Freshwater Macroalgae of Britain and Ireland with an introduction to their use in ecological assessment (RAPPER: Rapid Assessment of Periphyton Ecology in Rivers)

Martyn Kelly, Lydia King, Chris Carter, Jan Krokowski, Phil Harding and Allan Pentecost

Draft

Version 1.7
Freshwater macroalgae of Britain and Ireland
with an introduction to their use in ecological assessment
(RAPPER: Rapid Assessment of Periphyton Ecology in Rivers)

Martyn Kelly¹, Lydia King², Chris Carter³, Jan Krokowski⁴,
Phil Harding⁵ and Allan Pentecost⁶

¹Bowburn Consultancy, 11 Monteigne Drive, Bowburn, Durham DH6 5QB,
UK; MGKelly@Bowburn-consultancy.co.uk

²Basler Landstrasse 54, 79111 Freiburg, Germany.

³6 Church View, Wootton, Northampton, NN4 7LJ, UK.

⁴Scottish Environment Protection Agency, Parklands Avenue, Eurocentral, Holytown,
North Lanarkshire ML1 4WQ.

⁵Environment Agency, Scarrington Road, Westbridgeford, Nottingham NG2 5FA

⁶Freshwater Biological Association, The Ferry Landing,
Ambleside, Cumbria LA22 0LP.

Version: 1.7 (April 2016)

This is a working document and has been published in this format to facilitate testing of the
method. If you have any comments or suggestions on how this document can be
improved, please do get in touch and we will incorporate these into future versions
of the text. Comments should be sent to MGKelly@bowburn-consultancy.co.uk
CONTENTS

Contents ................................................................................................................................. 2

ACKNOWLEDGEMENTS ........................................................................................................ 4

1. Introduction ......................................................................................................................... 5
    1.1 Defining and identifying freshwater “macroalgae” ......................................................... 5
    1.2 Using macroalgae for rapid assessment ......................................................................... 6
    1.3 Conceptual basis for RAPPER ....................................................................................... 7

2. SURVEYING AND STUDYING MACROALGAE ................................................................. 9
    2.1 Collecting, preserving and examining freshwater macroalgae ....................................... 9
    2.2 Surveying macroalgae for ecological assessments ......................................................... 11

3. Identification of macroalgae: overview ............................................................................. 16
    3.1 Introduction ...................................................................................................................... 16
    3.2 Preliminary identification ............................................................................................... 18
        A. Crusts ............................................................................................................................ 19
        B. Colonies ....................................................................................................................... 20
        C. Mats, flocs and films ................................................................................................. 21
        D. Filaments ................................................................................................................... 22
        E. Other types of macroalgal growth form ..................................................................... 22

4. Cyanobacteria (blue-green algae) ..................................................................................... 24
    4.1 Introduction ...................................................................................................................... 24
    Chrococcales ........................................................................................................................ 24
    Synechococcales .................................................................................................................. 24
    Oscillatoriales ...................................................................................................................... 24
    Pseudanabaenales ............................................................................................................... 25
    Nostocales ............................................................................................................................ 25
    4.2 How to identify Cyanobacteria ....................................................................................... 25
    4.4 Descriptions of Cyanobacteria genera .......................................................................... 29

