, with clay also occasionally present. C2ii communities are this in geologically rich catchments and invariably C2ii communities give way downstream to B4iii or B4iv communities when fine substrates are important.

(RBSQ.C5) The base-richness of the geology is illustrated in the flora with *Pellia endiviifolia* being a major indicator species, together with the alga *Vaucheria* which is more characteristic of Group A and B communities. Other taxa to indicate the richness of substrate and water are: *Amblystegium riparium, Eupatorium cannibinum* (Hemp Agrimony), *Solanum dulcamara* (Bitter sweet), *Lemna minor* (Common Duckweed), *Scrophularia auriculata* and *Lythrum salicaria* (Purple Loosestrife). All are more common, or restricted to, C2ii communities within Group C yet are very common in Groups A and B. Undoubtedly the combination of lower altitudinal sources and rich geological strata are responsible for this. Six truly aquatic higher plants are also present in at least 20% of the sites, the combination of *Sparganium emersum* (Unbranched Bur-reed) and *Ranunculus penicillatus* being characteristic. With such a prominence of higher plants typical of meso-eutrophic soils in communities of C2ii it is important to elucidate why this community is not classified in Group B. The reason is undoubtedly that high rainfall creates flash floods and some coarse substrates on the river bed. On these are to be found many brophytes typical of most Group C communities.

The integrity of the C2ii community is confirmed by the indicator species key which assigns 92% of the sites correctly. In addition, only a single site is incorrectly assigned to the group.

Community C2iii—Oceanic Rivers on Neutral Geological Strata

This community is most typical of Silurian, Ordivician and non-sedimentary rocks and is found typically in England and Wales. The source of the ES Rother in south-east England has this community type because of its neutral geology derived from acid Tertiary sands and more basic clays. Substrata are frequently unstable sands, pebbles and cobbles but stability is often increased by the community being downstream of a regulatory influence. This may be in the form of reservoirs (W Dee), lakes (C Derwent) or flat upstream flood plains at low altitudes (Clettwr). Although often wide, C2iii communities are typically found on tree-lined rivers at altitudes below 150 m.

The lowland character of the flora is illustrated by *Eupatorium cannibinum, Impatiens glandulifera* (Indian Balsam) and *Solanum dulcamara*. However, the indicator species shown in Fig 7 indicate the importance of algae, lichens and bryophytes, as well as the importance of trees on the bank sides. Five truly aquatic high plants are important in the community, similar to those in C2ii but lacking *Lemna minor*. The mosses *Hygrohypnum ochraceum, Fontinalis squamosa* and *Racomitrium aciculare*, and the liverwort *Scapania undulata* are all important indicator species. They illustrate that there is a combination of mesotrophic species rooted in the finer substrates whilst oligotrophic species are present on the rocks.

75% of the sites are correctly assigned using the key but almost the same percentage are incorrectly assigned to the group also.

Community C2iv—Rapid, Upland, Shaded Rivers

This community is found in the uplands of Wales, northern England and southern Scotland. Typically the community is associated with waterfalls, ravines or densely shaded banksides, all of which produce a sheltered damp atmosphere. Rocks are usually resistant and base poor although some metamorphic or igneous rocks may be richer.

(RBSQ.C6) Bryophytes dominate this community with eight species being indicator taxa. These are all typical of neutral or slightly acid conditions. The presence of ferns, willows and other trees in the list of indicator taxa also illustrates the occluded nature of this river community. On less shaded banks *Agrostis stolonifera* and *Phalaris arundinacea* are found but these are never dominant. In more open water too, higher plants may be found, but truly aquatic taxa are limited to just three species, with *Littorella uniflora* (Shore-weed) being important in rivers below large pools and lakes.

Only 65% of the sites are correctly assigned using the key.

Community C2v—Slow Oligo-mesotrophic Rivers

This community is very similar to that of C2iv but differs in having higher plants as a more important element. This is because instead of being shaded, the margins of C2v rivers are open so that where water velocity is not rapid, reed margins can develop. Representatives are found in England, Scotland and Wales but there are few examples.

Because the water chemistry of C2iv and C2v are similar, bryophyte taxa are also similar but with one important difference. Species such as *Thamnobryum alopecurum* and *Solenostoma triste,* which occur commonly on solid rocks on shaded banks, are much less common whereas species such as *Bryum pseudotriquetrum* and *Calliergon cuspidatum,* which occur on open gravels, are much more common. This too is evident for flowering plants and the absence of ferns is indicative of open ground. Stable reed margins are indicated by the abundance of *Phalaris arundinacea* and a high water table is indicated by *Eleocharis palustris* (Common Spike-rush) and *Carex aquatilis* (Northern Sedge).

Four of the six examples are correctly assigned using the key indicator species alone.

Community C3i—Upland Rivers of Fen and Bog

This is a very distinct community which occurs only where large rivers flow through bogs or fens. Characteristically the water is peat stained and oligotrophic but the banks are mesotrophic and comprise fine sediments such as clay, alluvium and peat. The R Teifi as it flows through Tregaron Bog and the R Spey as it flows through Irish Marshes are characteristic, as well as showing a range of physical features. Both rivers have very shallow slopes (1m/km) which results in slack water during medium and low flows. The two rivers also share in common steep banks with a high water table which confines the river to a discrete channel. However the rivers differ in the R Teifi having a higher proportion of richer and finer substrates such as clay and silt whereas the R Spey is dominated more by sandy gravels.

The sluggish nature of the water and the richness of substrates accounts for all the indicator species shown in Fig 7 being higher plants. All but two of the most frequent truly aquatic higher plants present in group C as a whole are found in C3i communities with *Sparganium emersum* and *Potamogeton natans* (Broad-leaved Pondweed) being particularly characteristic. The reduced number of bryophytes and the increased number of higher plants makes this community distinct for oligotrophic rivers and is reflected in Table 2 which shows that the ratio of selected species in relation to all species recorded is high. This is because not only are fewer bryophytes recorded, but most of the marginal flora is comprised of higher plants which are true wetland species. Where extensive uniform bogs are traversed, habitat diversity may be limited and this will be reflected in relatively few species being recorded. Since many of these species are wetland taxa, and the habitat is an unusual one, rivers with this community type should be considered strongly for safeguard.

The indicator species key assigns 67% of the sites correctly.

(RBSQ.C7) **Community C3ii—Upland Rivers Below Lakes**

This community is characteristic of rivers flowing on the resistant rocks of the Lake District and north Wales where upstream lakes are normally present in the catchment. Whereas C3i communities occur where rivers flow through bogs and other stabilizing influences, C3ii communities occur downstream from them. Oligotrophic, peat-stained water is usual and stability of bed and banks is characteristic. Unlike C3i communities, large boulders and cobbles are important components of C3ii. Because most sites are found low in the catchment the stable banks are often enriched by fine gravels and alluvium.

C3ii communities often contain many of the characteristic wetland higher plants found in C3i with aquatic species such as *Myriophyllum alterniflorum, Callitriche hamulata* and *Littorella uniflora* at their most frequent. These species indicate the more oligotrophic nature of the substrate. Indicator species comprise algae, lichens, liverworts, mosses, horsetails and higher plants which illustrate the diversity of habitat. The importance of boulders over which oligotrophic water flows rapidly is indicated by the abundance of *Lemanea fluviatilis, Dermatocarpon fluviatile* and *Fontinalis squamosa.* On the other hand, the stability and enrichment of the banks is reflected in the number of emergent species which are more typical of rivers flowing on richer geological strata. The frequency of *Stachys palustris* (Marsh Woundwort), *Iris pseudacorus* (Yellow Flag) and *Sparganium erectum* (Branched Bur-reed) illustrate this. C3ii communities are generally species rich because they contain an unusual admix of oligotrophic taxa in midstream with mesotrophic species on the banks.

73% of the sites are assigned correctly using the indicator species key.

Community C3iii—Rivers below Reservoirs and Bogs

This community type is most typical of Wales where stability is afforded either by upstream reservoirs, bogs or flat flood plains. Examples of each type of regulatory influence are the R Dee, R Teifi and R Western Cleddau. Communities C3ii and C3iii share in common being distant from the regulatory influence but the former has much finer substrates on the river bed with large boulders being less important.

The stability and finer substates is reflected in all the important indicator species being higher plants. Nine truly aquatic higher plants occur frequently, with *Ranunculus penicillatus* and *Sparganium emersum* common. The absence of *Littorella uniflora* shows that upstream lakes are less important. On the banks, trees are generally interspersed with open banks of earth which favours such species as straggling and emergent monocotyledons rather than bryophytes. Generalist bryophytes which prefer oligo-mesotrophic conditions occur wherever boulders or embedded cobbles are present.

90% of the sites are assigned correctly using the indicator species key. In addition, almost 50% more sites are incorrectly assigned to this group.

Community C3iv—Small Streams Draining Flat Shales

This community, like C3iii, is characteristic of rivers in Wales. Rivers are rarely more than 10 m wide and drain flat ground below 200 m. Neutral shales are the characteristic rock types with unstable cobbles and gravels frequent. However the flat adjacent land is clay or alluvium and this gives the community a mesotrophic flora.

The indicator species for this community comprise at least one example of all the major taxonomic categories, with dicotyledons being most important. All the species indicate (RBSQ.C8) both a neutral water chemistry and mesotrophic soils. True aquatic higher plants are very rare, *Callitriche hamulata* being the only species to occur in at least 20% of the sites. Aquatic bryophytes are rarely common with *Pellia epiphylla,* which favours clay banks, being the only abundant species.

These narrow channels thus have few aquatic species present but many species invade onto the margins of the river from the waterlogged neutral clays on the banks. Both the Ivy-leaved Crowfoot (*Ranunculus hederaceus*) and the Round-leaved Crowfoot (*R omiophyllus*) are characteristic of the wet margins of these shallow streams. The frequency of ferns shows that where trees occlude the channel species favouring moist conditions will be common.

A high percentage of sites are correctly assigned using the indicator species key alone.

Community C3v—New Forest Streams

This community is associated almost exclusively with the New Forest where small streams draining acid sands and heaths cut into alluvium or clay in their lower reaches. Substrates are generally fine gravels and boulders are either absent or rare. The R Fowey which drains Bodmin Moor is the only site not in the New Forest.

This community has less in common with all other sub-groups of Group C with many species uniquely absent from the community as well as five species present only in it. Many bryophytes important throughout Group C are rare or absent in C3v communities. Those which are absent are usually species which are associated with torrential flows over boulders such as *Fontinalis squamosa* or *Racomitrium aciculare*. On the other hand species of acid heaths or bogs are frequent, with *Scapania undulata, Polytrichum commune* and *Sphagnum* sp(p) typical.

Higher plants illustrate the unique combination of acid water lovers and those of rich alluvium. In the former category are *Myriophyllum alterniflorum, Callitriche hamulata* and *Potamogeton polygonifolius* (Bog Pondweed) whilst in the latter category are *Apium nodiflorum, Alisma plantago-aquatica* (Water Plantain), *Nuphar lutea* and *Callitriche obtusangula* (Blunt-fruited Water-starwort). The combination of oligotrophic, acid waters and outcrops of meso-eutrophic soils thus produces a unique community type.

89% of the sites are correctly assigned using the indicator species key.

Community C4i—Large, Oligotrophic Scottish Rivers

This community is almost entirely confined to Scotland where it usually occurs in the lowland reaches of rapid, oligotrophic rivers. The most general features which categorise this community are a combination of loose unstable substrata but more stable banks. The water is generally acid and oligotrophic but because sites are in the lower reaches silt enriches the banks.

The instability of river bed is reflected in the few truly aquatic higher plants which occur, although the presence of *Ranunculus fluitans* and *Potamogeton natans* is typical. On the banks are to be found the greatest number of taxa with *Polygonum amphibium* (Amphibious Bistort) and *Glyceria maxima* (Reed Sweet-grass) indicating both stability and enrichment. *Phalaris arundinacea* is at least co-dominant in 90% of the sites and *Eleocharis palustris* occurs at its most frequent in this community type. There are a wide range of oligo-mesotrophic bryophytes of boulders and cobbles but species which favour open gravel margins, such as *Philonotis fontana* and *Brachythecium rivulare,* are absent.

An average number of sites are keyed correctly using the indicator species.

(RBSQ.C9) **Community C4ii—Upland Rivers in Wide Glacial Valleys**

This community can be found in the uplands of Wales, the Lake District and Scotland where highland rivers flow through glacial valleys. Characteristically the rivers have shallow banks with a combination of cobbles, loose gravel, shingle and finer silts and clay outcrops. Peat is very limited so that the community has a neutral, slightly mesotrophic expression.

The species listed as indicators in Fig 7 show a range of bryophytes and higher plants. Some of these prefer solid rocks whereas others prefer fine shingles. Because there is such a range of substrates, C4ii communities are typically species rich. However, because the rivers are generally fast-flowing and the finer substrata in the river are unstable, truly aquatic higher plants are few. Only three species are present and *Myriophyllum alterniflorum* is particularly common. Within the river, algae and widespread bryophytes such as *Fontinalis squamosa* and *Rhynchostegium riparioides* dominate indicating the neutral water chemistry. Enriched banks with compacted silt or clay are indicated by species such as *Alopecurus geniculatus* (Marsh Foxtail) and *Rorippa nasturtium-aquaticum* (Water-cress). On the other hand the prominence of *Tussilago farfara* (Coltsfoot) and *Equisetum arvense* (Common Horse-tail) indicate that loose shingles occur intermixed with stable banks.

67% of the sites are correctly assigned using the indicator species and no other sites are incorrectly assigned to the community type.

Community C4iii—Highland Rivers with Gravel and Peat

This community is typically upstream of either C4i or C4ii communities. Rivers are thus more upland and oligotrophic in nature and the influence of peat is obvious. C4iii communities occur typically in boulder-strewn rivers of Scotland.

The indicator species listed in Fig 7 show that acid loving bryophytes are very important but moorland higher plants are also indicative. Despite being in the uplands, five truly aquatic plants are important components in this community type. These plants occur because the peat within the catchments provide some stability to loose gravels. It is on these gravels which *Juncus bulbosus* (Bulbous Rush) also occurs most frequently.

The indicator species key assigns 83% of the site correctly and also assigns several additional sites incorrectly to it.

Group D Communities (RBSQ) (RBSQ.D1)

Most communities in this small group of 135 sites can be described as truly oligotrophic. However where clay is present or where upland silt accumulates in slow-flowing rivers traversing upland plains an oligo-mesotrophic flora may develop.

Geographical distribution

All Group D communities are found where solid geology and resultant soils are neutral or where Quaternary deposits are acid. Most sites are also found at high altitudes. Since there is a good correlation between an increase in altitude and a decrease in base-richness of substrates, evaluating the primary determinand of the community group is difficult. The presence of these communities in lowland peatlands of Scotland and on the Tertiary sands and heaths of the New Forest in England suggests that where acid peats and sands occur Group D communities will be present, even at low altitudes.

Almost all the streams and small rivers flowing over extensive areas of highlands and mountains in England, Wales and Scotland at altitudes above 300 m (1,000 ft) will have plant communities in Group D. As a result, such communities are typical of the uplands of south-west England (Bodmin, Dartmoor and Exmoor), the highlands of Wales (Black Mountains and Cambrian mountains) the Pennines from Derbyshire to Cumbria, the North York Moors, the mountains of the Lake District and almost all the sources of rivers in Scotland except those which rise in the lowland, rich geological formations along the east coast from Berwickshire to Buchan. There are very few exceptions; these are usually due to the presence of a rich drift deposit such as clay, or a nutrient or base rich solid geological formation such as Carboniferous Limestone or sandstone which procludes the development of peat.

National Variation

Reference to Table 9 shows the range of Group D community types within the classification. These communities are exclusively found at the sources of rivers unless the river remains oligotrophic in its lower reaches. Although only six variations are recognised, Group D communities occur in more than 60 rivers in the sample. In all but three rivers, Group D communities either persist throughout the river from source to mouth (eg R Carron, R Oykel and R Inver in Scotland) or gradually change to the oligo-mesotrophic communities of Group C.

The exceptions (R Dove, R Elwy and R Bervie) all pass directly to the much more meso-eutrophic communities of Group B because they flow on limestone or sandstone. All fall within the same group in the classification with sources between 200–500 m, flowing on limestone or sandstone and having mesotrophic chemistries.

Almost half the rivers with their uppermost sites in Group D have only this single upland site in this category. The more oligotrophic the system remains downstream, irrespective of size, the greater the extent of Group D communities. Thus the many large rivers in the sparsely cultivated areas of Scotland will remain in Group D into at least their mid-reaches.

Vegetation characteristics of Group D communities

One hundred and one taxa are represented in Table 7. This is the smallest number for the four major groups and it is also the only group in which bryophyte taxa equal the numbers of dicotyledons or monocotyledons. In addition, many bryophytes which are not easily identified have been omitted from this data set, the inclusion of which would have further illustrated their importance. There are very few purely aquatic (submerged
(RBSQ.D2) or floating) higher plant species, *Equisetum fluviatile* (Water Horsetail), *Callitriche hamulata* (Intermediate Water-starwort), *C stagnalis* (Common Water-starwort), *Littorella uniflora* (Shoreweed), *Myriophyllum alterniflorum* (Alternate-flowered Water-milfoil), *Nuphar lutea* (Yellow Waterlily), *Juncus bulbosus* (Bulbous Rush), *Potamogeton polygonifolius* (Bog Pondweed), *Potamogeton natans* (Broad-leaved Pondweed), *Sparganium emersum* (Unbranched Bur-reed) and *Sparganium augustifolium* (Floating Bur-reed) being the only eleven species which occur in at least 20% of the sites in at least one sub-group. This compares with 43 in Group A, 24 in Group B and 23 in Group C.

By reference to the Keys and Fig 7 it is easy to see which plants are the indicator species of Group D and its six sub-groups. Reference to Table 3 shows which plants are confined to being important in Group D and Table 7 show which plants are important components in each of the six sub-groups.

The gradual decrease of trophic status from Group A to Group D is shown in Table 3. The truly oligotrophic status of Group D is shown by the absence of all those species which were common in Groups A and B and rare in Group C. Typical examples include the algae *Vaucheria sessilis* and *Cladophora glomerata* and the flowering plants *Rorippa nasturtium-aquaticum* (Water-cress) and *Solanum dulcamara* (Bitter-sweet). On the other hand, *Marsupella emarginata, Blindia acuta, Schistidium agassizii, Viola palustris* (Marsh Violet) and *Juncus bulbosus* are five examples of 22 taxa indicative of obligotrophic conditions which are restricted to being important in Group D alone.

The relative similarity of the six sub-group communities in Group D is illustrated in Table 7 which shows that approximately 40% of the taxa occur in at least 20% of the sites in all sub-groups. Both liverworts and mosses have more species common to all groups than species which show preference to particular sub-groups. Although 40% of the taxa occur in at least 20% of the sites in all the sub-groups, many of the species are indicative of particular sub-groups where they are particularly prevalent.

Community D1i—Mountain Rivers with Gravel Margins

This community is the most species-rich of all the 56 British communities identified. Only very rarely will the community be encountered outside Scotland with rivers flowing from the Grampians and the North West Highlands containing 75% of the sites. Outside Scotland the most likely rivers to have such a community type are the highest rivers draining the Pennines. D1i rivers are generally at least 10 m wide. The R Oykel is particularly characteristic of this river type.

Although gravel margins are characteristic, D1i sites are usually physically diverse with small areas of stable margin or slack water being protected by shingle bars and islands. The presence of *Philonotis fontana, Equisetum arvense* (Common Horsetail), *Tussilago farfara* (Coltsfoot), *Sagina procumbens* (Procumbent Pearlwort), *Callitriche stanalis* (Common Water-starwort), *Calliergon cuspidatum* and *Ranunculus flammula* (Lesser Spearwort) at their most abundant indicates the extent and importance of the unstable and transient shingle margins. Such areas rarely develop in narrow mountain streams. The presence of stable, often waterlogged, margins in limiting stretches of the sites are indicated by how commonly *Caltha palustris* (Marsh Marigold), *Achillea ptarmica* (Sneezewort) and *Carex rostrata* (Bottle Sedge) occur. The absence of *Sphagnum* spp. indicates that drier heathlands are more important than peat bogs on the margins.