5. Chlorophyta and Xanthophyta ......................................................................................... 47
    5.1 Introduction ...................................................................................................................... 47
    Tetrasporales ....................................................................................................................... 48
    Volvocales ............................................................................................................................ 48
5.2 How to identify filamentous Chlorophyta and Xanthophyta ......................... 50
5.3 Keys to Chlorophyta and Xanthophyta ....................................................... 52
5.4 Descriptions of Chlorophyta genera ......................................................... 57
5.5 Descriptions of Charophyta genera ............................................................ 79
5.6 Descriptions of Xanthophyta genera ......................................................... 84
6. Rhodophyta .................................................................................................. 86
6.1 Introduction ................................................................................................ 86
6.2 How to identify red algae found in freshwater benthic habitats .................. 87
6.3 Key to common freshwater Rhodophyta .................................................... 87
6.4 Descriptions of Rhodophyta genera ............................................................ 90
7. Other groups .................................................................................................. 101
  7.1. Diatoms (Bacillariophyta) ..................................................................... 101
  7.2 Chrysophyta .............................................................................................. 106
  7.3 Phaeophyta ................................................................................................ 109
  7.4. Other organisms ....................................................................................... 111
8. Interpretation .................................................................................................. 114
  8.1 Introduction ................................................................................................ 114
  8.2 Application of RAPPER to survey results ................................................. 114
9. REFERENCES ................................................................................................. 120
Appendix A. RAPPER Survey Sheet ................................................................. 127
ACKNOWLEDGEMENTS

The first version of this guide (by MK and LK) was produced for a training course organised in Ireland for the North-South Share project, funded by the INTERREG IIIA programme for Ireland / Northern Ireland. Participants on this and subsequent training courses made many useful comments that we incorporated into this version.

We are grateful to the Scottish Environment Protection Agency for funding the development of RAPPER.

All illustrations, unless otherwise acknowledged, by Chris Carter (CFC), Lydia King (LK) or Martyn Kelly (MK). Other photographers: BK: Bryan Kennedy; BnC: Bernadette ní Chatháin; GP: Geoff Phillips; MG: Martin Gemmall; RB: Roland Bengtsson; SS: Susi Schneider; TC: Tim Coalburn;
1. INTRODUCTION

1.1 Defining and identifying freshwater “macroalgae”

‘Macroalgae’ is a term used to describe algae that can be recognised, and at least partially identified, with the naked eye. The best-known examples are the seaweeds of marine and estuarine environments, but ‘macroalgae’ also form a conspicuous part of the flora of freshwater habitats, and which may be an important food resource. In a few cases they may cause problems, either by affecting other parts of the stream ecosystem or by detracting from the aesthetic value of the ecosystem. In many lowland rivers, blanket weed (*Cladophora*, p. 60) thrives in the nutrient-rich water and smothers all available surfaces. At the other extreme, the beds of many upland streams are covered by a patchwork of red, green, brown and turquoise growths. Whilst *Cladophora* has long been recognised as an indicator of enrichment (Whitton, 1970; Bolas & Lund, 1974), other macroalgae are often overlooked as environmental indicators, with freshwater environmental monitoring focussing on invertebrates, diatoms and ‘macrophytes’. Some of the more conspicuous macroalgae are included in macrophyte survey methods, but the smaller macroalgae are easily overlooked.

The purpose of this booklet is to provide a guide to the macroalgal growth forms likely to be encountered in freshwaters in Britain and Ireland. The objective is to unlock the potential of these organisms as environmental indicators by introducing biologists involved in monitoring work to their range and diversity and guiding them through the process of identification. Having identified these algae, we then go on to show how these may be used for ecological assessment. The sections concerned with identification are intended to complement, rather than replace, more comprehensive guides such as *The Freshwater Algal Flora of the British Isles* (FAFBI: John et al., 2011). This is the authoritative guide to freshwater algae (excluding diatoms) of the region but it is rather intimidating to use. This booklet is designed as a user-friendly introduction to recognising macroalgae in the field that also guides the user to the appropriate sections of FAFBI or the interactive CD-ROMs to blue-green and green algae (Whitton et al., 2000; 2002). It is, however, not exhaustive and users may encounter taxa that are not described here, or which occur as a different growth form to that described here. We hope that the number of such instances will be small and that the guidance provided will help with navigation through the more technical literature.

A few macroalgae are confined to terrestrial or subaerial habitats and these have not been included. There is often not a clear distinction between amphibious or semi-aquatic habitats and terrestrial or sub-aerial ones, so the decision to include or exclude taxa is not always straightforward. Where confusion might occur, we have included notes to this effect along with cross-references.