Within the channel large boulders are few with stability afforded by smaller rocks embedded by gravels. In such areas bryophytes occur, as do six of the elevent truly aquatic taxa found in Group D. In general, however, standing crop is low and transient algae such as the diatum *Didymosphenia geminata* and filamentous green algae pre-
(RBSQ.D3) dominate on the unstable river bed. Although D1i and D1ii have many species in common, the former has a large number of indicator species which are commonly occurring and often dominant.

Di communities have 83% of their sites assigned correctly using the indicator species key.

Community D1ii—Mountain Rivers with Stable Margins

This community, like its closest ally D1i, is typical of mountain rivers about 10 m wide. It is also species rich. However, D1ii has a much less discrete geographical range, occurring in suitable mountainous areas in England, Scotland and Wales.

In contrast to the unstable, often shifting, margins of the rivers with D1i plant communities, rivers with D1ii plant communities occur where the margins are very stable. In most examples both large boulders and sheet rock will occur amongst solid banks of clay or earthy peat. Shingle is much less significant. The stability of the banks also often imparts stability to the river bed.

Because of this unusual stability of both the banks and the river bed, eight species occur commonly in this sub-group but not in any of the other sub-groups in Grouup D except D4i which also has very stable banks. These are shown clearly in Table 7 and all indicate both stability and unusual richness of substrate. Indicator species illustrate the great range of habitats expected to be found in D1ii rivers: the lichen *Dermatocarpon fluviatile* indicates the importance of large, emergent boulders; the liverwort *Marsupella emarginata* shows the importance of submerged, stable rocks; the moss *Polytrichum commune* indicates the presence of heathland abutting onto the river, the Water Horsetail (*Equisetum fluviatile*) indicates the presence of sheltered alcoves with fine particulate matter on the river bed, the Marsh Foxtail (*Alopecurus geniculatus*) and the Reed Canary-grass (*Phalaris arundinacea*) indicate the presence of stable, and slightly enriched, margins.

Because of the stability and the presence of either clay or peat on the river bed, seven of the eleven truly aquatic species present in Group D are commonly found in D1ii.

The D1ii community is accurately determined by solely using indicator species. 92% of the sites were correctly assigned.

Community D2i—Highland Streams of Exposed Topography

This community is characteristically ultra-oligotrophic and will be found only in the uppermost reaches of mountain streams. Community D2i may thus be encountered in the highlands of England, Scotland or Wales. Reference to Table 9 shows that 80% of the communities are represented by only the uppermost site surveyed in each river. The exceptions are the R Findhorn and R Urquart (Note: R Inver, Site 3 is on its tributary R Traligill).

All D2i sites are characteristically in exposed areas in highlands where rainfall is high and extremes in temperatures and flow regime are experienced. Streams may thus be expected to change rapidly from almost dry channels to raging torrents in a few hours. Plant communities therefore epitomise the alpine river flora, being able to withstand both desiccation and erosive floods. In general most sites contain a mixture of stable boulders and unstable gravels but fine substrates are absent and clays and peats generally do not occur adjacent to the water-line of the river.

The common occurrence of many bryophytes and the paucity of flowering plants is the
(QBSQ.D4) most characteristic feature of D2i communities. Eighteen bryophytes species all occur in at least two-thirds of all the sites whereas only six higher plants are similarly represented. All these higher plants except *Sagina procumbens* are hardy monocotyledons characteristic of moorlands. The absence of many truly aquatic flowering plants as well as *Glyceria fluitans* (Floating Sweet-grass) illustrates that the few higher plants which are represented will be found at the margins and not within the channel of the river.

The floras found in both Groups D1 and D2 have many similarities. Because of the large numbers of taxa common to these sub-groups there are no obvious indicator species of sub-group D2i, the sub-group being identified primarily by the absence of species. This is particularly pertinent for the higher plants, especially the aquatic species. On the other hand, Fig 7 shows that the indicator species which are frequent or dominant are predominantly bryophytes. Similarly the taxa which are very common in both D1 and D2 sub-groups are almost all bryophytes.

The absence or rare occurrence of common plants such as Water Mint (*Mentha aquatica*), Water Forget-me-not (*Myosotis scorpioides*), Marsh Marigold (*Caltha palustris*) and trees illustrate that few areas on the bank are composed of clay or soil into which these plants could root. The abundance, on the other hand, of mosses and liverworts such as the genera *Scapania, Solenostoma, Blindia, Brachythecium, Bryum, Dichodontium, Hygrohypnum* and *Racomitrium* illustrate that both solid rock and gravels are common.

87% of the sites are assigned correctly using the indicator species key.

Community D3i—Shaded Moorland Rivers with Earth and Rock Margins

This community is typical of moorland areas in both England and Wales but is rare in Scotland. Most sites are relatively species poor with instability of substrate and degree of shading combining to produce a naturally impoverished flora. Typically the rivers with D3i communities rise at altitudes between 300–500 metres, and rarely above this height. Most sites are at about 200 m OD and are small rivers about 5 m wide which descend from moorlands into valleys where natural woodland remains. Streams draining the North York Moors such as the Esk, Rye and Seven are typical. In general the rivers are fast flowing over mixed substrates of stable boulders and unstable cobbles, pebbles and gravels. Banks usually contain boulders, gravels, clays and are usually shaded by trees which are generally rooted at the immediate edge of the river.

Not only are individual sites poor in species, the whole community type has a limited flora as indicated by as few as 51 taxa being represented in 20% of the sites. This compares with 86, for instance, in D4i. Since the only stable substrates within the river channel are solid rock, the only truly aquatic plants to occur in D3i communities are the opportunists *Callitriche stagnalis* and *Juncus bulbosus*. On the other hand, both algae and bryophytes typical of solid rock and those more common on mobile cobbles or gravels are common. In the former category are *Marsupella emarginata, Scapania undulata, Hygrophynum ochraceum* and *Racomitrium aciculare* whereas in the latter category filamentous green algae and the lichen *Verrucaria* are characteristic.

On the banks trees such as alders and willows are characteristic and these favour the growth of shade tolerant bryophytes. In particular *Hyocomium armoricum* thrives. On the unshaded banks monocotyledons are dominant with moorland species such as *Nardus stricta* (Mat-grass) occurring commonly alongside more widespread and less specialised species such as *Agrostis stolonifera* (Creeping Bent), *Juncus effusus* (Soft Rush) and *Glyceria fluitans*. The community indicates that the banks are well defined, confining the water to a distinct channel with little deposition of gravel at the margins. The community retains the influence of moorlands in having *Polytrichum commune* represented in all the sites but species characteristic of wet peat bogs are rare.

(RBSQ.D5) The indicator species of D3i communities show that the flora is not ultra-oligotrophic and no species which thrive in acid conditions are important. Generalist species are thus important in the group and all taxa occur in other community types also.

All 26 sites are correctly assigned to this group using the indicator species key. In addition, only two other sites are incorrectly assigned to it.

Community D3ii—Moorland Rivers with Boulders and Adjacent Peat

Unlike D3i communities, this community occurs throughout England, Scotland and Wales. Sites are almost all confined to high altitudes where rivers traverse heaths and moors. Where trees occur they are sparse, resulting in the channels having little shading. The substrate of the river usually contains an admix of boulders and loose gravels and is confined within a distinct channel by steep sided banks of peat or peaty soil. Boulders along the banks are also common and where reduced slope is combined with slack water above solid rock barriers, a fine substrate containing peat develops.

D3ii communities are very oligotrophic and because the banks contain the river in a discrete channel, and inhibit the development of shingle, the community is characteristically species poor. Very common species present which best illustrate the character of D3ii communities are: *Nardia compressa*, a liverwort which occurs at high altitudes on solid boulders over which water flows rapidly; *Sphagnum* sp(p) which are only common in rivers abutting directly on to very wet peaty margins; *Potamogeton polygonifolius* which is characteristic of shallow moorland streams with peat in their substrates; both *Molinea caerulea* (Purple Moor-grass) and *Nardus stricta* are at their most abundant in this group.

An unusual feature of D3ii communities is the diversity of physical characteristics and richness of species within the channel but the very impoverished and uniform bank. Five truly aquatic higher plants occur in the river alongside a rich variety of submerged liverworts and mosses on the boulders. On the banks, however, emergent monocotyledons dominate on the steeply inclined peat to the exclusion of other species. This is illustrated in Fig 8 which shows that there are far more monocolyledons than dicotyledons in this group. The lack of species richness is therefore not due to the lack of diversity within the channel but due to bank uniformity. It is important to consider that the uniformity is natural and results from a uniform adjacent habitat and land use along the whole length of the site.

Like the previous community type, a very high number of sites (96%) are assigned to their correct group using indicator species alone.

Community D4i—Slow-flowing Upland Rivers

This community occurs throughout upland Britain but rarely occurs in rivers rising above 500 m. D4i communities are a very distinct group because although sites have peat-stained acid and oligotrophic water, their substrates contain high proportion of fine particulate matter such as peat, silt and occasionally clay. This results from the sites having a very gentle slope and a slow water velocity. Sites normally occur where rivers traverse flat peat bogs or where resistant rock impounds peat stained water to create slacks or pools.

(RBSQ.D6) Reference to Table 7 shows how different the communities of D4i are from all other community types. All the indicator species are higher plants and all the species which are dominants are also higher plants. Higher plants do not dominate to exclude bryophytes altogether but the lack of consolidated boulders and extensive rocky areas limits their abundance but has little affect in reducing the number of taxa. The total dominance by higher plants in both bank and river habitats in D4i makes this river type unique for oligotrophic, acid waters. Because of the stability of substate and bank and the range of habitats, D4i has more taxa represented than any of the other sub-groups in Group D.

Table 7 shows the similarity of communities of D4i and D1i but also shows how many species are uniquely well represented in D4i. All eleven truly aquatic higher plants represented in Group D occur in at least 20% of D4i sites, three of the species being unique to this sub-group. *Hippurus vulgaris* (Mare's-Tail) is an unusual component in this community type in northern Scotland but does not occur in 20% of the sites.

D4i plant communities are not only species rich themselves, they also normally occur in rivers which are species rich overall. Characteristically they add a totally different plant assemblage to the expected upland river flora. Like Community C3i, this community should be especially considered for safeguard.

79% of the sites are correctly assigned using the indicator species key.

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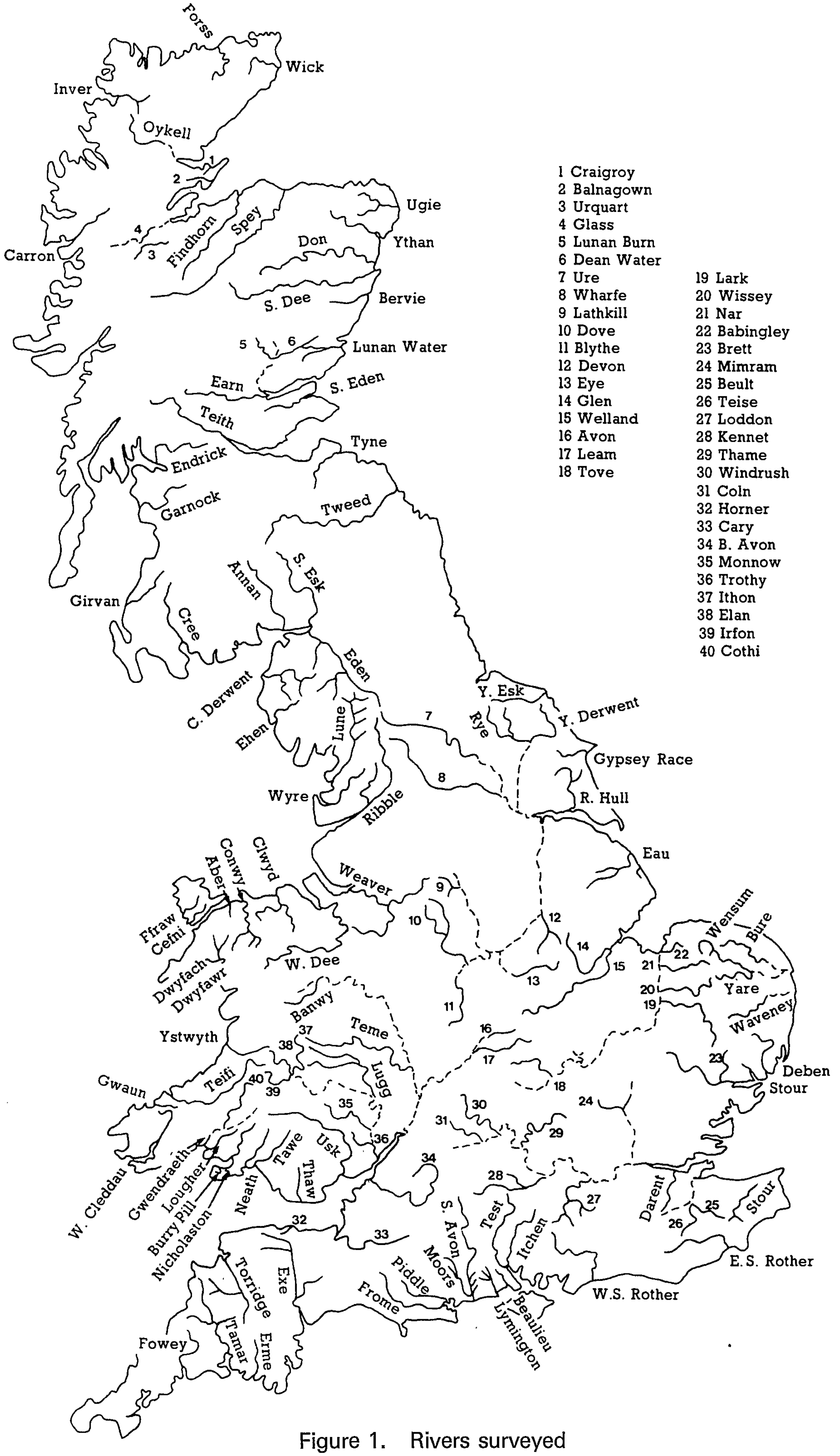
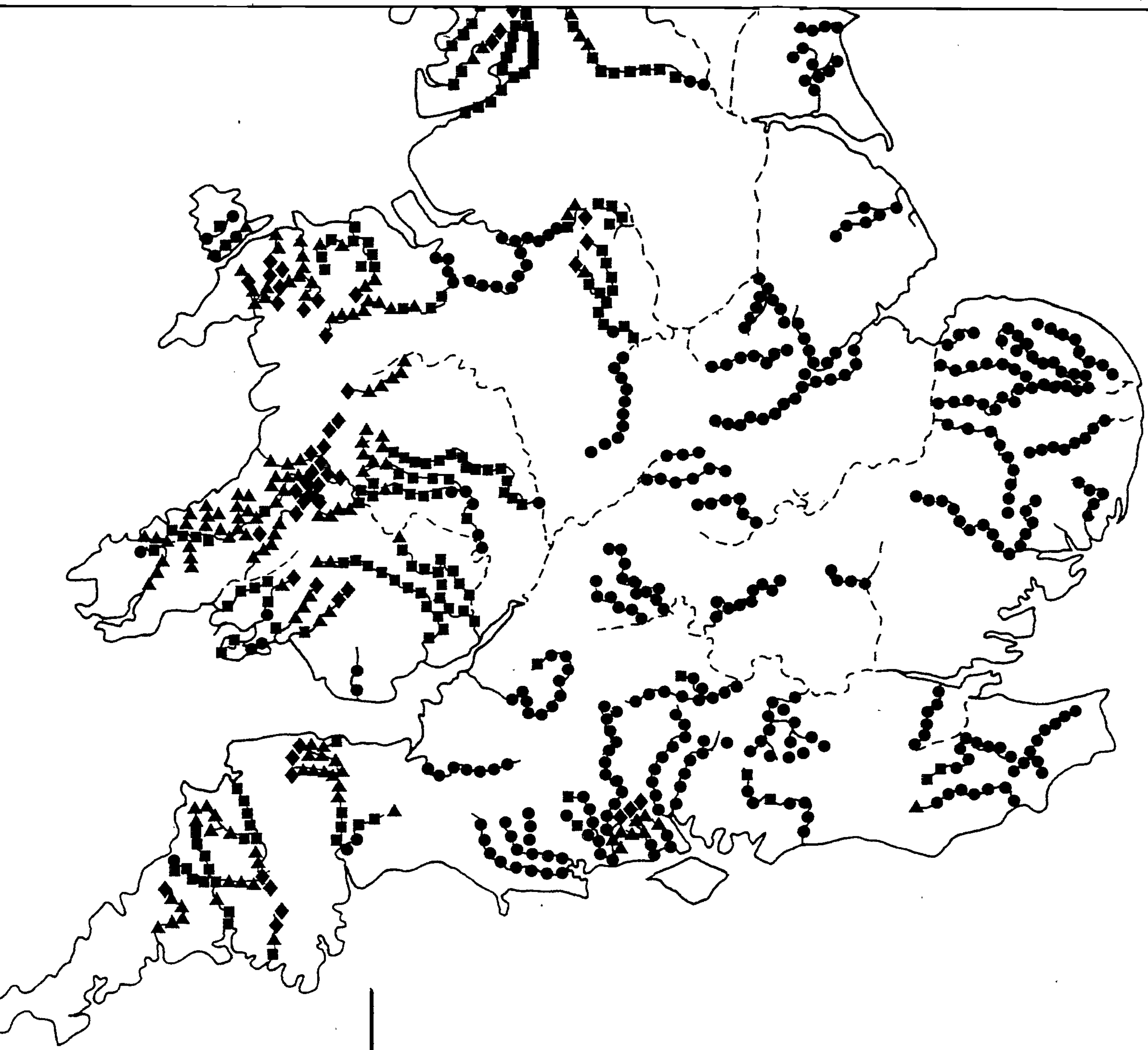


Figure 1. Rivers surveyed

Figure 2. Distribution of main groups A, B, C and D

Figure 2. Distribution of main groups A, B, C and D



● Group A: Lowland and rich geology

■ Group B: Sandstone, millstone and hard limestone

▲ Group C: Resistant geology

◆ Group D: Upland acid and nutrient poor

Figure 3. Distribution of individual communities of group A

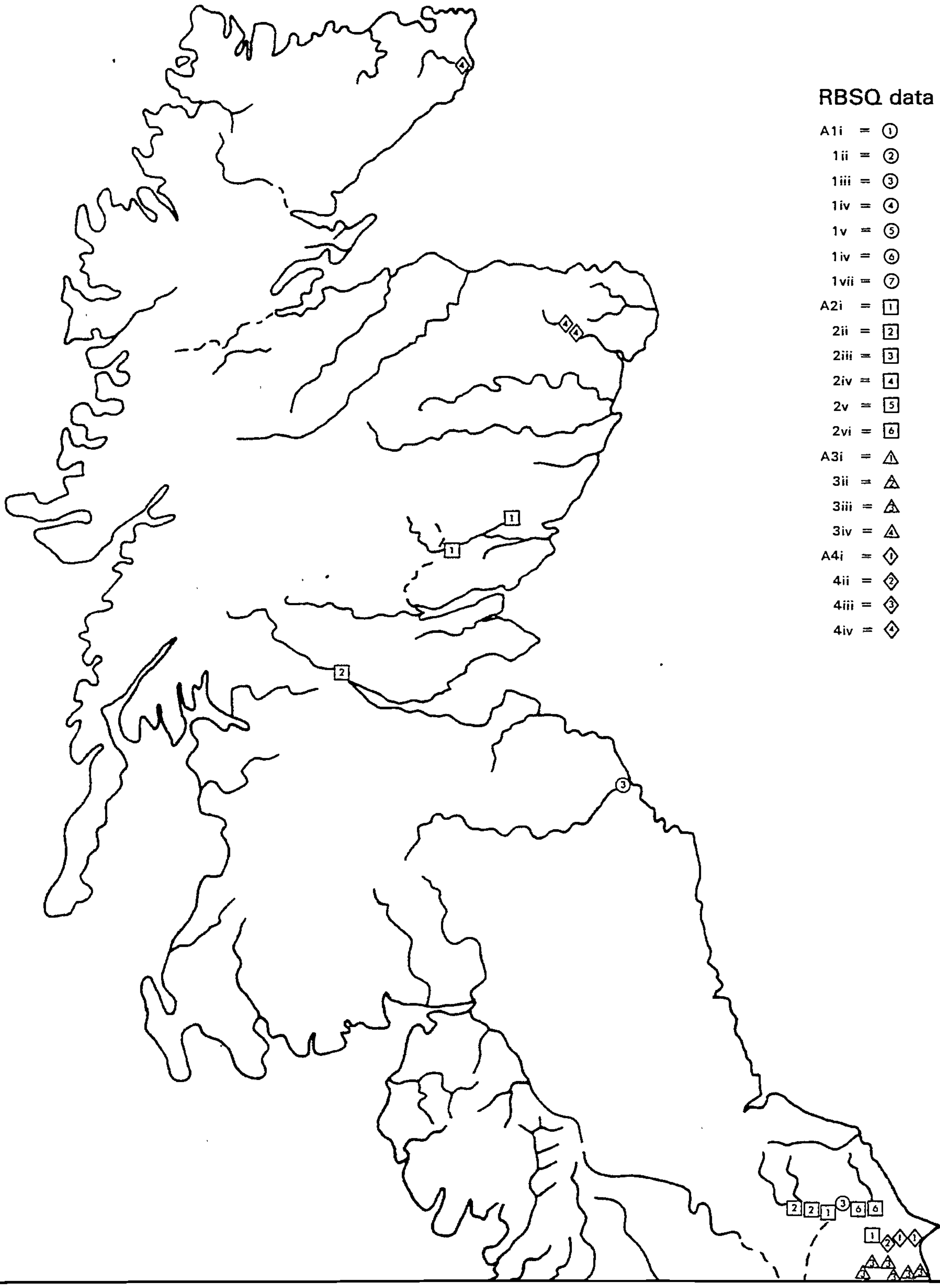


Figure 3. Distribution of individual communities of group A

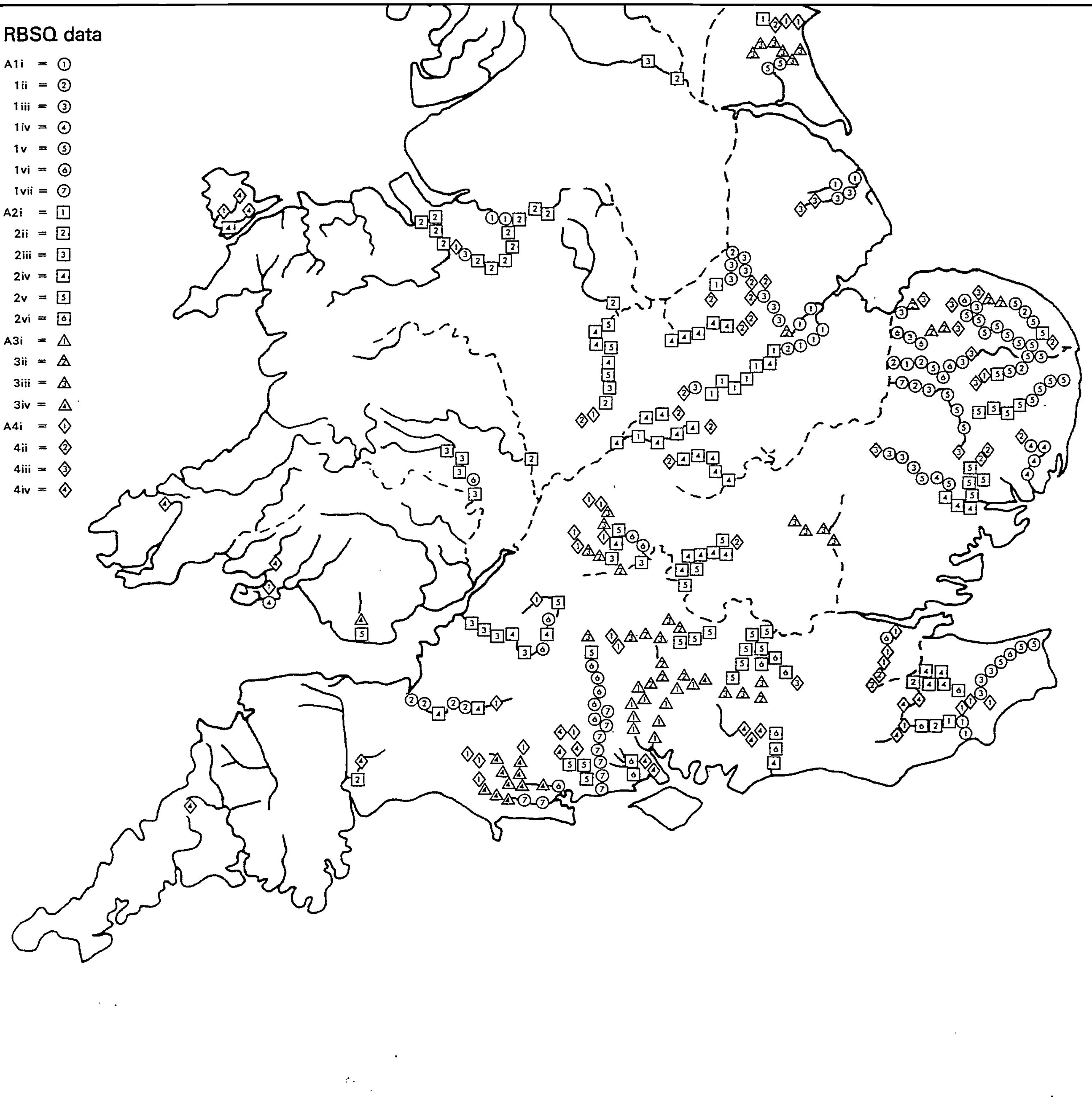


Figure 4. Distribution of individual communities of group B

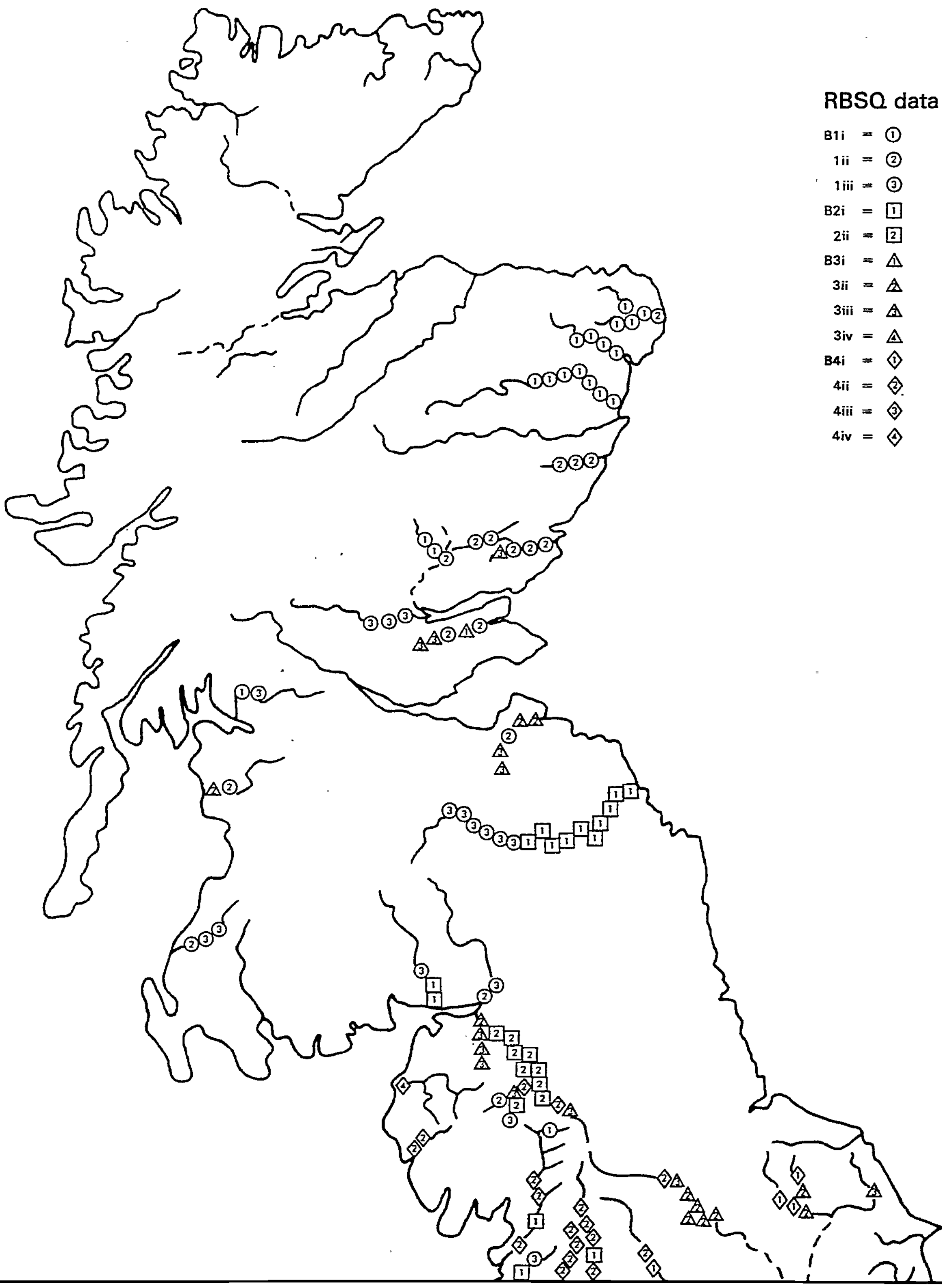


Figure 4. Distribution of individual communities of group B

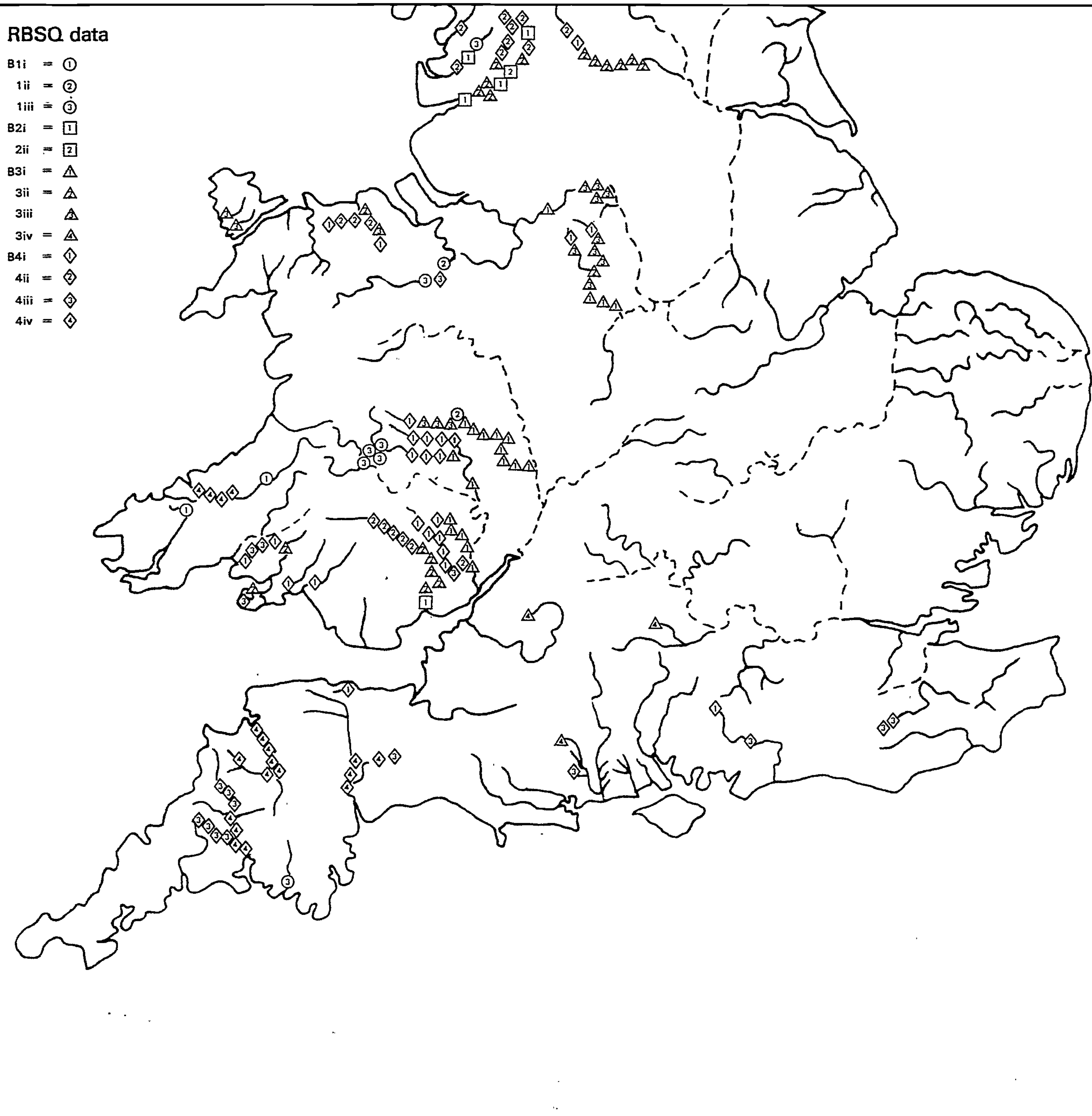


Figure 5. Distribution of individual communities of group C

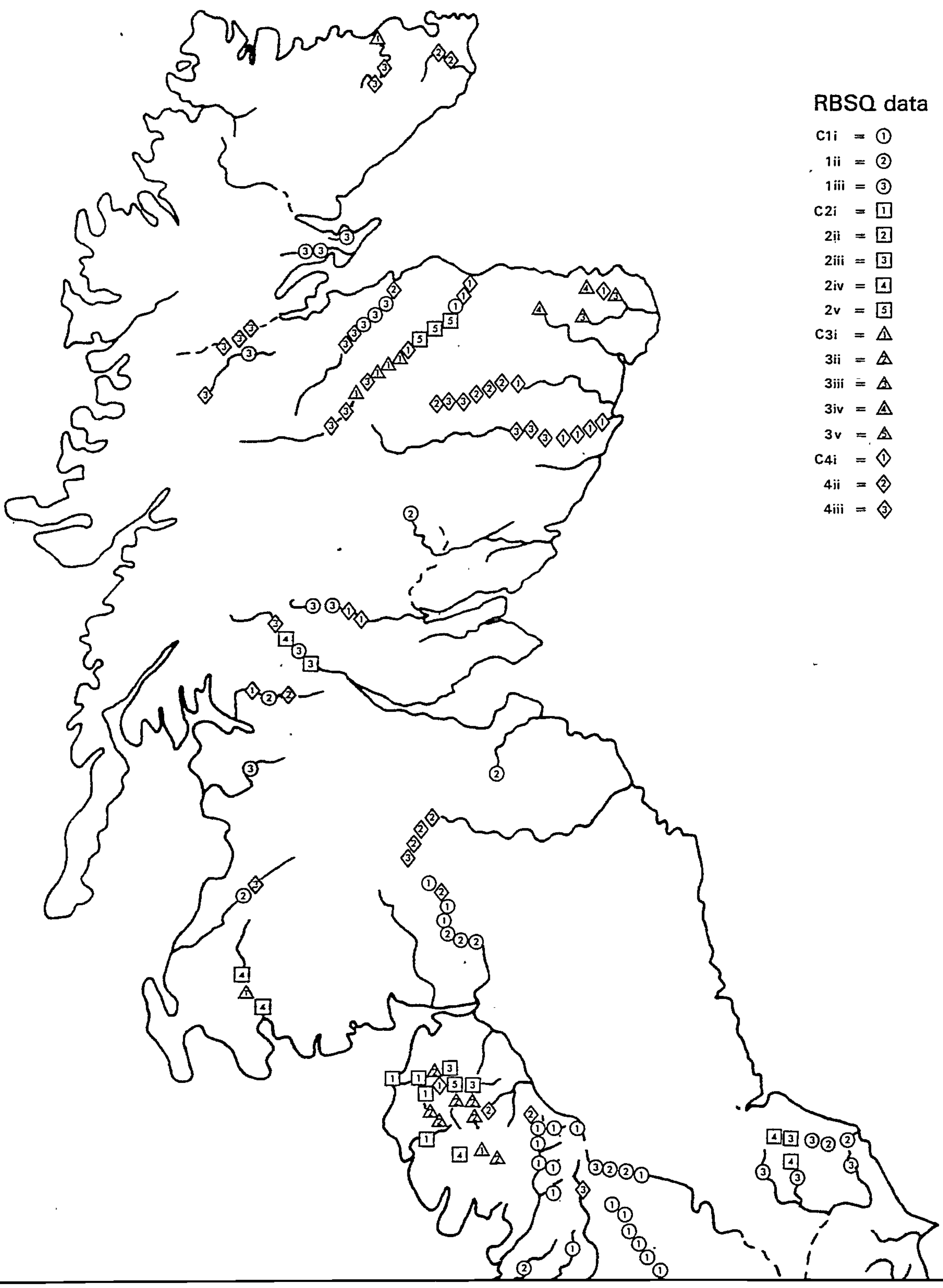


Figure 5. Distribution of individual communities of group C

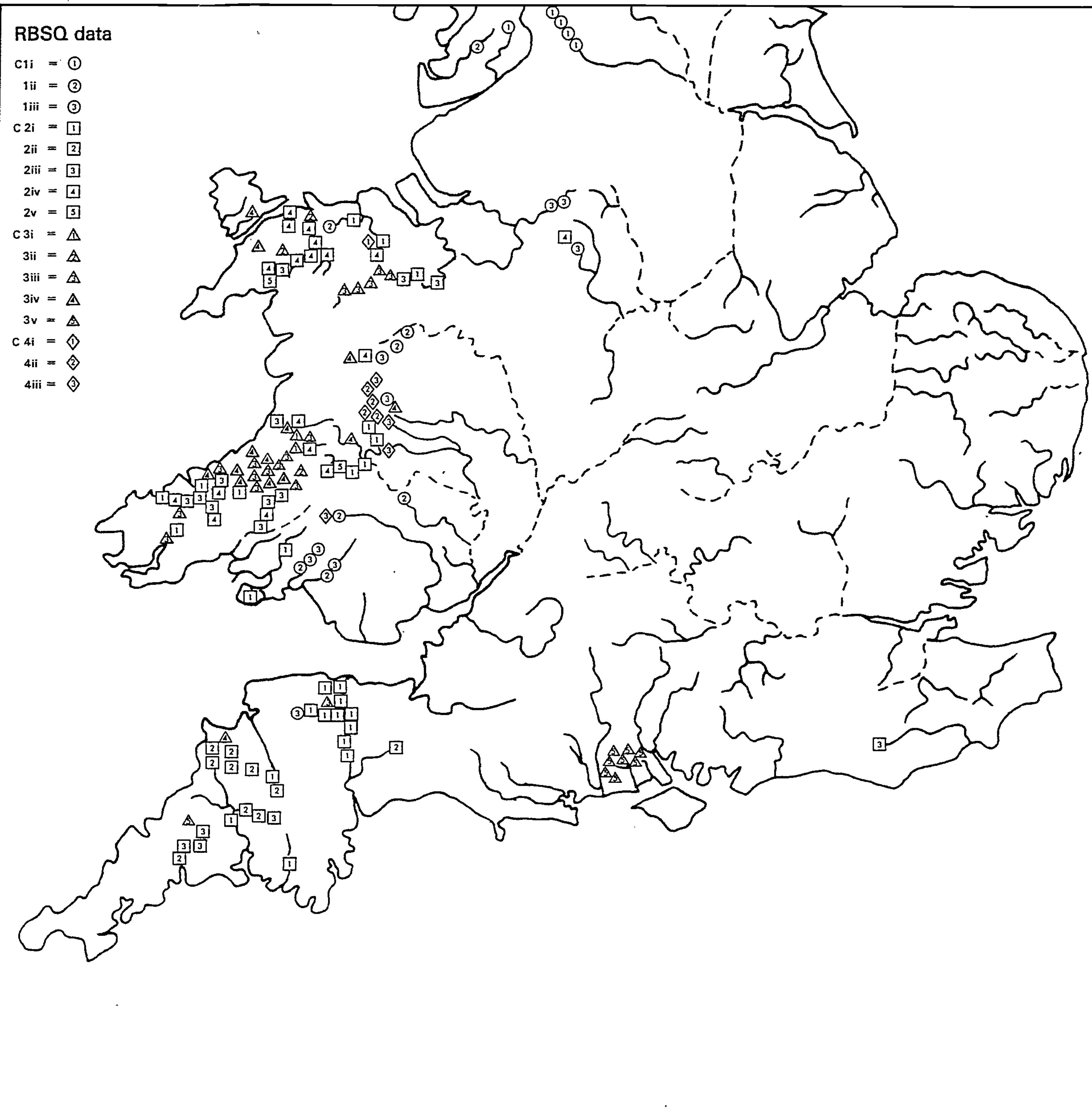


Figure 6. Distribution of individual communities of group D

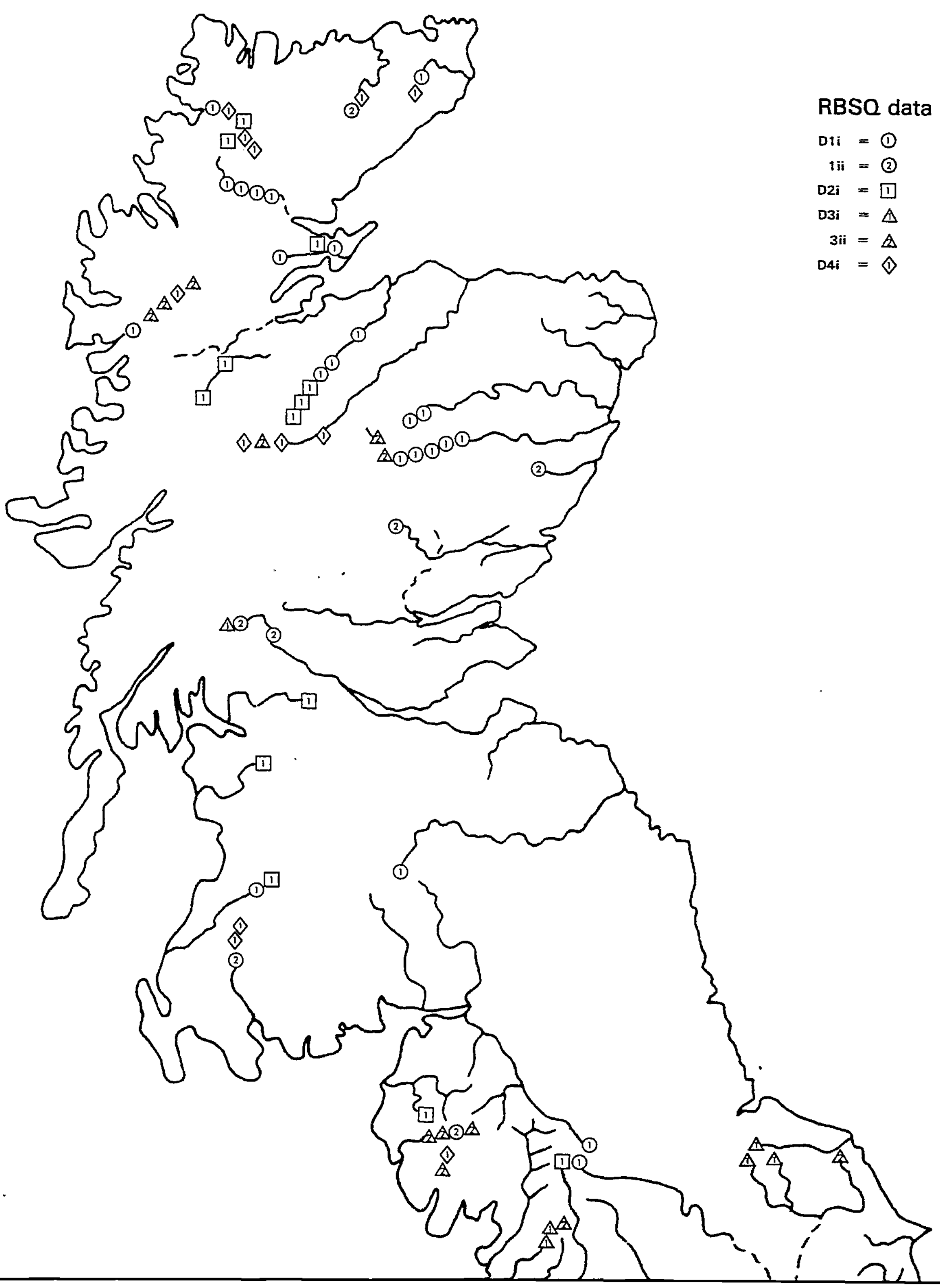


Figure 6. Distribution of individual communities of group D

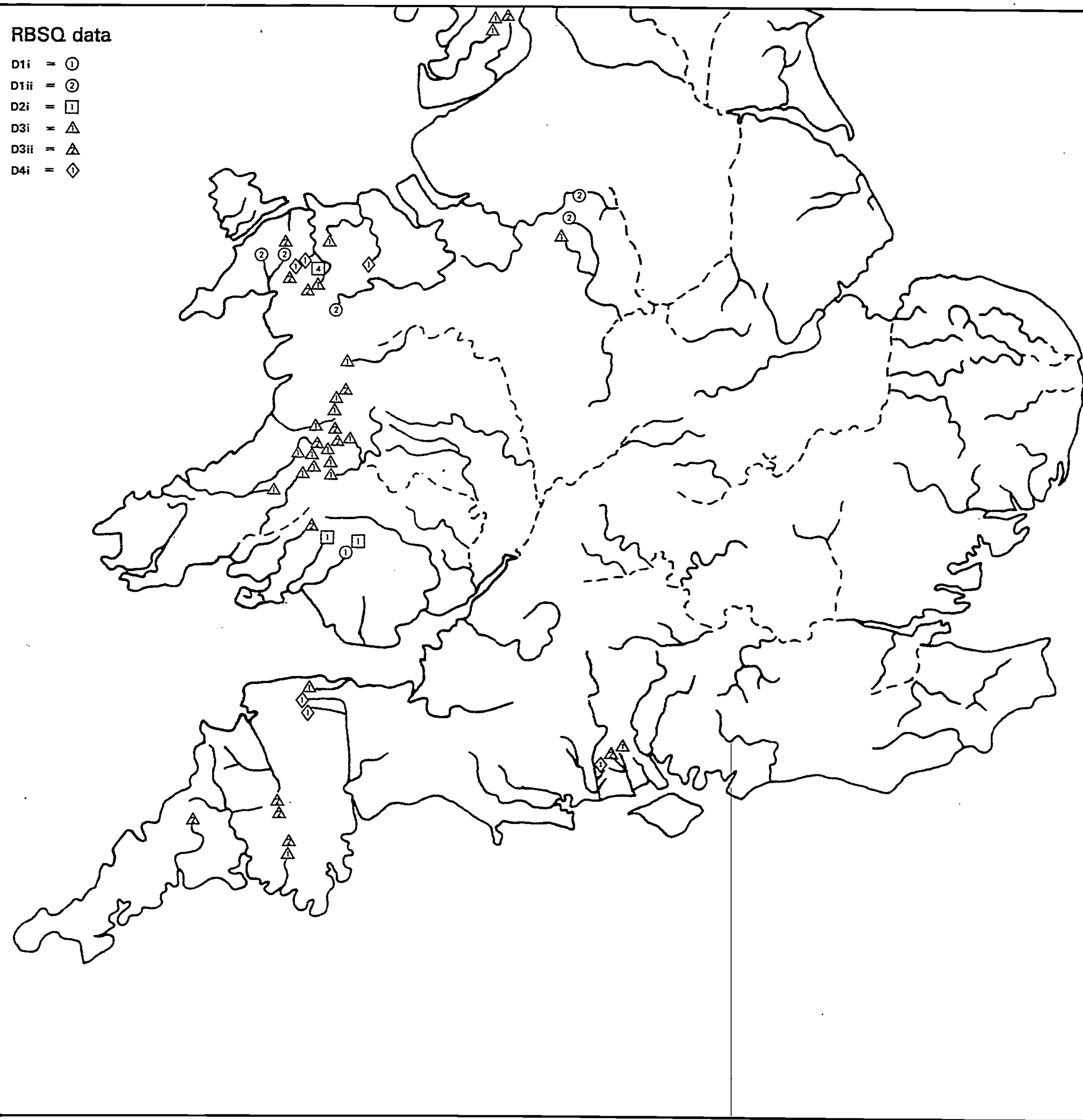


Table 1. Names of Community Types
(Accuracy of the Indicator Species Key is also shown for each community type)

		% accuracy
A1i	Man-made, Sluggish, Polluted Tidal Rivers	58
A1ii	Canalised, Fenland Clay and Sand Mix Rivers	91
A1iii	Highly Managed Unstable Sand Rivers	96
A1iv	Sluggish Mixed Sand/Clay Rivers	83
A1v	East-Anglian Fen Rivers Fed by Calcareous Water	90
A1vi	Fast-flowing Calcareous Small Rivers on Mixed Substrates	59
A1vii	Large Rivers with Calcareous Water Flowing over Acid Tertiaries	80
A2i	Highly Managed Clay Rivers with Soft Limestone in Catchment	69
A2ii	Large, Sluggish, Polluted Rivers on Mudstone and Clay	52
A2iii	Clay Rivers with Additional Coarse Substrates	38
A2iv	Central England Clay Rivers	87
A2v	Clay Rivers Fed from Chalk Aquifers	81
A2vi	Lowland Clay Rivers Fed by Acid Sands or Heathlands	73
A3i	Classic Chalk Rivers	100
A3ii	Small Chalk Streams	40
A3iii	Small, Silted, Enriched Chalk Rivers	86
A3iv	Chalk Rivers with Clay Influence	92
A4i	Calcareous Ditches	57
A4ii	Clay Ditches	84
A4iii	Spring Fed Streams in Clay Catchments	64
A4iv	Neutral or Acid Ditches	25
B1i	Enriched Rivers of NE Scotland	33
B1ii	Small Sandstone Rivers with Limited Basic Influence	70
B1iii	Rivers on Sandstone and Basic Silurians	81
B2i	Large Rivers on Old Red Sandstone, Carboniferous Limestone and Millstone Grit	89
B2ii	Rapid Rivers on Old Red Sandstone and Limestone	67
B3i	Large Rivers in their Lower Reaches on Old Red Sandstone	81
B3ii	Rapid Sandstone Rivers	93
B3iii	Small Rivers on Mixed Sandstone and Limestone	87
B3iv	Winterbournes	100
B4i	Small Sandstone Rivers with Shaded Margins	73
B4ii	Rivers on Calciferous Millstone Grit Series	79
B4iii	Small Lowland Rivers on Mixed Sands	58
B4iv	Large Mesotrophic Sandstone Rivers	71
C1i	Upland, Rapid Rivers on Carboniferous Limestone	63
C1ii	Upland, Shaded Rivers on Rich Geological Strata	74
C1iii	Upland, Rapid Rivers with Acid Water but Rich Substrates	84
C2i	Oceanic Rivers Dominated by Bryophytes	82
C2ii	South-west England Rivers at Low Altitudes	92
C2iii	Oceanic Rivers on Neutral Geological Strata	75
C2iv	Rapid, Upland, Shaded Rivers	65
C2v	Slow Oligo-mesotrophic Rivers	67

Table 1. *contd*

C3i	Upland Rivers of Fen and Bog	67
C3ii	Upland Rivers below Lakes	73
C3iii	Rivers below Reservoirs and Bogs	90
C3iv	Small Streams Draining Flat Shales	83
C3v	New Forest Streams	89
C4i	Large, Oligotrophic Scottish Rivers	77
C4ii	Upland Rivers in Wide Glacial Valleys	67
C4iii	Highland Rivers with Gravel and Peat	83
D1i	Mountain Rivers with Gravel Margins	80
D1ii	Mountain Rivers with Stable Margins	92
D2i	Highland Streams of Exposed Topography	87
D3i	Shaded Moorland Rivers with Earth and Rock Margins	100
D3ii	Moorland Rivers with Boulders and Adjacent Peat	96
D4i	Slow-flowing Upland Rivers	79
	Mean	76.1

Table 2. Summary of Community Types derived from Combined River and Bank Data

River Type	No. of Sites	No. of Rivers	No. Sites/ Rivers	All Species			Selected spp.			All/Selected spp. ratio	Name of Community Type	
				Max	Mean	Min	Max	Mean	Min			
A1i	12	6	2	50	30	13	52	28	11	93%	Man-made, sluggish, polluted, tidal. Very impoverished.	
ii	11	7	1.6	61	45	28	54	41	24	90%	Canalised, sluggish, clay/sand mix; fenland.	
iii	24	15	1.6	48	36	24	42	31	22	86%	Highly managed, unstable sands. Selection of v. species poor, basic sites.	
iv	6	3	2	61	53	45	56	47	40	87%	Lowland, sluggish, neutral rivers of mixed clay and sand.	
v	29	9	3.2	56	46	36	53	42	34	91%	Gravels/sands of E Anglian fens fed by calcareous water.	