The Water Framework Directive (WFD: European Union, 2000) provides the legislative framework behind this work. The goal of the WFD is for all water bodies to achieve at least ‘good ecological status’, defined as having biota that are only slightly different to those
expected in the absence of anthropogenic influence. Algae are important primary producers in both freshwater and marine ecosystems and the need to evaluate the condition of algae – both planktonic and benthic – is specified in Annex V of the WFD. The most common reason for a deviation from this state for algae is nutrient enrichment from a variety of sources, including sewage effluents and diffuse runoff from agricultural land, although their response to other environmental variables is also considered. In several cases, genus-level identification is sufficient to draw conclusions about ecological status, which is convenient as species-level identification of many algal genera is often difficult. Future research may provide insights into the species within several of these genera but we believe that, with the current level of knowledge, the costs of species-level identification often outweigh the benefits. Where species-level identification is possible, this is indicated in the text.

Note: there is still debate about higher classification levels (phyla, kingdoms); many place the eukaryotic “algae” in the kingdom Prototista along with protozoans and some fungi, whilst the blue-green algae are placed in a separate kingdom (“Monera”) of prokaryotic organisms. We follow Bolton (2016) in retaining the term “algae” as a non-technical term for “all plants, excluding the Embryophyta” (i.e. “higher plants”), where a “plant” is defined as an organism which carries out chloroxyogenic photosynthesis” (i.e photosynthesis using chlorophyll a and producing oxygen).

1.2 Using macroalgae for rapid assessment

The core principle of the WFD is to ensure sustainable water supplies for Europe; however, this objective is qualified in several ways, including assessing costs and benefits (Article 4), cost recovery (Article 9) and public participation (Article 14). The latter, in particular, provided one of the stimuli for the present project, as most of the methods that had been developed to fulfil the WFD’s requirements to assess the condition of water bodies are time-consuming and require high levels of expertise to be used properly. There is, in other words, a risk that the objectives of the WFD will not be achieved because the benefits are not adequately justified to those who pay for water services, either as customers or via their taxes. We explored the possibility that a method could be devised for assessing the condition of rivers that was within the capabilities of many more people than a small group of specialist biologists in regulatory bodies, consultancies and universities.

The trend towards specialism is not, of itself, bad, but it is often at the expense of individuals developing a broad overview of several trophic levels, and of the physical and chemical processes that work together to shape the freshwater landscape. Part of the rationale for the present work was to enable biologists who were not specialist phycologists to know enough about the algae that they saw on visits to rivers to give them additional insights, as well as to better understand the outputs from more specialist methods. RAPPER (Rapid Assessment of Periphyton Ecology in Rivers) was designed to be faster to use than standard methods, allowing more sites to be assessed during the course of a day, and results to be available to decision-makers more quickly than is presently the case. It can be considered to be the
ecologist’s equivalent of medical “triage”: giving a high level overview of a situation in order to prioritise the use of limited resources.

The principle of the method is that a short length of a stream or river is surveyed and all algal growths that are visible to the naked eye are either identified in situ or sampled for subsequent identification in the laboratory. The proportion of stream or river bed that they cover is also recorded. Identification of the dominant algae to genus is then used to predict the risk of eutrophication at the site.

This is a work in progress: the RAPPER method has been trialled amongst biologists working for the Scottish Environment Protection Agency (SEPA) and in some other parts of the UK with encouraging results (Kelly et al., 2016). The next step is to broaden these trials and to encourage participation by other stakeholders including anglers and students. In order to do this, however, a field manual, that enabled users to collect, identify and interpret macroalgal communities from rivers was required.

1.3 Conceptual basis for RAPPER

Moss (2008) listed four general properties of “high ecological status”: parsimony of nutrient availability; characteristic physical and biological structure; connectivity and exchange of materials and organisms with other systems; and sufficiency of size to maintain internal mechanisms for resilience to change. RAPPER gives insights into the first (“parsimony of nutrient availability”) and part of the second (“characteristic ... biological structure”) of these.