vi	22	12	1.8	64	49	30	58	45	28	92%	Rivers with calcareous water, moderate velocity, gravels, rocks and clay.	
vii	10	3	3.3	57	50	38	53	46	36	92%	Large lowland rivers with calcareous water, moderate velocity and traversing acid Tertiaries.	
A2i	13	7	1.9	53	42	11	44	37	8	88%	Highly managed clay rivers with soft limestone in catchment.	
ii	23	12	1.9	50	35	20	46	30	14	86%	Large, sluggish, polluted, neutral, lowland rivers dominated by Triassic and Permian Mudstones.	
iii	13	8	1.6	56	46	29	51	41	23	89%	Large, lowland reaches of rivers flowing over substantial clay with sandstone.	
iv	39	15	2.6	68	51	37	62	46	32	90%	Classic central England clay rivers. Species rich when little management.	
v	32	15	2.1	68	51	35	61	45	32	89%	Calcareous clay rivers fed from Chalk aquifers.	
vi	11	7	1.6	61	45	26	55	40	23	88%	Lowland clay rivers fed by acid sands, heaths or moorlands. Often shaded.	
A3i	15	2	7.5	69	58	46	61	52	42	90%	Classic Chalk rivers of Hampshire. Very species rich.	
ii	15	10	1.5	67	49	38	58	44	33	90%	Small Chalk streams and purest Oolite. Less species rich.	
iii	21	11	1.9	61	43	27	55	38	24	88%	Smaller, slower, siltier and more enriched Chalk streams and small rivers.	less spp rich
iv	12	5	2.4	52	43	30	47	39	27	90%	Chalk streams flowing over clay. Margins of clay/peat, channels of gravel.	
A4i	28	17	1.6	60	41	22	52	35	19	87%	Calcareous ditches—sources of Chalk and Oolite streams which are dredged.	Usually V spp. poor and highly managed.
ii	19	15	1.3	50	37	13	43	30	8	81%	Sources of clay rivers—stream order 2/3 dredged ditches.	
iii	11	10	1.1	45	38	32	38	33	26	86%	Fenland sources of rivers—Chalk aquifers combined with fen or clay banks.	
iv	20	14	1.4	60	41	27	51	36	24	87%	Dredged lowland ditches on neutral clays and acid sands.	
B1i	21	9	2.3	59	50	38	49	42	31	84%	Enriched, lowland reaches of sandstone/rich intrusive metamorphics of N-E Scotland.	Predominate in East Scotland
ii	20	12	1.7	67	49	38	58	42	31	84%	Small sandstone rivers with little limestone influence.	
iii	21	10	2.1	71	59	54	59	52	46	88%	Species rich (especially higher plant) rivers on sandstone/ silurian/ordovician with limestone.	

Table 2. *contd*

River Type	No. of Sites	No. of Rivers	No. Sites/ Rivers	All Species			Selected spp.			All/Selected spp. ratio	Name of Community Type	
				Max	Mean	Min	Max	Mean	Min			
B2i	18	6	3	70	53	33	59	43	25	81%	Old Red Sandstone, large rivers.	
ii	12	3	4	68	59	51	57	46	41	77%	Old Red Sandstone, high water velocity and substantial limestone influence.	
B3i	21	8	2.6	70	53	35	61	45	28	85%	Herefordshire Old Red Sandstone rivers. Fine sand/silt or clay substrates.	
ii	27	13	2.1	63	49	30	51	40	28	82%	Fast-flowing sandstone rivers with mixed, coarser substrates. More calcareous, unstable, rocky and shaded.	
iii	30	18	1.7	67	48	28	53	40	25	83%	Sandstone small rivers with limestone in catchment.	
iv	3	3	1	46	35	28	37	28	22	80%	Winterbournes. Very species poor.	
B4i	29	19	1.5	57	43	23	44	34	19	79%	Small sandstone, mesotrophic rivers with sandy or silty substrates and shaded margins.	
ii	28	12	2.3	64	43	26	53	35	22	81%	Calciferous, Millstone Grit, large rivers	
iii	19	11	1.7	57	47	32	51	39	26	83%	Small rivers on a variety of sands—low altitudinal sources.	
iv	21	6	3.5	77	50	31	64	42	28	83%	Large, mesotrophic sandstone rivers.	
C1i	19	9	2.1	64	51	39	54	40	28	78%	Rapid, open, mesotrophic rivers in uplands flowing predominantly on Carboniferous Limestone.	Bryophytes dominate (C1i–iii)
ii	19	14	1.4	68	47	27	56	38	22	80%	Shaded upland rivers on rich geological strata.	
iii	25	19	1.3	80	57	38	68	45	31	80%	Fast-flowing oligo/mesotrophic rivers.	
C2i	28	19	1.5	64	45	27	52	36	15	80%	Species poor, bryophyte dominated, shade impoverished oceanic rivers.	
ii	12	8	1.5	59	48	33	49	39	26	81%	Small rivers with low altitudinal sources in SW England. Mesotrophic, enriched and silty.	
iii	20	14	1.4	66	49	28	54	39	22	80%	Larger, upland, oligo/mesotrophic rivers. Oceanic with neutral rocks.	
iv	26	19	1.4	67	50	22	58	40	20	79%	Upland, narrow, oligotrophic, fast-flowing shaded rivers.	
v	6	4	1.5	61	45	33	48	37	25	81%	Wide oligotrophic rivers with slow velocity and reedy margins.	
C3i	9	5	1.8	75	46	28	66	41	27	89%	Distinct upland fen/bog rivers. Higher plants dominate in slow flows.	closely allied (C3i–iii)
ii	11	7	1.8	77	56	42	63	48	39	86%	Species rich, oligo-mesotrophic rivers with natural stability due to upstream lakes.	
iii	20	9	2.2	59	47	35	50	40	28	84%	Oligo-mesotrophic rivers with stabilized flow by reservoirs, bogs, etc.	
iv	17	14	1.2	67	48	34	51	38	28	79%	Small, upland oligo-mesotrophic streams on flat shales	
v	9	7	1.3	56	39	28	48	31	22	82%	Distinct community of New Forest. Unique oligo and mesotrophic admix.	

Table 2. *contd*

River Type	No. of Sites	No. of Rivers	No. Sites/ Rivers	All Species			Selected spp.			All/Selected spp. ratio	Name of Community Type
				Max	Mean	Min	Max	Mean	Min		
C4i	13	7	1.9	62	52	42	53	43	35	83%	Lower reaches of oligotrophic rivers in Scotland. Unstable river bed but stable banks.
ii	18	9	2.0	70	59	43	56	49	37	83%	Upland, fast-flowing oligotrophic rivers with wide, indiscrete gravel margins.
iii	24	15	1.6	85	55	41	71	46	34	83%	Bryophyte and heathland dominates oligotrophic large rivers.
D1i	25	14	1.8	74	63	44	62	52	37	82%	Oligotrophic, upland/mountain rivers. Unstable coarse substrates and gravel margins. Very species rich.
ii	12	11	1.1	83	59	40	67	48	31	81%	Oligotrophic water/oligo-mesotrophic, more stable substrates, including clay, silt and peat. Clay or boulder margins. Species rich.
D2i	15	12	1.3	63	46	24	47	37	18	81%	Ultra-oligotrophic highland sites. Exposed topography, rapid velocity. Higher plants v.v. rare.
D3i	26	20	1.3	56	41	30	44	33	18	80%	Moorland rivers with mixed earth banks. Shade impoverished but relatively stable, Species poor.
ii	26	18	1.4	54	40	21	45	26	14	83%	Highland, oligotrophic rivers with moorland or heathland wet edges. Very species poor.
D4i	19	14	1.4	71	57	39	65	43	33	84%	Upland, oligotrophic water with fine particled substrates. Slow flow velocity, often clay present. Margins dominated by higher plants.
MEAN					*47.9*			*40.4*			

Table 3. Numbers give % occurrence in each Community Type

RBSQ—16 Main Groups	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Ceratophyllum demersum	28	6														
Oenanthe fluviatilis	30	6														
Potamogeton berchtoldii	22	5														
Ranunculus circinatus	21	9														
Lemna gibba	20	10														
Potamogeton lucens	31	17														
Elodea nuttallii	21	19														
Sagittaria sagittifolia	49	47														
Dipsacus fullonum	17	27														
Rorippa amphibia	19	54														
Berula erecta	35	11	84	37												
Callitriche obtusangula	10	28	84	29												
Pulicaria dysenterica	21	6	39	12												
Ranunculus sceleratus	29	45	11	23												
Rumex hydrolapathum	28	19	46	3												
Veronica catenata	31	36	20	16												
Veronica anagallis-aquatica	46	29	85	33												
Carex acutiformis	43	39	90	28												
Carex riparia	57	49	65	12												
Phragmites australis	43	16	52	10												
Scirpus lacustris	42	64	25	3												
Typha latifolia	21	16	33	6												
Hippurus vulgaris			41	0												
Impatiens capensis			25	1												
Carex paniculata			47	8												
Catabrosa aquatica			20	5												
Groenlandia densa			30	2												
Glyceria maxima	73	56	79	25	29	10										
Lemna minor	58	41	53	23	37	26										
Zannichellia palustris	64	21	46	29	8	26										
Potamogeton pectinatus	76	52			6	23										
Butomus umbellatus	34	29			0	36										
Carex acuta	1	25			9	36										
Potamogeton natans	11	28			20	13										
Potamogeton gramineus					14	20										
Apium nodiflorum	75	50	93	79			35	23								
Callitriche platycarpa	46	36	68	38			8	20								

Table 3 *contd*

RBSQ—16 Main Groups	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Lycopus europaeus	44	52	65	30			20	30								
Lythrum salicaria	42	66	66	29			17	30								
Myosoton aquaticum	14	33	4	21			32	2								
Juncus inflexus	56	58	79	51			30	19								
Amblystegium riparium	45	54	37	58	47	30	64	61								
Epilobium hirsutum	87	92	100	91	46	83	92	59								
Polygonum amphibium	50	67	39	28	62	80	34	7								
Ranunculus calcareus	42	32	88	25	11	60	44	28								
Scrophularia auriculata	56	67	84	70	8	23	40	16								
Symphytum officinalis	41	41	60	29	38	30	43	15								
Elodea canadensis	74	63	52	16	74	96	41	39								
Potamogeton crispus	54	39	19	20	62	80	24	19								
Enteromorpha sp(p.)	71	45			3	53	22	5								
Ranunculus fluitans	30	30			16	93	53	12								
Rorippa palustris	7	43			29	20	24	10								
Rorippa sylvestris	5	21			30	86	50	29								
Potamogeton perfoliatus	53	29			20	50	23	3								
Collema fluviatile					18	23										
Cladophora aegagropila					31	63										
Ranunculus peltatus					20	1										
Glyceria plicata			25	30			25	5								
sponge					35	43	7	22								
Lysimachia vulgaris					9	40	13	24								
Carex hirta					12	32	20	19								
Scirpus sylvaticus					30	50	17	22								
Myriophyllum spicatum	69	42	33	8	1	63	32	7								
Cladophora glomerata	75	79	65	65	82	100	90	85	52	18						
Pellia endiviifolia	11	21	24	46	18	23	67	69	32	25						
Petasites hybridus	14	24	31	16	40	53	72	41	47	8						
Sparganium erectum	88	94	95	84	96	96	77	59	14	30						
Eupatorium cannibinum	44	34	69	39			24	42	1	27						
Impatiens glandulifera	4	22			25	80	48	32	3	22						
Hildenbrandia rivularis					63	93	64	67	46	26						
Carex remota							4	28	39	41						
Cardamine amara									23	8						
Alisma plantago-aquatica	28	58	12	38	22	40	33	25			25	5				
Rorippa nasturtium-aquaticum	84	67	87	73	56	46	59	8			21	29				

Table 3 *contd*

RBSQ—16 Main Groups	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Vaucheria sessilis	88	79	79	60	37	60	80	77	32	48	30	13				
Brachythecium rutabulum	23	29	30	53	55	53	56	45	44	25	18	27				
Solanum dulcamara	80	80	87	87	54	50	59	59	9	33	24	1				
Stachys palustris	21	24	30	15	46	30	22	16	7	23	37	23				
Lunularia cruciata			3	29	34	10	52	53	33	39	21	7				
Mimulus guttatus			30	10	82	86	49	17	58	23	12	40				
Cinclidotus fontinaloides					35	83	64	47	63	36	15	25				
Ranunculus penicillatus					4	30	1	21	0	30	25	1				
Alopecurus geniculatus	14	26	12	32	66	36					30	30	27	0		
Conocephalum conicum			10	37	48	47	75	85	87	78	26	35	22	33		
Marchantia polymorpha			8	23	18	20	42	48	49	42	18	25	33	7		
Amblystegium fluviatile			29	18	79	83	84	68	90	61	41	73	27	13		
Thamnobryum alopecurum					9	36	23	39	61	70			16	46		
Brachythecium rivulare					31	7	41	26	83	42	12	49	62	93		
Veronica beccabunga	78	83	81	82	69	73	81	39	49	23	33	40	24	0		
Oenanthe crocata	21	29	36	38	30	46	35	77	23	28	66	12			1	21
Glyceria fluitans	40	34	25	42	62	50	45	57	44	64			89	0	57	94
Juncus acutiflorus	13	35	31	39	85	80	58	69	85	79			97	73	82	100
Iris pseudacorus	37	27	79	30	33	23			3	20	42	16			0	21
Phalaris arundinacea	98	96	100	91	98	100	98	90	68	86					5	36
Juncus effusus	19	54	39	67	90	23	48	36	60	66			89	66	90	94
Sparganium emersum	70	77	33	24			6	24			39	5			0	21
Nuphar lutea	50	72													1	21
filamentous green algae	17	23	17	37	84	53	37	36	86	67	62	93	100	100	94	89
Fontinalis antipyretica	37	41	65	36	95	90	99	92	90	79	85	95	86	80	40	37
Rhynchostegium riparioides	27	33	49	50	90	100	95	94	98	94	84	90	81	66	34	26
Equisetum arvense	12	28	23	41	87	83	71	43	69	36	40	70	72	13	17	21
Angelica sylvestris	30	25	58	51	48	43	32	34	41	43	56	69	48	6	15	21
Callitriche stagnalis	59	54	77	69	72	48	32	26	22	35	65	50	45	20	21	36
Filipendula ulmaria	50	64	88	79	87	56	56	58	74	68	60	81	72	33	19	63
Mentha aquatica	84	75	98	87	96	93	91	86	82	70	89	89	48	6	17	47
Myosotis scorpioides	92	95	96	91	98	96	97	54	63	44	66	96	62	13	21	63
Salix sp(p.)	63	93	88	83	91	80	79	95	84	85	92	87	83	53	67	63
trees	58	86	80	78	85	73	90	94	87	92	87	76	70	26	74	47
Agrostis stolonifera	97	96	90	98	100	100	97	100	96	97	98	92	100	46	67	68
Deschampsia cespitosa	11	32	19	24	25	10	35	35	58	33	46	58	70	66	57	84
Verrucaria sp(p.)			25	27	90	100	85	89	95	98	68	85	76	53	38	21

Table 3 *contd*

RBSQ—16 Main Groups	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Caltha palustris			44	25	77	60	54	45	73	58	60	87	89	20	28	68
Galium palustre			28	12	29	10			25	32	69	56	62	33	44	73
Batrachospermum sp(p.)			35	19											21	21
Chiloscyphus polyanthos					44	7	26	60	86	89	68	58	59	67	21	21
Lemanea fluviatilis					50	60	46	69	84	74	30	67	51	60	31	21
Schistidium alpicola					29	30	12	26	76	50	25	74	86	73	32	36
ferns					50	23	20	27	55	53	63	45	48	86	51	68
Callitriche hamulata					41	0	11	23	20	52	74	54	56	0	25	73
Myriophyllum alterniflorum					72	36	1	29	26	47	66	90	67	0	21	84
Sagina procumbens					32	23	24	17	79	23	27	58	78	66	13	21
Tussilago farfara					40	6	37	14	71	11	10	69	72	53	11	21
Eleocharis palustris					48	83	23	24	25	21	31	65			1	68
Stellaria alsine					27	20			17	22	31	38	43	20	13	36
Dermatocarpon fluviatile					19	20			22	53	33	24	27	20	15	21
Equisetum fluviatile					29	10					37	41	27	0	3	78
Senecio aquaticus					40	10					42	36	29	0	1	26
Equisetum palustre							22	43	31	25	16	25			13	31
Fontinalis squamosa							2	29	41	86	62	50	51	46	51	42
Cardamine amara									23	8						
Hygrohypnum luridum									38	6	4	34	59	80		
Pellia epiphylla									51	78	71	53	97	80	100	100
Scapania undulata									43	57	45	36	95	87	98	84
Solenostoma triste									41	30	17	35	100	87	77	37
Brachythecium plumosum									67	34	20	36	86	93	63	58
Bryum pseudotriquetrum									46	20	21	51	84	87	69	95
Calliergon cuspidatum									43	10	9	60	76	53	10	47
Dichodontium pellucidum									73	14	5	29	76	87	12	47
Hygrohypnum ochraceum									57	75	56	65	94	93	69	47
Philonotis fontana									26	3	4	27	62	73	21	36
Racomitrium aciculare									25	45	33	36	89	100	86	73
Achillea ptarmica									33	28	48	78	89	60	25	84
Montia fontana									22	9	33	45	67	40	11	42
Ranunculus flammula									41	59	71	80	94	40	69	89
Anthroxanthum oderatum									23	7	12	34	97	73	86	84
Carex nigra									30	9	9	69	81	53	59	94
Dichodontium flavescens									52	7			54	87	8	26
Hyocomium amoricum									9	27			67	80	90	68

Table 3 *contd*

RBSQ—16 Main Groups	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**B4**	**C1**	**C2**	**C3**	**C4**	**D1**	**D2**	**D3**	**D4**
Mimulus guttatus x leteus											13	26				
Carex aquatilis											21	23				
Didymosphenia geminata											0	31	43	60		
Carex ovalis											7	20	40	13		
Ranunculus omiophyllus											33	3			21	31
Littorella uniflora											13	25	24	0	9	52
Lotus pediculatus											34	43	56	40	51	63
Potentilla erecta											15	23	62	60	57	63
Carex demissa											3	20	40	53	42	31
Carex rostrata											25	60	45	0	11	89
Molinea caerulea											6	23	51	26	51	68
Nardus stricta											3	21	56	60	53	73
Carex pulicaris													2	20		
Carex binervis													2	33		
Marsupella emarginata													35	67	85	42
Nardia compressa													27	27	58	26
Blinda acuta													38	60	19	26
Dicranella palustris													35	47	10	42
Polytrichum commune													29	53	92	63
Schistidium agassizii													35	33	9	21
Sphagnum sp(p.)													18	33	69	89
Viola palustris													43	20	57	73
Carex echinata													13	26	50	63
Carex panicea													24	6	19	42
Juncus bulbosus													89	66	73	100
Juncus squarrosus													8	2	26	21
Potamogeton polygonifolius													21	0	34	63
Hydrocotyle vulgaris															11	26
Veronica scutellata															7	36
Carex curta															15	31
Carex flacca															9	21
Juncus articulatus															21	5
Narthecium ossifragum															21	21
Sparganium angustifolium															5	21
Myrica gale															5	31

Table 4. Numbers give % occurrence in each Community Type

RBSQ-A	A1i	A1ii	A1iii	A1iv	A1v	A1vi	A1vii	A2i	A2ii	A2iii	A2iv	A2v	A2vi	A3i	A3ii	A3iii	A3iv	A4i	A4ii	A4iii	A4iv
Scirpus maritimus	25																				
Potamogeton pusillus	42																				
Potamogeton friesii	42																				
Carex otrubae	25	36						23													
Elodea nuttallii	58	73						46				22									
Ceratophyllum demersum	75	55			24		30			23											
Ranunculus circinatus	50	36		50	24					23											
Potamogeton perfoliatus	67	64	29		52	77	70	54	22	38	38										
Potamogeton pectinatus	100	73	54	33	86	77	100	85	57	62	56	38	27								
Butomus umbellatus	33	55		33	38	27	70				72										
Enteromorpha spp.	92	100	96	100	86			62	35	77	59	31									
Potamogeton lucens	42	36			41		90				36	25		40							
Rorippa amphibia	25				24	32		62	43	54	74	47									
Senecio aquaticus	33					23								20							
Rumex hydrolapathum	25	45	21	33	24	36	30			23	23	34		93	73						
Dipsacus fullonum		45	29					23		38	49	28									
Sagittaria sagittifolia		100	29	67	59	45	60	31		38	79	63									
Nuphar lutea		91	33	83	76	27	40	38	22	54	100	94	82								
Oenanthe fluviatilis		27		67	45	45	20							53							
Lemna gibba		27				27	70				31										
Potamogeton berchtoldii		27		67	38		30							20							
Phragmites australis	42	36		83	48	50	80					31	27	80	40	38	58				
Myriophyllum spicatum	83	73	50		59	100	100		30	69	38	59	36	20	60	33		21			
Potamogeton alpinus				50																	
Cardamine amara					21																
Ranunculus trichophyllus					21																
Equisetum palustre						32	40		22	46											
Potamogeton x salicifolius							50														
Azolla filiculoides							50														
Eleocharis palustris							20														
Scirpus sylvaticus								54													
Bidens tripartita									22												
Potamogeton nodosus										23											
Cinclidotus fontinalioides										38											
Alisma lanceolatum										23											
Rorippa sylvestris								23	39	69											
Rorippa palustris							60	69	52		44	34	55								

Table 4 *contd*

RBSQ-A	A1i	A1ii	A1iii	A1iv	A1v	A1vi	A1vii	A2i	A2ii	A2iii	A2iv	A2v	A2vi	A3i	A3ii	A3iii	A3iv	A4i	A4ii	A4iii	A4iv
Carex acuta								46		31	49										
Scutellaria galericulata				50				23			23										
Bidens cernua				50			20			23			27								
Ranunculus peltatus													45								
Scirpus lacustris				83	59	68	60	62		69	89	91		53	20						
Ranunculus fluitans		36	21			50	80		43	77		34					25				
Myosoton aquaticum			21	33			20	62	22		56		36						42		
Typha latifolia		36		33		23	20					25	27	33	47	20	42				
Zannichellia palustris			63	50	79	91	90	46		38		22		87	67	29		43	21	55	
Ranunculus sceleratus		55	29	33	45			69	43	23	51	50				29			53	27	
Pulicaria dysenterica		36		83		23	30							80	53					55	
Berula erecta		55		67	45	50						41		93	87	81	75			27	
Glyceria plicata			27	21										27		29	33	36	47	27	
Elodea canadensis	92	73	63	67	76	77	80	69	43	69	69	72	45	93	47	33	42	25	21		
Carex riparia	25	73	33	100	93	41	50	54		31	74	78		67	67	67	58		26		
Veronica catenata	25	55		33	38	27	40	31			67	50		20		29	33	25	32		
Veronica anagallis-aquatica	33	36	42		55	73	30	54		23	23	44	45	87	93	71	100	39	26	64	
Lemna minor	83	73	71	100	62	32		77	39	23	59	25		80	47	29	75	29		55	
Juncus inflexus	42	64	42	100	59	59	60	54	26	46	90	66		80	67	81	92	57	74	82	
Deschampsia cespitosa	25							31			46	31	55	20	20				37		40
Glyceria maxima	75	100	33	50	86	82	100	77		23	82	72		80	80	90	58	43			20
Alopecurus geniculatus	33	20	25				20	54	48		23						42	43	26		40
Polygonum amphibium	75	82	38	83	24	50	70	77	48	69	90	72		73	40	24	25	32	32	27	20
Cladophora glomerata	83	82	79		76	82	60	77	91	100	74	78	55	67	67	81	33	79	68	73	40
Callitriche platycarpa	25	36	46	67	52	41	70	23	26		54	41	27	93	73	81		36	53	27	35
Callitriche stagnalis	25	55	46	83	83	68	40	31	26		62	81	91	60	80	90	75	57	63	64	95
Vaucheria sessilis	75	73	96	83	97	100	50	85	61	100	77	91	64	80	87	81	67	64	63	55	55
Apium nodiflorum	33	82	75	100	83	77	80	54	35	23	56	69	36	100	87	90	100	89	74	82	70
Epilobium hirsutum	50	82	88	83	97	100	90	85	83	100	97	100	73	100	100	100	100	100	100	100	65
Filipendula ulimaria	25	55	25	67	52	64	90	54	34	54	64	81	91	100	93	81	83	82	74	91	75
Mentha aquatica	67	73	63	100	93	100	100	62	43	85	79	94	82	100	100	100	92	93	79	91	85
Myosotis scorpioides	67	82	92	100	100	100	100	92	87	92	97	100	100	100	100	100	83	93	95	82	90
Rorippa nasturtium-aquaticum	58	82	92	83	90	86	80	92	35	38	72	97	45	93	80	86	92	79	79	99	50
Scrophularia auriculata	33	36	50	83	76	73		31	35	38	90	84	91	73	87	100	67	71	79	73	60
Veronica beccabunga	33	100	79	100	79	86	80	85	83	69	90	94	55	80	87	86	100	86	89	91	65
Salix spp.	33	64	54	67	72	77	90	85	96	100	100	84	91	87	93	90	83	82	74	91	90
Agrostis stolonifera	100	100	100	100	93	95	100	100	96	100	100	91	100	87	80	100	92	100	95	100	100