All submerged surfaces in freshwaters are covered by a thin “skin” of micro-organisms, both heterotrophic and autotrophic which play an important role in ecosystem processes and biogeochemical fluxes (Battin et al., 2016). The autotrophic components (mostly “algae”) of these biofilms produce oxygen, as a result of photosynthesis which replaces oxygen consumed by other microorganisms during respiration. This oxygen, in turn, ensures favourable conditions for aerobic microbial processes and limits anaerobic processes (which can produce greenhouse gases). Biomass produced in biofilms, in turn, can be a major source of energy for higher trophic levels.

The balance of autotrophic organisms within a biofilm is the outcome of a variety of “bottom-up” and “top-down” processes. The former refers to controls via the availability of resources (nutrients, light) whilst the latter refers to grazing/predation by higher trophic levels. Moss (2008)’s reference to “parsimony of nutrient availability” refers to naturally low concentrations of the elements most likely to limit growth (phosphorus and nitrogen). As a result, many of the organisms associated with “natural” or “pristine” water bodies have adaptations to scavenge these nutrients e.g. via phosphatase enzymes (Whitton & Harding, 1978; Livingstone & Whitton, 1984; Gibson & Whitton, 1987a; Whitton, 1988) or, in the case of cyanobacteria, nitrogen fixation (Livingstone et al., 1984; Scott & Macarelli, 2012). By contrast, when this natural limitation is removed (e.g. by addition of nutrients via run-off from agricultural land or from sewage works), these species are out-competed by faster growing, competitive organisms such as Cladophora glomerata (Biggs et al., 1998).
In practice, the quantity of biomass is also controlled by a combination of hydrological pressures and “top-down” control by grazers (Stevenson, 1990; Law, 2011). All of these processes operate at different magnitudes throughout the year, leading to seasonal fluctuations in composition and, in particular, quantity of biomass (Marker, 1976; Marker & Collett, 1997; Schneider, 2015; Snell et al., 2014). However, it is possible to generalise that, under “natural” conditions, the combination of bottom up and top down processes combine to produce generally low biomass (particularly in summer when grazers are most active) composed of a range of organisms adapted to nutrient stresses. As nutrient levels increase, grazers may thrive on the additional biomass that becomes available; however, if there is any disturbance to the grazers, competitive algae such as *Cladophora* may become established (Sturt et al., 2011). Thus, as a stream moves from “natural” to significantly “impacted”, so the potential for these competitive algae to establish increases. A smaller number of organisms may now cover a significant part of the stream bed (if there are suitable substrata).

At other times of year, the balances of these forces may be different. In particular, early spring in clean streams and rivers is often associated with high coverage of benthic algae such as *Ulothrix zonata*, which is capable of growing at low temperatures, and gains an advantage in the period before grazers are active (Graham et al., 1985). However, this high cover soon disappears. Similarly, freshwater red algae such as *Lemanea* and *Audouinella* are most conspicuous in the cooler periods of the year (Sheath, 1984). A large biomass of freshwater algae, in other words, does not necessarily indicate poor conditions; in many cases large biomasses are transient, as would be expected if this was the outcome of dynamic interactions between trophic levels, with differences in generation times imparting a “lag” to the response of grazers.

Some genera appear to be slow-growing and/or grazer resistant. These include crustose algae, some of which appear to thrive across the nutrient gradient (e.g. *Hildenbrandia*) whilst others are confined to cleaner waters.