Table 4 *contd*

RBSQ-A	A1i	A1ii	A1iii	A1iv	A1v	A1vi	A1vii	A2i	A2ii	A2iii	A2iv	A2v	A2vi	A3i	A3ii	A3iii	A3iv	A4i	A4ii	A4iii	A4iv
Phalaris arundinacea	100	100	96	100	100	95	100	92	96	100	97	97	100	100	100	100	100	93	79	100	95
Sparganium erectum	50	100	83	100	93	95	100	92	83	100	100	97	91	100	100	90	92	86	79	73	95
Solanum dulcamara		73	83	100	76	91	90	69	52	85	85	97	82	100	87	71	100	96	84	100	70
Amblystegium riparium		20	67	83	48	50			61	54	54	69	45		40	48	50	57	84	55	45
Glyceria fluitans		45	42		31	45	90	46	43	31	41	22				33	58	64	21		50
Ranunculus calcareus		20	29		52	82	70	31		54	23	47	55	100	93	81	83	39			40
filamentous green algae		36	21	67				46			36				47				53	64	40
Equisetum arvense		36					20	46	39		23		45		27	24	42	46	42	27	40
Angelica sylvestris		27	21	50	31	27	80				21	38	73	73	60	33	83	54	37	45	65
Callitriche obtusangula		36	21		31	68	30				26	59	55	100	93	81	75	36		27	50
Lycopus europaeus		27		50	55	68	100		43	92	56	66	36	100	80	29	67	21	37	27	40
Lythrum salicaria		36	21	100	41	73	50	31	57	62	67	84	82	100	80	33	67	25	21		55
Oenanthe crocata		27				36	70		26	46	23	20	82	67			83	46			80
Stachys palustris		27		50	21		90		30		33		55	87							30
Symphytum officinalis		55			28	77	100		17	77	36	69	36	93	33	43	83	39			40
trees		36	50	100	62	91	50	54	78	100	90	94	91	53	93	90	83	82	95	91	85
Alisma plantago-aquatica		45	38	50	41		20	23	43	62	72	63	64		20			32	32	45	50
Potamogeton crispus		45	63	50	66	59	50	69	39	38	36	34	36	33	40			21	26		20
Sparganium emersum		64	54	83	100	82	60	38	70	62	87	84	100	53	60			21			60
Juncus effusus			29	50		23		77	52		62	47	91	20	20	57	58	64	53	73	85
Iris pseudacorus		36		83	48	41	80				28	50	27	87	73	76	83	57			30
Juncus acutiflorus			25			23	20	62	43	58	33	22	36	60	20		33	43	32	27	50
Eupatorium cannibinum				100	62	64	80			31	23	75	45	100	80	33	83	32	21	73	50
Pellia endiviifolia				33		23				38	26	25	45	40		20	25	32	79	55	30
Brachythecium rutabulum			33	33	28	36				54	33	47			33	57		39	84	64	35
Carex acutiformis		45		50	55	64	80				59	31		100	87	95	75	50	21		
Amblystegium fluviatile						27			20	54				27	47	33		25	21		
Batrachospermum sp(p.)					21									20	47	20	67	32		37	
Hildenbrandia rivularis						23	20			31				20	33			21			
Carex hirta							40							20		29					
Hippurus vulgaris				67										73	47	38					
Lemna trisulca														60							
Impatiens capensis														100							
Lysimachia vulgaris														47							
Ranunculus vertumnus															27						
Groenlandia densa			21											53	33	24					
Carex paniculata	25													80	53	33	25				

Table 4 *contd*

RBSQ-A	A1i	A1ii	A1iii	A1iv	A1v	A1vi	A1vii	A2i	A2ii	A2iii	A2iv	A2v	A2vi	A3i	A3ii	A3iii	A3iv	A4i	A4ii	A4iii	A4iv
Petasites hybridus				83				23	35	23		34		53	33	29		21	21	27	
Potamogeton natans			21	50				23			38	28	64								30
Equisetum fluviatile				33										53	20						25
Fontinalis antipyretica					34	86	80	23	35	77	28	50	55	100	60	48	58	46			65
Rhynchostegium riparioides			29		31	59		23	20	85	23	50		60	67	33	42	54	37	36	65
Mimulus guttatus									35					80	20						20
Verrucaria spp.						50			22	31				20	33	24	25	25	21	27	35
Marchantia polymorpha										31			27					25	26	45	
Conocephalum conicum										54		22	73		20			32	32	64	35
Caltha palustre												31		73	40	33	33	39			25
Lunularia cruciata													55					29	26	27	35
Galium palustre											36		27	60	20						25
Impatiens glandulifera									65				45								30
ferns													45							36	50
Carex remota													36							27	20
Callitriche hamulata													45								20
Pellia epiphylla																					40
Chiloscyphus polyanthos																					25
algae	3	4	4	3	4	3	3	4	3	4	4	3	2	4	5	3	3	4	3	4	3
lichens						1			1	1				1	1	1	1	1	1	1	1
liverworts				1		1				3	1	2	4	1	1	1	1	4	4	4	5
mosses		1	2	2	4	5	1	2	4	6	4	4	2	3	5	5	3	5	4	3	3
vascular cryptogams		1		1		1	3	1	2	1	1		2	1	2	1	1	1	1	2	3
dicotyledons	20	35	26	31	35	35	35	26	33	30	36	35	32	38	32	29	26	27	23	23	28
monocotyledons	21	27	22	24	23	24	29	26	15	21	27	26	16	26	23	19	19	18	16	11	15
	44	68	54	62	66	70	71	59	58	66	73	70	60	74	69	59	54	60	52	48	58

Table 5. Numbers give % occurrence in each Community Type

RBSQ-B	B1i	B1ii	B1iii	B2i	B2ii	B3i	B3ii	B3iii	B3iv	B4i	B4ii	B4iii	B4iv
Equisetum fluviatile	57												
Potamogeton alpinus	43												
Achillea ptarmica	33												
Carex rostrata	29												
Glyceria maxima	52	25											
Collema fluviatile	28		24	33									
Potamogeton gramineus	38				50								
Potamogeton natans	38				25								
Potamogeton perfoliatus	43			39	67	52	26						
Ranunculus aquatilis		20	29										
Potamogeton pectinatus		20		33		29							
Zannichellia palustris		25			58	33							
Stellaria alsine	33	35			42			27					
Galium palustre	33	20	33					40					
Senecio aquaticus	43	30	48			24			33				
Rorippa nasturtium-aquaticum	71	70	29	33	67	48	44	77	100				
Mimulus guttatus	81	100	67	78	100	33	63	53			39		
Polygonum amphibium	62	45	81	78	83	62	33	20					
Alopecurus geniculatus	67	55	76	44	25				66				
Rorippa palustris	30	20	29	33		71					29		
Montia sibirica			24										
Potamogeton x salicifolius				28									
Carex acuta			29		67								
Butomus umbellatus					67								
Dermatocarpon fluviatile			33		25								
Enteromorpha sp(p.)				50	58	57	20						
Cardamine amara					33			37					
Myosoton aquaticum						48	26						
Sagina procumbens		40	48	28		24	26	27		31			
Mimulus guttatus x luteus			48					20		27	32		
Myriophyllum spicatum				56	75	62	44				21		
Ranunculus fluitans			24	89	100	86	70	20					
Veronica beccabunga	76	85	48	61	92	71	78	93	66	65	29	47	
Lemna minor	62	30	20	33		24	22		66				38
Potamogeton crispus	48	60	80	83	75		41	23			21	32	33
Symphytum officinalis	24	65	29	33		81	52		33			32	20

Table 5 *contd*

RBSQ-B	B1i	B1ii	B1iii	B2i	B2ii	B3i	B3ii	B3iii	B3iv	B4i	B4ii	B4iii	B4iv
Callitriche stagnalis	76	80	62	39	50			53	66			58	24
Callitriche hamulata	67	30	29			29						36	52
Schistidium alpicola	24		48	39			26			21	50		29
Fontinalis squamosa	62		57	28	75							26	57
sponge	38	30	38	56	25						21	26	38
Myriophyllum alterniflorum	81	40	95	50							29	37	67
Iris pseudacorus	52	25	24		33						21	26	24
Elodea canadensis	62	75	86	100	92	52	67				54	21	76
Stachys palustris	71	45	24		50	48	20		33			37	24
Angelica sylvestris	43	45	57	33	58	20	30	47		38		63	24
Eleocharis palustris	33	20	76	89	75		37	20			43		43
Cladophora aegagropila	38		52	61	67		41				32		24
Equisetum arvense	76	95	90	83	83	71	81	70		65	36	53	
ferns	43	35	71	27				47		31			
filamentous green algae	90	75	86	78		29	37	43	33	31	50		57
Hildenbrandia rivularis	43	45	100	89	100	38	89	67		69	89	42	57
Caltha palustris	81	80	71	50	75	24	70	67		31	57	31	62
Sparganium erectum	100	95	95	100	92	95	70	80		31	50	89	86
Lemanea fluviatilis	52	20	76	89	92	33	63	37	66	65	86	47	71
Cladophora glomerata	62	90	95	100	100	95	100	83	33	83	100	74	76
other Verrucaria spp.	85	90	95	100	100	67	93	93	66	90	100	68	90
Amblystegium fluviatile	67	75	95	89	75	90	78	83	100	93	71	42	52
Amblystegium riparium	28	55	57	28	33	76	59	57	100	69	39	68	71
Brachythecium rutabulum	20	75	71	39	75	43	74	50	33	45	32	53	57
Fontinalis antipyretica	86	100	100	89	92	100	96	100	100	90	96	84	95
Rhynchostegium riparioides	90	85	95	100	100	90	96	97	100	100	96	79	100
Filipendula ulmaria	95	80	86	56	58	33	59	73	33	48	46	79	71
Mentha aquatica	95	95	100	89	100	90	85	97	100	79	89	95	86
Myosotis scorpioides	95	100	100	94	100	95	100	97	100	55	61	63	38
Solanum dulcamara	62	40	62	22	92	86	52	50	33	55	36	95	67
Salix spp	76	100	100	78	83	95	89	63	33	96	89	100	100
trees	67	90	100	67	83	90	85	93	100	100	82	100	100
Agrostis stolonifera	100	100	100	100	100	100	96	100	66	100	100	100	100
Glyceria fluitans	81	35	71	61	33	33	41	57	66	48	39	74	81
Juncus acutiflorus	86	85	86	89	67	67	63	47	66	59	75	63	81
Phalaris arundinacea	95	100	100	100	100	100	96	100	100	76	96	95	100

Table 5 *contd*

RBSQ-B	B1i	B1ii	B1iii	B2i	B2ii	B3i	B3ii	B3iii	B3iv	B4i	B4ii	B4iii	B4iv
Chiloscyphus polyanthos	33	25	71				30	37		65	32	79	71
Deschampia cespitosa	20	30	29			33	41	37		52	29	37	20
Juncus effusus	86	95	90	33		48	26	70	33	41	20	68	24
Callitriche platycarpa	24										21	42	24
Sparganium emersum	33											58	43
Carex hirta				33	33	29		20	66	24	32		
Tussilago farfara		65	48			29	41	43		27	20		
Brachythecium rivulare		45	43			43		67	33	41	32		
Petasites hybridus		60	62	50	58	76	78	73		65	57	21	
Ranunculus calcareus				78	33	43	44	47	33	27	50	21	
Vaucheria sessilis		25	71	56	67	95	81	73	33	76	61	89	90
Conocephalum conicum		55	81	33	67	86	78	70	33	90	71	89	90
Epilobium hirsutum		95	43	72	100	95	93	93	66	86	39	74	38
Oenanthe crocata		35	48	33	67	48	30	33	33	72	61	84	100
Lunularia cruciata		40	52			33	48	73		65		63	71
Scirpus sylvaticus		30	52	50	50	38			33			22	43
Rorippa sylvestris		30	57	100	67	62	89			21	46		43
Impatiens glandulifera		35	43	72	92	81	70		33	20	29	26	67
Marchantia polymorpha			29	22		24	41	57	33	52	50	47	43
Pella endiviifolia			29		42	67	81	57	33	86	46	74	71
Cinclidotus fontinaloides			81	78	92	57	78	60	33	45	75		57
Thammobryum alopecurum			29	28	50	20	30	27	33	55	46	21	24
Alisma plantago-aquatica			38	39	42	67	33					42	48
Lysimachia vulgaris			24	22	67		30				25		76
Ranunculus flammula			24										33
Scrophularia auriculata					33	67	48		33			42	24
Eupatorium cannibinum						24	26	27			25	74	81
Ranunculus penicillatus					75								81
Rorippa amphibia						50							
Ranunculus sceleratus						29							
Veronica anagallis-aquatica		45						27	100				
Glyceria plicata						43		33	33				
Juncus inflexus						43		37	33	20	29	21	
Apium nodiflorum						48		50	100	21		68	
Ranunculus vertumnus							30						
Batrachospermum sp(p.)									33				

Table 5 *contd*

RBSQ-B	B1i	B1ii	B1iii	B2i	B2ii	B3i	B3ii	B3iii	B3iv	B4i	B4ii	B4iii	B4iv
Veronica catenata									33				
Calliergon cuspidatum									33				
Lythrum salicaria						52						42	100
Lycopus europaeus						71						42	71
Equisetum palustre						24	22	23		38	57		62
Pellia epiphylla								33				53	
Callitriche obtusangula									33			21	
Carex remota										55		47	
Dichodotium pellucidum											24	25	
Lotus pedunculatus												21	
Potamogeton berchtoldii													33
algae	6	6	7	8	7	6	7	5	5	5	7	5	7
lichens	2	1	3	2	2	1	1	1	1	1	1	1	1
liverworts	1	3	5	2	2	4	5	6	3	5	4	6	5
mosses	7	6	10	9	8	8	8	8	9	10	9	7	9
vascular cryptogams	3	2	2	2	1	2	2	3	—	3	3	2	2
dicotyledons	24	30	34	26	28	35	29	27	22	19	22	27	26
monocotyledons	20	16	15	17	19	17	14	12	11	10	13	16	16
	63	64	76	66	67	73	66	62	51	53	59	64	66

Table 6. Numbers give % occurrence in each Community Type

RBSQ-C	C1i	C1ii	Ciii	C2i	C2ii	C2iii	C2iv	C2v	C3i	C3ii	C3iii	C3iv	C3v	C4i	C4ii	C4iii
Carex acuta	21															
Scirpus sylvaticus	21															
Collema fluviatile		21	50													
Epilobium hirsutum				21												
Cardamine amara	21		32													
Thamnobryum alopecurum	53	68	64	79	50	70	85	20	22	64						
Pellia endiviifolia	42	37	20	25	92	25								31		
Hildenbrandia rivularis	68	58	20	69											33	
Cladophora glomerata	79	68	20	36	42										22	
Cinclidotus fontinaloides	89	68	40	71	25	20	23				45			23	29	
Vaucheria sessilis	47		32	61	92	45	20	33		27	45	41		38		
Solenostoma triste	26		76		25		77	33	44							63
Dichodontium flavescens	63	37	56													29
Carex hirta	26	32												23	39	
Mimulus guttatus	84	58	40	21	33	30		33						62	56	
Lunularia cruciata		42	40	50	83	50					40	29				
Oenanthe crocata		47		100	92	70	81	33	33	91	75	76	33		33	
Eupatorium cannibinum				25	75	45										
Impatiens glandulifera					25	40										
Juncus inflexus					25											
Brachythecium rutabulum	32	58	44	32	33	35		33		27	20	29		46	44	
Equisetum palustre	53	21	24	32	58		20	33		55		24			39	25
Brachythecium plumosum	63	68	68	21			77	20	33	55					56	38
Brachythecium rivulare	89	68	88	54	25	30	54	20				24			78	50
Lemanea fluviatilis	100	74	80	71	75	70	77	83		100	40			92	72	50
Amblystegium fluviatile	95	95	84	82	33	60	42	100		36	65	47		92	83	54
Conocephalum conicum	68	95	80	86	100	90	58	50		54	30	29		46	44	21
Marchantia polymorpha	58	47	44	57	33	30	42	33		27	35			31	20	29
Hygrohypnum ochraceum	53	26	84	61	25	90	96	100	56	91	65	47		69	44	79
Equisetum arvense	63	74	72	21	33	35	46	83	22	27	45	71		69	94	54
Filipendula ulmaria	74	74	76	64	92	75	54	83	78	73	60	76		92	94	96
Phalaris arundinacea	74	86	52	82	92	85	88	100	100	100	100	88		100	83	54
filamentous green algae	95	58	100	57	25	75	88	83	56	100	65	65		92	100	88
Verrucaria spp.	100	95	92	100	100	100	92	100	44	91	90	76		92	94	75
Myriophyllum alterniflorum	37	26	20	61	42	40	38	67	89	100	95		44	85	100	88

Table 6 *contd*

RBSQ-C	C1i	C1ii	Ciii	C2i	C2ii	C2iii	C2iv	C2v	C3i	C3ii	C3iii	C3iv	C3v	C4i	C4ii	C4iii
Molinea caerulea	21															50
Didymosphenia geminata	42														39	38
Petasites hybridus	47	68	32											31	22	33
Bryum pseudotriquetrum	53	21	60				35	67	44	64				31	22	83
Calliergon cuspidatum	58		52					67	22					46	50	75
Dichodontium pellucidum	79	42	92				31	33		27					22	42
Tussilago farfara	68	68	76					33		27				31	94	71
Hygrohypnum luridum	42		52				23								56	38
Philonotis fontana	32		36					22							39	33
Schistidium alpicola	84	68	76	39		35	81	100	33	55		29		85	83	63
Sagina procumbens	58	84	92		25	25	42			36	25	29	44	46	72	54
Veronica beccabunga	53	42	52	25	33	25			22	20	35	53	22	31	61	29
Achillea ptarmica	37	32	32		20	20	46	83	89	73	35	47		69	72	88
Carex nigra	53		32				31	20	22	36				23	83	83
Eleocharis palustris	47	37		25		30		67	56	64	30			92	67	50
Chiloscyphus polyanthos	63	95	96	100	100	90	77	67	56	82	80	71	33	69	39	67
Fontinalis antipyretica	95	89	88	89	83	70	73	83	89	91	95	82	56	100	100	88
Rhynchostegium riparioides	100	95	100	96	83	100	92	100	67	100	100	82	56	92	100	83
Angelica sylvestris	32	37	52	29	67	50	42	50	89	55	45	65	33	77	72	63
Caltha palustris	100	58	64	71	50	25	77	50	100	81	55	53	22	77	94	88
Mentha aquatica	100	79	72	64	67	80	65	100	78	100	85	88	100	100	100	75
Myosotis scorpioides	58	58	72	36	33	60	38	83	100	64	55	71	56	100	94	96
Ranunculus flamula	21	21	72	46	50	55	81	67	78	82	50	71	100	54	83	92
Salix spp.	79	79	92	75	92	90	96	67	78	91	100	94	89	92	94	79
trees	74	84	100	89	100	100	88	83	67	100	80	94	100	69	70	79
Agrostis stolonifera	89	100	100	96	100	100	96	100	89	100	100	100	100	100	100	83
Juncus acutiflorus	79	84	92	79	67	85	81	83	100	100	95	88	100	100	100	100
Glyceria fluitans	37	42	52	57	83	70	54	83	100	82	100	100	100	100	94	96
Juncus effusus	42	53	80	64	42	65	77	83	100	100	85	88	100	69	94	88
Deschampsia cespitosa	53	58	64		42	50	42	50	78	27	20	59	89	46	56	67
Pellia epiphylla		42	76	57	92	90	88	67	67	82	55	82	78	23	28	88
ferns		74	80	21	50	95	69		22	64	55	76	100	31	56	46
Gallitriche stagnalis		37	20		33	65	42		44	20	85	65	100	77	39	46
Gaiium palustre		21	36	29		40	46		56	73	80	65	67	38	78	50
Fontinalis squamosa		42	64	82	50	95	96	100	44	100	90	41		69	44	46