The discussion so far has considered only enrichment by nutrients; however, other stresses can also influence the benthic algal assemblage. These include disruption to the hydrological regime, acidification and heavy metals. The River Nent in Cumbria is a good example of how heavy metals can impact a stream. The river receives drainage from several lead-zinc mines in the catchment, along with associated spoil heaps, and also inputs from a small sewage works. The river bed is typically bright green in colour, due largely to lush growths of *Stigeoclonium tenue*, thought to thrive partly due to an evolved tolerance to metals (Harding & Whitton, 1976), but also due to an absence of grazers, which are sensitive to the metals (Armitage, 1979). At present, RAPPER has not been configured to assess the scale of such pressures; the survey method can still be used, but alternative approaches to data analysis and interpretation will need to be sought.
2. SURVEYING AND STUDYING MACROALGAE

This chapter is divided into two sections: first of all, the general approach to collecting, preserving and examining the larger attached algae in rivers is described, after which a method for systematic assessments of the condition of macroalgal communities is presented. The former can be used by anyone interested in understanding more about the algae found in our rivers (and, with minor modifications, lake littoral zones); the latter produces data that can be evaluated using RAPPER (chapter 8).

2.1 Collecting, preserving and examining freshwater macroalgae

The identification of macroalgae relies on two distinct activities:

- observation of the organism in situ
- confirmation of the identification of the taxon using a microscope. In the case of RAPPER, only the dominant taxa in a sample need to be identified, although information on other taxa present in the sample may be useful for interpretative purposes.

In a few cases, a definite identification can be made without the use of a microscope but for beginners, especially, it is good practice to take a sample of all specimens back to the laboratory for confirmation or, if possible, take a portable microscope into the field. A x10 or x20 magnification hand lens is useful for checking material in the field.

2.1.1 Observation in situ

Field records should be collected in a standardised manner, in order to facilitate comparisons between samples (a form for recording information is in Appendix 1). The following information will help with the identification of each growth form encountered:

- **type of habitat**: (lake, river, wetland etc)
- **growth form**: (see chapter 3, p. 17)
- **dimensions**: the type of measurements will depend upon the growth form.

We suggest the use of a few categories for dimensions, rather than attempting precise measurements in every case:

- **length**: (e.g. for filaments): record the maximum and typical lengths of filaments
- **thickness**: (e.g. for films and encrusting algae): suggested categories:
  - thin: texture of substratum still can be felt;
o moderate: does not necessarily cover the entire surface of a substratum but, where present algal growth form a complete film but does not alter the topography of the substrate;

o thick: depth of algal growth exceeds a couple of millimetres.

o massive: growths completely obscure substratum

- **diameter:** (e.g. for hemispherical colonies): <1 cm, 1-3 cm, 3-10 cm, >10 cm (record maximum and typical)

- **colour:** bright green / yellow green / olive-green / blue-green / light brown / dark brown / black / red / white

- **additional information:** record any additional information that might aid later identification of the alga, or subsequent interpretation of environmental conditions. For example, note whether filaments are branched/unbranched, slimy or coarse in texture, if there are protuberances along filaments etc.

### 2.1.2 Collecting specimens

Where the organism can be lifted from the substratum easily (with fingers or forceps), a small portion should be removed and placed in a vial or other container with a small amount of water. The specimen plus water should account for no more than about 10 per cent of the total volume of the container, to ensure that the water remains well aerated. Preservatives should not be added unless a long period (>2 weeks) elapses between collection and examination and/or the specimen cannot be stored in a dark, cool place. We recommend that each growth form is stored in a separate vial, labelled with date and location.

Where the organism cannot be removed easily (e.g. in the case of crusts and endolithic algae), the entire stone (or a fragment) can be taken back to the laboratory, placing it in a sealable plastic bag for transport. Alternatively, a small portion of the growth could be scraped off using a knife and transported to the laboratory in a plastic bag or sample bottle.

It is a good idea to take a photograph as well. Ideally, a waterproof camera should be used to photograph the alga in situ. If this is not possible, a polarizing filter attached to the lens should be used on the camera to reduce glare from the water surface. If neither of these options are practical, remove the substratum and photograph it on the bank.

### 2.1.3 Preservation

If guidance in 2.1.2 is followed, preservation should only be necessary in a few cases where there is a long delay between collection and identification. All chemical preservatives have limitations, and are, by their nature, toxic. Lugol’s Iodine is a good general preservative but can complicate identification of Cyanobacteria and, as it is often supplied in an acidified form, may dissolve calcareous structures. Formalin (formaldehyde) and Glutaraldehyde are
widely recommended but are highly toxic. Finally, many larger algae, particularly the Characeae, can be dried for storage. More details are given in John et al. (2011).