Table 6 *contd*

RBSQ-C	C1i	C1ii	Ciii	C2i	C2ii	C2iii	C2iv	C2v	C3i	C3ii	C3iii	C3iv	C3v	C4i	C4ii	C4iii
Dermatocarpon fluviatile			40	43		55	77	67	33	100	30			46		25
Scapania undulata			84	25	25	60	96	83	22	82	50	41	22	23		67
Callitriche hamulata			44		75	65	69	33	67	82	80	65	78	77	28	63
Racomitrium aciculare			52	25		50	88	20	44	73	25	24		23		58
Montia fontana			48				20	33		64	20	41	33		56	54
Lotus pedunculatus			40			25				27	20	47	78		67	42
Littorella uniflora							20	33	33	45				38		38
Stellaria alsine			20		33	35	31	20			30	88	22		56	42
Senecio aquaticus			20			35				27	40	59	67	23	67	21
Anthroxanthum oderatum			44				23				20				33	54
Viola palustris			32				23			27			33			33
Montia sibirica		26	24		25									23		
Rorippa sylvestris		32												62		
Hyocomium armoricum			24		42	25	54		22	36						
Ranunculus penicillatus				36	42	30	27		22	20	55					
Cladophora aegagropila				25										23		
Amblystegium riparium					75						35	29		31		
Apium nodiflorum				29		20						29	67			
Callitriche platycarpa					25	30			33	33	35					
Lycopus europaeus				21									33			
Solanum dulcamara		26		43	67	55					40	35				
Carex remota		58	56	50	58	35	38						56		33	
Alopecurus geniculatus		21	20		25						50	53		23	61	
Alisma plantago-aquatica					25				22	45		24	67			
Sparganium emersum					67	35			100	20	50		33			
Elodea canadensis				29					33		35			31		
Iris pseudocorus				29		30			44	73	45	35			33	
Lemna minor					33						20					
Scrophularia auriculata					25								22			
Lythrum salicaria					33				22				22			
Apium inundatum									22	27			22			
Ranunculus fluitans								50						23		
Rorippa nasturtium-aquaticum						25					20	35	22	31	50	
Stachys palustris						40	35		33	45	50	24	33	38	28	
Mimulus guttatus x luteus							23	33		20	20			23	61	25

Table 6 *contd*

RBSQ-C	C1i	C1ii	Ciii	C2i	C2ii	C2iii	C2iv	C2v	C3i	C3ii	C3iii	C3iv	C3v	C4i	C4ii	C4iii
Juncus bulbosus			20				23		33	45	25	29	67	38	33	75
Sparganium erectum				36	50	50			56	82	80	65	56	54	78	33
Carex aquatilis								50	100		20			31	22	21
Carex rostrata									78	45	20			46	61	67
Potamogeton natans									78	45	20			46	61	67
Equisetum fluviatile									89	27	40	35		38	44	42
Potentilla erecta									33		20		22		28	33
Schistidium agassizii								33	22							
Galium boreale								33	33							
Menyanthes trifoliata									33							
Potentilla palustris									33							
Scirpus fluitans									22							
Scirpus lacustris									22							
Lysimachia vulgaris									22	36						
Nuphar lutea									44				22			
Nitella opaca									33							25
Ranunculus hederaceus												35				
Sphagnum sp(p.)													22			
Polytrichum commune													22			
Callitriche obtusangula													67			
Hydrocotyle vulgaris													33			
Juncus articulatus													33			
Ranunculus omiophyllus											35	41	78			
Ranunculus peltatus										20	20			31		
Polygonum amphibium														31		
Glyceria maxima														31		
Ranunculus aquatilis													22		22	
Carex acutiformis															28	
Potamogeton polygonifolius													56			25
Carex ovalis															33	21
Lupinus nootkatensis																21
sponge																29
Carex demissa																38
Nardus stricta																50

Table 6 *contd*

RBSQ-C	C1i	C1ii	Ciii	C2i	C2ii	C2iii	C2iv	C2v	C3i	C3ii	C3iii	C3iv	C3v	C4i	C4ii	C4iii
algae	6	4	5	6	4	3	3	3	2	3	3	2	—	4	5	5
lichens	1	2	3	2	1	2	2	2	2	2	2	1	—	2	1	2
liverworts	5	6	8	7	8	7	6	6	4	5	6	5	3	6	4	6
mosses	15	14	19	11	11	12	15	15	13	14	8	10	4	6	4	15
vascular cryptogams	2	3	3	3	3	2	3	2	3	4	3	4	1	3	4	4
dicotyledons	16	21	25	19	24	28	22	21	27	28	30	25	32	28	28	26
monocotyledons	12	10	11	10	14	11	10	9	20	15	19	11	13	16	19	19
	57	60	74	58	65	65	61	58	71	71	71	58	53	69	76	77

Table 7. Numbers give % occurrence in each Community Type

RBSQ-D	D1i	D1ii	D2i	D3i	D3ii	D4i
Marchantia polymorpha	44					
Amblystegium fluviatile	32					
Mimulus cupreus hybrids	20					
Veronica beccabunga	32					
Carex ovalis	48	25				
Hygrohypnum luridum	76	25	80			
Didymosphenia geminata	64		60			
Conocephalum conicum	24		33			
Alopecurus geniculatus		50				
Sparganium erectum		33				
Thamnobryum alopecurum		25	47			
Brachythecium rivulare	56	75	93	23		
Caltha palustris	92	83	20	42		69
Filipendula ulmaria	84	50	33	27		63
Carex flacca	24					21
Littorella uniflora	20	33				53
Senecio aquaticus	32	25				27
Callitriche bamulata	52	67			35	74
Myriophyllum alterniflorum	68	67			31	84
Montia fontana	64	75	40			42
Stellaria alsine	40	50	20			37
Tussilaga farfara	80	58	53			21
Sagina procumbens	84	67	67			21
Schistidium agassizii	40	25	33			21
Calliergon cuspidatum	92	42	53			47
Dichodontium flavescens	64	33	87			26
Dichodontium pellucidum	76	75	87			47
Dicranella palustris	40	25	47			42
Equisetum arvense	55	42		27		21
Angelica sylvestris	44	58		27		21
Mentha aquatica	56	33		27		47
Myosotis scorpioides	60	67		23	20	63
Carex panicea	36				35	42
Carex rostrata	60				23	89
Equisetum fluviatile		50				79
Equisetum palustre		25				32
Oenanthe crocata		33				21
Veronica scutellata		25				27
Phalaris arundinacea		58				37
Sparganium emersum		25				21
Chiloscyphus polyanthos	52	75	67	38		21
ferns	40	67	87	54		68
lemanea fluviatilis	52	50	60	35	27	21
filamentous green algae	100	100	100	92	96	89
Verrucaria sp(p.)	80	67	53	58	20	21
Marsupella emarginata	24	58	67	81	88	21
Nardia compressa	24	33	27	42	73	26
Pellia epiphylla	96	100	80	100	100	100
Scapania undulata	92	100	87	100	96	84
Solenostoma triste	100	100	87	62	92	37
Brachythecium plumosum	84	92	93	69	58	58
Bryum pseudotriquetrum	92	67	87	73	65	95
Fontinalis antipyretica	100	58	80	46	35	37
Fontinalis squamosa	48	58	47	58	46	42
Hygrohypnum ochraceum	96	92	93	85	54	47
Hyocomium armoricum	64	75	80	92	88	68
Philonotis fontana	80	25	73	23	20	37
Polytrichum commune	20	50	53	100	85	63

Table 7. *contd*

RBSQ-D	D1i	D1ii	D2i	D3i	D3ii	D4i
Racomitrium aciculare	84	100	100	88	85	74
Rhynchostegium riparioides	80	83	67	50	20	26
Schistidium alpicola	92	75	73	23	42	37
Achillea ptarmica	96	75	60	31	20	84
Callitriche stagnalis	52	33	20	23	20	37
Galium palustre	60	67	33	42	46	74
Lotus uliginosum	60	50	40	50	54	63
Potentilla erecta	60	67	60	50	65	63
Ranunculus flammula	100	83	40	62	77	89
Viola palustris	44	42	20	50	65	74
Salix sp(p.)	84	83	53	92	42	63
tree genera	72	67	27	88	62	47
Agrostis stolonifera	100	100	47	92	42	68
Anthroxanthum oderatum	96	100	73	92	81	84
Carex demissa	44	33	53	27	58	32
Carex nigra	96	50	53	50	69	95
Deschampsia cespitosa	68	75	67	69	46	84
Juncus acutiflorus	100	92	73	81	85	100
Juncus bulbosus	96	75	67	58	88	100
Juncus effusus	88	92	67	96	85	95
Molinea caerulea	56	42	27	35	69	68
Nardus stricta	68	33	60	23	85	74
Blindia acuta	54		60		31	26
Glyceria fluitans	84	100		69	46	95
Potamogeton polygonifolius	24				62	63
Carex echinata	20		27	35	65	63
Sphagnum sp(p.)		33	33	42	96	89
Carex binervis			33			
Carex pulicaris			20			
Dermatocarpon fluviatile		50	20	27		21
Juncus articulatus					27	
Juncus squarrosus			20		42	21
Ranunculus omiophyllus		25			31	32
Carex curt					23	32
Batrachospermum sp(p.)					35	21
Narthecium ossifragum					31	21
Hydrocotyle vulgaris						26
Myrica gale						32
Nuphar lutea						21
Eleocharis palustris						68
Iris pseudacorus						21
Potamogeton natans						32
Sparganium augustifolium						21

RBSQ-D	D1i	D1ii	D2i	D3i	D3ii	D4i	D
algae	3	2	3	2	3	3	4
lichens	2	2	2	2	1	2	2
liverworts	8	6	7	6	5	6	8
mosses	21	20	21	13	13	18	22
vascular crytogams	2	4	1	2	1	4	4
dicotyledons	24	25	15	14	13	28	30
monocotyledons	17	15	14	12	19	25	31
	77	74	63	51	55	86	101

Table 9. Classification

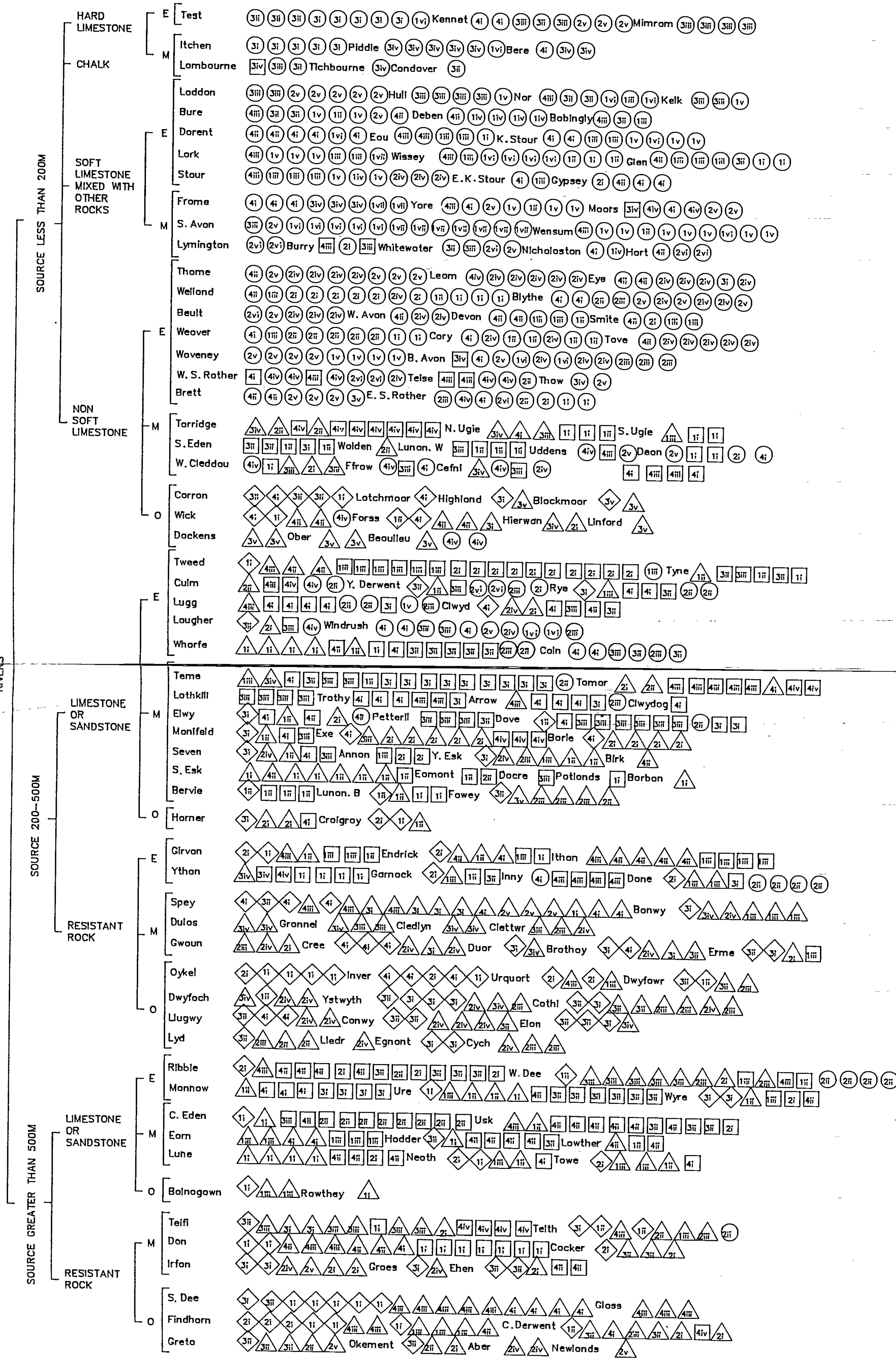


Table 8. Component taxa in the four major groups of plant communities (RBSQ)

	A		B		C		D	
	No.	%	No.	%	No.	%	No.	%
Algae	6	5	9	8	9	6	4	4
Lichens	1	1	3	3	3	2	2	2
Liverworts	6	5	6	5	8	6	8	8
Mosses	6	5	12	10	23	16	22	22
Vascular cryptogams	5	4	4	3	4	3	4	4
Dicotyledons	58	44	54	45	57	40	30	30
Monocotyledons	49	37	32	27	37	26	31	31
Total	131		120		141		101	

Note: This Table is based on the reduced species list which is duplicated in the Appendix. As there have been more bryophytes than vascular plants removed the differences between Groups A/B and C/D is less evident here than it is using the full species complement.

SURVEY CARD

BATRACHO
HILDENBR
LEMANEA
VAUCHERI
DIDYMOSP
SPONGE
ENTEROMO
CLAD AEG
CLAD GLO
FIL GREE
CHARA VU
NITELLA F
NITELLA O
COLL FLUV
DERM FLUV
VERR SPP
CHIL POLY
CONO CONI
LUNU CRUC
MARC POLY
MARS EMAR
NARD COMP
PELL ENDI
PELL EPIP
SCAP UNDU
SOLE TRIS
AMBL FLUV
AMBL RIPA
BLIN ACUT
BRAC PLUM
BRAC RIVU
BRAC RUTA
BRYU PSEU
CALL CUSP
CINC FONT
DICH FLAV
DICH PELL
DICR PALU
FONT ANTI
FONT SQUA
HYGR LURI
HYGR OCHR
HYOC ARMC
PHIL FONT
POLY COMM
RACO ACIC
RHYN RIPA
SCHI AGAS
SCHI ALPI
SPHAGNUM
THAM ALOP
AZOL FILI
EQUI ARVE
EQUI FLUV
EQUI PALU
FERNS
ACHI PTAR
ANGE SYLV

APIU INUN
APIU NODI
BERU EREC
BIDE CERN
BIDE TRIP
CALL HAMU
CALL HERM
CALL OBTU
CALL PLAT
CALL STAG
CALT PALU
CARD AMAR
CERA DEME
DIPS FULL
EPIL HIRS
EUPA CANN
FILI ULMA
GALI PALU
GALI BORE
HIPP VULG
HYDR VULG
IMPA CAPE
IMPA GLAN
LITT UNIF
LOTU ULIG
LUPI NOOT
LYCO EURO
LYSI VULG
LYTH SALI
MENT AQUA
MENY TRIF
MIMU GUTT
MIMU GULU
MIMU CUPR
MONT FONT
MONT SIBI
MYRI GALE
MYOS SCOR
MYOS AQUA
MYRI ALTI
MYRI SPIC
NUPH LUTE
NYMP ALBA
OENA CROC
OENA FLUV
PETA HYBR
POLY AMPH
POTE EREC
POTE PALU
PULI DYSE
RANU AQUA
RANU CALC
RANU CIRC
RANU FLAM
RANU FLUI
RANU HEDE
RANU OMIO
RANU PELT

RANU PENI
RANU TRIC
RANU SCEL
RANU VERT
RORI AMPH
RORI NAST
RORI PALU
RORI SYLV
RUME HYDR
SAGI PROC
SCRO AURI
SCUT GALE
SENE AQUA
SOLA DULC
STAC PALU
STEL ALSI
SYMP OFFI
TUSS FARF
VERO ANAG
VERO BECC
VERO CATE
VERO SCUT
VIOL PALU
SALIX
TREES
dicots

ACOR CALA
AGRO STOL
ALIS LANC
ALIS PLAN
ALOP GENI
ANTH ODER
BUTO UMBE
CAR ACUTA
CAR ACUTI
CARE AQUA
CARE BINE
CARE CURT
CARE DEMI
CARE DIST
CARE ECHI
CARE ELAT
CARE FLAC
CARE HIRT
CARE OTRU
CARE OVAL
CARE LEPI
CARE NIGR
C. PANICE
C. PANICU
CARE PEND
CARE PULI
CARE REMO
CARE RIPA
CARE ROST
CARE VESI
CATA AQUA

CROC CROC
DESC CESP
ELEO PALU
ELOD CANA
ELOD NUTT
GLYC DECL
GLYC FLUI
GLYC MAXI
GLYC PLIC
GROE DENS
IRIS PSEU
JUNC ACUT
JUNC ARTI
JUNC BULB
JUNC EFFU
JUNC INFL
JUNC SQUA
LEMN GIBB
LEMN MINO
LEMN POLY
LEMN TRIS
MOLI CAER
NARD STRI
NART OSSI
PHAL ARUN
PHRAG AUS
POTA ALPI
POTA BERC
POTA CRIS
POTA FREI
POTA GRAM
POTA LUCE
POTA NATA
POTA NODO
POT OLIV
POTA PECT
POTA PERF
POTA POLY
POTA PRAE
POTA PUSI
POTX SALI
SAGI SAGI
SCIR FLUI
SCIR LACU
SCIR MARI
SCIR SYLV
SPAR ANGU
SPAR EMER
SPAR EREC
TYPH LATI
ZANN PALU
monocots

Key to RIVER TYPES based on 223 Selected River and Bank Species and 624 pseudospecies (RBSQ)

For a worked example see p 175

Start here, summing minuses and pluses according to presence or absence

A Epilobium hirsutum −, Solanum dulcamara −, Cladophora glomerata −, Hygrohypnum ochraceum +, Pellia epiphylla +, Ranunculus flammula +, Scapania undulata +

If Score −1 or less proceed to **B**
If Score 0 or more proceed to **C**

then continue working throughout in the same way until you obtain the group

B Glyceria maxima −, Verrucaria spp +, Hildenbrandia rivularis +, Amblystegium fluviatile +, Rhynchostegium riparioides +, Lemanea fluviatile +, Conocephalum conicum +

Score 2 or less **D**
Score 3 or more **E**

C Phalaris arundinacea −, Anthroxanthum oderatum +, Polytrichum commune +, Hyocomium armoricum +, Juncus bulbosus +, Marsupella emerginata +, Racomitrium aciculare (2) +

Score 2 or less **F**
Score 3 or more **G**

D Potamogeton pectinatus −, Enteromorpha spp −, Nuphar lutea −

Score −1 or less **H**
Score 0 or more **I**

E Mimulus guttatus −, Potamogeton crispus −, Polygonum amphibium −, Elodea canadensis (2) −, Alopecurus geniculatus −, Myriophyllum alterniflorum −, Pellia endiviifolia +

Score −3 or less **J**
Score −2 or more **K**

F Thamnobryum alopecurum −, Conocephalum conicum −, Rhynchostegium riparioides (3) −, Glyceria fluitans (2) +, Myriophyllum alterniflorum (2) +, Equisetum fluviatile +, Juncus acutiflorus(2) +

Score 0 or less **L**
Score 1 or more **M**

G Brachythecium rivulare −, Sagina procumbens −, Dichodontium pellucidum −, Hygrohypnum luridum −, Schistidium alpicola (2) −, Sphagnum spp +

Score −2 or less **N**
Score −1 or more **O**

Note: start the sections that follow these at the (A) subsection (see example on p. 175).

H Zannichellia palustris −, Enteromorpha spp (2) −, Sparganium erectum (3) +, Rorippa palustris +, Juncus effusus +, Rorippa amphibia (2) +, trees (2) +

Score 0 or less	LOWLAND ENGLAND—RIVERS WITH SANDS & GRAVELS	**A1**
Score 1 or more	LOWLAND ENGLAND—RIVERS DOMINATED BY CLAY	**A2**

I Carex acutiformis (2) −, Berula erecta −, Ranunculus calcareus −

Score −2 or less	ALL LOWLAND ENGLISH RIVERS DOMINATED BY CHALK	**A3**
Score −1 or more	LOWLAND ENGLAND—RIVERS WITH IMPOVERISHED DITCH FLORA	**A4**

J Juncus effusus −, Myriophyllum alterniflorum (2) −, Ranunculus fluitans +, Myriophyllum spicatum +, Impatiens glandulifera +, Rorippa sylvestris +, Enteromorpha spp +

Score 1 or less	NEUTRAL, MESO-EUTROPHIC LOWLAND RIVERS OF N-E SCOTLAND	**B1**
Score 2 or more	BASIC, ENTRICHED LOWLAND RIVERS OF N ENGLAND	**B2**

K Epilobium hirsutum (2) −, Ranunculus fluitans −, Rorippa nasturtium-aquaticum −, Myosotis scorpioides (−), Lemanea fluviatilis 2(+), Oenanthe crocata (2) +

Score −2 or less	LOWLAND RIVERS ON SANDSTONE OR LIMESTONE	**B3**
Score −1 or more	WESTERN & UPLAND RIVERS ON SANDSTONE OR LIMESTONE	**B4**

L Dichodontium pellucidum −, Tussilago farfara −, Sagina procumbens −, Oenanthe crocata +, Fontinalis squamosa (3) +

Score −1 or less	BASIC, MESOTROPHIC UPLAND RIVERS	**C1**
Score 0 or more	NEUTRAL, OCEANIC WESTERN RIVERS	**C2**

M Oenanthe crocata −, Tussilago farfara +, Carex nigra +, Calliergon cuspidatum 2, Schistidium alpicola +, Myosotis scorpioides (2) +

Score 1 or less	OLIGO-MESOTROPHIC UPLAND RIVERS IN ENGLAND AND WALES	**C3**
Score 2 or more	OLIGO-MESOTROPHIC UPLAND RIVERS IN SCOTLAND	**C4**

N Glyceria fluitans −, Agrostis stolonifera (2) −, Myriophyllum alterniflorum −, Ranunculus flammula −

Score −2 or less	UNSTABLE RIVERS IN MOUNTAINS	**D1**
Score −1 or more	STABLE MOUNTAIN RIVERS	**D2**

O Scapania undulata (3) −, Carex rostrata +, Equisetum fluviatile +, Eleocharis palustris +, Myriophyllum alterniflorum +, Achillea ptarmica +, Juncus acutiflorus (3) +

Score 3 or less	EXTREME MOUNTAINOUS RIVERS WITH LIVERWORTS	**D3**
Score 4 or more	STABLE MOUNTAIN RIVERS WITH HIGHER PLANTS	**D4**

Key to LOWLAND ENGLAND RIVER TYPES (A1–4) based on 223 Selected River and Bank species and 624 pseudospecies (RBSQ)

A1a Enteromorpha spp (2) −, Eupatorium cannabinum (1) +, Scirpus lacustris (1) +, Fontinalis antipyretica (1) +, Sparganium emersum (2) +, Carex acutiformis (1) +, Lycopus europeaus (1) +

- Score 1 or less — **(A1b)**
- Score 2 or more — **(A1c)**

A1b Ceratophyllum demersum (2) −, Epilobium hirsutum (2) +, Solanum dulcamara (1) +, Veronica beccabunga (1) +

- Score 0 or less — **GROUPA1i**
- Score 1 or more — **(A1d)**

A1c Enteromorpha spp (1) −, Nuphar lutea (2) −, Carex riparia (1) −, Symphytum officinalis (1) +, Myriophyllum spicatum (1) +, Fontinalis antipyretica (1) +

- Score 0 or less — **(A1e)**
- Score 1 or more — **(A1f)**

A1d Sagittaria sagittifolia (1) −, Nuphar lutea (2) −, Glyceria maxima (1) 1, Elodea nuttallii (1) 1, Butomus umbellatus 1(−)

- Score −4 or less — **GROUPA1ii**
- Score −3 or more — **GROUPA1iii**

A1e Lemna minor (2) 1−, Petasites hybridus (1) −

- Score −2 — **GROUPA1iv**
- Score −1 or more — **GROUPA1v**

A1f Stachys palustris (1) +, Potamogeton lucens (1) +, Solanum dulcamara (2) +

- Score 1 or less — **GROUPA1vi**
- Score 2 or more — **GROUPA1vii**

A2a Nuphar lutea (2) +, Callitriche stagnalis (1) +, Scrophularia auriculata (1) +

- Score 1 or less — **(A2b)**
- Score 2 or more — **(A2c)**

A2b Glyceria maxima (1) −, Rorippa nasturtum-aquaticum (1) −, Lemna minor (1) −, filamentous green algae (1) −, Lycopus europaeus (1) + Impatiens glandulifera (1) +

- Score −2 or less — **GROUPA2i**
- Score −1 or more — **(A2d)**

A2c Carex riparia (1) −, Polygonum amphibium (1) −, Scirpus lacustris (1) −, Juncus inflexus (1) −, Conocephalum conicum (1) +

- Score −1 or less — **(A2e)**
- Score 0 or more — **GROUPA2vi**

A2d Impatiens glandulifera (1) −, Rhynchostegium riparioides (1) +, Scirpus lacustris (1) +, Symphytum officinalis (1) +, trees (2) +, Conocephalum conicum (1) +, Lycopus europaeus (1) +

Score 2 or less — **GROUPA2ii**
Score 3 or more — **GROUPA2iii**

A2e Myosoton aquaticum (1) −, Butomus umbellatus (1) −, Lemna minor (1) −, Galium palustre (1) −, Eupatorium cannibinum (1) +, trees (2) +, Callitriche stagnalis 2(+)

Score 0 or less — **GROUPA2iv**
Score 1 or more — **GROUPA2v**

A3a Rumex hydrolapathum (1) −, Zannichellia palustris (1) −, Impatiens capensis (1) −, Pulicaris dysenterica (1) −

Score −2 or less — **(A3b)**
Score −1 or more — **(A3c)**

A3b Impatiens capensis (1) −, Stachys palustris (1) −, Mimulus guttatus (1) −, Symphytum officinalis (1) −, Lemna trisulca (1) −

Score −3 or less — **GROUPA3i**
Score −2 or more — **GROUPA3ii**

A3c Callitriche platycarpa (1) −, Myosotis scorpioides (2) −, Brachythecium rutabulum (1) −, Oenanthe crocata (1) +, Catabrosa aquatica (1) +

Score −1 or less — **GROUPA3iii**
Score 0 or more — **GROUPA3iv**

A4a Juncus inflexus (1) −, Cladophora glomerata (2) −, Epilobium hirsutum (2) −, Sparganium emersum 1(+), Oenanthe crocata (1) +, ferns (1) +

Score 0 or less — **(A4b)**
Score 1 or more — **GROUPA4iv**

A4b Iris pseudacorus 1 (−), Glyceria fluitans (1) −, Oenanthe Crocata (1) −, Fontinalis antipyretica (1) −, Ranunculus calcareus (2) −, Pellia endiviifolia (2) +, filamentous green algae (1) +

Score −1 or less — **GROUPA4i**
Score 0 or more — **(A4c)**

A4c Sparganium erectum (2) −, Pellia endiviifolia (2) −, Rorippa nasturtium-aquaticum (3) +, Eupatorium cannibinum (1) +, Pulicaria dysenterica (1) +, Lemna minor (1) +, Filipendula ulmaria (2) +

Score 0 or less — **GROUPA4ii**
Score 1 or more — **GROUPA4iii**

Key to SANDSTONE, MUDSTONE, HARD LIMESTONE AND BASIC RESISTANT ROCK RIVER TYPES (B1–4) based on 223 selected River and Bank species and 624 pseudospecies (RBSQ)

B1a	Salix spp (2) +, Petasites hybridus (1) +, Epilobium hirsutum (1) +		
		Score 0	**GROUPB1i**
		Score 1 or more	**(B1b)**
B1b	Epilobium hirsutum (2) −, Mimulus guttatus (2) −, Eleocharis palustris (1) +, Cinclidotus fontinaloides (1) +, Myriophyllum alterniflorum (1) +, Lemanea fluviatilis (1) +		
		Score 1 or less	**GROUPB1ii**
		Score 2 or more	**GROUPB1iii**
B2a	Filamentous green algae (1) −, Eleocharis palustris (2) −, Ranunculus calcareus (3) −, R. penicullatus (1) +		
		Score −1 or less	**GROUPB2i**
		Score 0 or more	**GROUPB2ii**
B3a	Impatiens glanduliferea (1) −, Rorippa sylvestris (1) −, Ranunculus fluitans (1) −, Symphytum officinalis (1) −, Myriophyllum spicatum (1) −		
		Score −2 or less	**(B3b)**
		Score −1 or more	**(B3c)**
B3b	Lycopus europaeus (1) −, Sparganium erectum (2) −, Rorippa palustris (1) −, Hildenbrandia rivularis (3) +		
		Score −2 or less	**GROUPB3i**
		Score −1 or more	**GROUPB3ii**
B3c	Phalaris arundinacea (2) −, Veronica anagallis-aquatica (2) +		
		Score 0 or less	**GROUPB3iii**
		Score 1	**GROUPB3iv**
B4a	Petasites hybridus (1) −, Rhynchostegium riparioides (3) −, Lythrum salicaria (1) +, Eupatorium cannibinum (1) +, Sparganium erectum (2) +, Ranunculus penicillatus (1) +, Oenanthe crocata (2) +		
		Score 1 or less	**(B4b)**
		Score 2 or more	**(B4c)**
B4b	trees (3) −, Conocephalum conicum (2) −, Pellia endiviifolia (2) −, Phalaris arundinacea (3) +, Cinclidotus fontinaloides (2) +		
		Score −1 or less	**GROUPB4i**
		Score 0 or more	**GROUPB4ii**

B4c Apium nodiflorum (1) −, Ranunculus penicillatus (1) +, Lysimachia vulgaris (1) +, filamentous green algae (1) +, Cinclidotus fontinaloides (1) +, Lythrum salicaria (1) +, Elodea canadensis (1) +

Score 2 or less	**GROUPB4iii**
Score 3 or more	**GROUPB4iv**

Key to RIVER TYPES (C1–4) flowing on SILURIAN, ORDIVICIAN, ACID SAND OR RESISTANT ROCK based on 223 River and Bank species and 624 pseudospecies (RBSQ)

C1a Cladophora glomerata (1) −, Hildenbrandia rivularis (1) −, Scapania undulata (1) +, Solenostoma triste (1) +, Hygrohypnum ochraceum (2) +, Ranunculus flammula (1) +

Score 1 or less	**(C1b)**
Score 2 or more	**GROUPC1iii**

C1b Calliergon cuspidatum (1) −, Cinclidotus fontinaloides (3) −, ferns (1) +, trees (3) +, Chiloscyphus polyanthos (2) +, Conocephalum conicum (2) +, Carex remota (1) +

Score 1 or less	**GROUPC1i**
Score 2 or more	**GROUPC1ii**

C2a Solanum dulcamara (1) −, Lunularia cruciata (1) −, Hygrohypnum ochraceum (2) +, Scapania undulata (1) +, Schistidium alpicola (1) +, Solenostoma triste (1) +

Score 2 or less	**(C2b)**
Score 3 or more	**(C2c)**

C2b Hildenbrandia rivularis (1) −, Cinclidotus fontinaloides (1) −, ferns (1) +, Conocephalum conicum (2) +, Callitriche hamulata (1) +, Sparganium emersum (1) +, Pellia epiphylla (1) +

Score 1 or less	**GROUPC2i**
Score 2 or more	**C2d**

C2c Racomitrium aciculare (1) −, ferns (1) −, Thamnobryum alopecurum (1) −, Calliergon cuspidatum (1) +

Score −2 or less	**GROUPC2iv**
Score −1 or more	**GROUPC2v**

C2d Pellia endiviifolia (1) −, Amblystegium riparium (1) −, Conocephalum conicum (3) −, Lunularia cruciata (2) −, Equisetum palustris (1) −, Hygrohypnum ochraceum (1) +

Score −2 or less	**GROUPC2ii**
Score −1 or more	**GROUPC2iii**

C3a Myriophyllum allerniflorum (1) −, Phalaris arundinacea (3) −, Fontinalis squamosa (1) −, Lemanea fluviatilis (1) −, ferns (2) +, trees (3) +, Stellaria alsine (1) +

Score −1 or less — **(C3b)**
Score 0 or more — **(C3c)**

C3b Carex aquatilis (2) −, Fontinalis squamosa (2) +

Score −1 — **GROUPC3i**
Score 0 or more — **(C3d)**

C3c Phalaris arundinacea (1) −, Verrucaria spp (1) −, Filipendula ulmaria (1) −, Callitriche stagnalis (2) +

Score −1 or less — **GROUPC3iv**
Score 0 or more — **GROUPC3v**

C3d Dermatocarpon fluviatilis (1) −, Bryum pseudotriquetrum (1) −, Pellia epiphylla (2) −, Callitriche stagnalis (1) +

Score −1 or less — **GROUPC3ii**
Score 0 or more — **GROUPC3iii**

C4a Phalaris arundinacea (2) −, Salix spp (2) −, Pellia epiphylla (1) +, Bryum pseudotriquetrum (1) +, Scapania undulata (1) +

Score 0 or less — **(C4b)**
Score 1 or more — **GROUPC4iii**

C4b Phalaris arundinacea (3) −, Equisetum arvense (2) +, Tussilago farfara (2) +, Hygrohypnum luridum (1) +, Juncus acutiflorus (3) +, Stellaria alsine (1) +, Brachythecium rivulare (1) +

Score 0 or less — **GROUPC4i**
Score 1 or more — **GROUPC4ii**

Key to OLIGOTROPHIC, MOUNTAIN AND UPLAND RIVER TYPES (D1–4) based on 223 River and Bank species and 624 pseudospecies

D1a Calliergon cuspidatum (2) −, Didymosphenia geminata (1) −, filamentous green algae (3) −, Philonotis fontana (1) −, Phalaris arundinacea (1) +

Score −2 or less — **GROUPD1i**
Score −1 or more — **GROUPD1ii**

D3a Salix spp (2) −, Agrostis stolonifera (1) −, Nardus stricta (1) +, Potamogeton polygonifolius (1) +, Sphagnum spp (1) +

Score 0 or less — **GROUPD3i**
Score 1 or more — **GROUPD3ii**

Note: **D2** and **D4** have only single groups represented and are thus keyed to an end group in the initial key.

A WORKED EXAMPLE OF HOW TO USE THE MACROPHYTE RIVER TYPING KEY

1. Survey the length of river for macrophytes, recording the presence or absence of plants given in the checklist. Record separately those plants found growing in the water ('river' records) from those found at the base of the bank near the medium-flow water mark ('bank' records).

2. Assess the abundance of the species present using the following:
   1 =<0.1% cover in the channel (river) or at its wetted margins (bank)

   2=0.1−5.0% cover as river or bank spp.

   3=>5% cover as river or bank spp.

3. With the completed list of taxa recorded from the site, work through the key from the beginning using all the 'indicators species' recorded to arrive at a score which will determine the next step in the key to which you should proceed. This is easily achieved by a single negative or positive score which is derived from the sum of the negative and positive scores attributed to the 'indicator species' present in the survey length.

4. The following is a shortened list of plants recorded from a 500 m length of river in central England showing the abundance scores assigned for each of them within the 'river' and on the 'bank'.

Species name	'river'	'bank'
	abundance	
Cladophora glomerata	2	
Enteromorpha sp(p).	3	
Vaucheria sp(p).	1	
Rhynchostegium ripariodes	1	1
Fontinalis antipyretica	1	
Apium nodiflorum	2	1
Callitriche stagnalis	1	
Epilobium hirsutum		3
Filipendula ulmaria		1
Mentha aquatica		1
Myosoton aquaticum		1
Myriphyllum spicatum	1	
Nuphar lutea	3	
Ranunculus calcareus	2	
trees		2
Butomus umbellatus	2	
Carex acuta		1
Lemna minor	2	
Glyceria maxima	1	3
Juncus effusus		1
Phalaris arundinacea	1	2
Potamogeton pectinatus	3	
Potamogeton lucens	1	
Scirpus lacustris	1	
Sparganium erectum	3	1
Zannichellia palustris	1	

5. Using the above list in conjunction with the KEY the site is classified into Community **A2iv—Central England Clay Rivers**, in the following sequence:

   A Epilobium [−], Cladophora [−] gives a total score of −2. A score of −1 or less means proceed to B.

   B Glyceria [−], Rynchostegium [+] gives a score of 0. A score of 2 or less means proceed to D.

   D Potamogeton pectinatus [−], Enteromorpha [−], Nuphar lutea [−] gives a score of −3. A score of −1 or less means proceed to H.

H Zannichellia [–], Enteromorpha (abundance 2 or more) [–], Sparganium (abundance 3) [+], Juncus [+], trees (abundance 2 or more) [+] gives a score of 1 which assigns community into sub-group **A2—Lowland England; Rivers Dominated by Clay**. Proceed through key to A2a

A2a Nuphar lutea (abundance 2 or more) [+], Callitriche [+] scores 2. A score of 2 or more means proceed to A2c.

A2c Scirpus [–] gives score of – 1. A score of – 1 or less means move to A2e.

A2e Myosoton [–], Butomus [–], Lemna [–], trees (abundance 2 or more) [+] gives total of – 2. NOTE Callitriche is not used in the classification since inclusion requires recording at a minimum of abundance 2. A score 0 or less assigns the community to its endgroup **A2iv**.

In the above keying of the recorded assemblage, 10 of the species recorded were not used in the key. However had the community been different, these might have been used in a different part of the key.

NOTE. The figure in parenthesis following the name of the plant taxon in the key indicates the minimum abundance level it must be recorded in either the river or on the bank to be included in the classificatory process. Thus (1) or nothing indicates that a simple record of presence is adequate for it to be used in that step of the classification. However if the taxon is followed by a (2), only records at abundance 2 or 3 will feature for that taxon in the keying process.

Notes

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