**2.1.4 Microscopic examination**

This can be undertaken using a field microscope, but it is usually more convenient to take a specimen back to the laboratory for examination. A light microscope equipped with low and medium power objectives and a calibrated eyepiece graticule is all that is needed. A digital camera is useful, but not essential. A low-power dissecting microscope is also useful.

The easiest method is to pour the contents of a vial into a Petri dish or similar container, and then to tease out a small portion of the alga using needles and forceps and place it onto a glass slide. Add a drop of water, place a coverslip on top and then examine the specimen using a light microscope. It is best to start with low magnification (e.g. x4 or x10 objective), moving to a medium magnification (e.g. x40 objective) to check particular features. Higher power objectives are rarely necessary; however, you should make sure that your microscope is equipped with a calibrated eye-piece graticule so that you can measure cell dimensions.

Organisms which form crusts can be scraped from their substratum using a needle or single-edged razor blade and placed on a slide, though it may be difficult to avoid small rock particles which can make it difficult for the cover slip to lay flat. Viewing the specimen under a dissecting microscope to avoid incorporating rock particles is recommended. Sandstones can be particularly troublesome.

Addition of a drop of Lugol’s iodine (prepared by combining 2 g potassium iodide and 1 g iodine in 300 mL distilled water) to the sample on a slide is a useful means for separating Chlorophyta and Xanthophyta. The iodine reacts with stored starch in cells of Chlorophyta to give a blue-black colour whereas Xanthophyta lack starch and there is no reaction with the iodine.

**2.2. Surveying macroalgae for ecological assessments**

**2.2.1. General principles**

A known length of a river or stream is surveyed by wading back and forth whilst observing the stream bed; all algal growths that are present, along with their extent, are recorded. Those algae that can be identified in the field can be recorded directly but, in most cases, small portions of the growth need to be collected for confirmation of identification in the laboratory.

The survey method is akin to a very short macrophyte survey, albeit conducted over 10, rather than 100 metres or more. The method is based on a survey method that has been used for many years (e.g. Holmes & Whitton, 1981) and is supported by a European standard (EN 15708; CEN, 2009). It differs only in that the abundance of each algal growth is expressed as
the proportion of the river bed that it covers (as in macrophyte surveys) rather than as the relative abundance. Similar methods are used in Norway, Germany and Austria.

2.2.2. Timing of surveys

Visible growths of algae can be found at all times of the year and some species have distinct seasonal preferences. Surveys between late Spring and early Autumn are recommended as the combination of low flows and warm temperatures will encourage a wide range of algae (including nuisance species such as Cladophora and Hydrodictyon). The survey period may be extended further into autumn if weather and flow conditions are favourable.

Surveys should be carried out during normal flow. Immediately after spates, rivers may be discoloured, preventing a clear view of benthic algae, as well as creating difficulties when wading across the river. Spates may also move substrata and scour algae. We recommend that surveys are not conducted within two weeks of a major spate.

2.2.3. Location of survey reaches

The location of survey reaches will be determined by study objectives and accessibility. However, these factors may still present you with 200 metres or more of stream or river from which a shorter length needs to be selected for the survey. How should you do this?

The abundance of macroalgae may vary considerably over relatively short lengths of a river and it is important to select study sites that allow valid comparisons between sites. Factors that can have a major effect on algal biomass include shade and the availability of suitable substrata. It would not be wise, therefore, to compare the results from a survey at a well-lit riffle with those from a shaded pool.

If possible, survey well-lit riffles, runs or glides where there are substrata of a range of sizes, up to and including cobbles and boulders. The water should be shallow enough to permit safe wading and you should be able to see the bottom.

2.2.4 Preparing for the survey

The survey takes place along a 10 m length of the river channel. Before starting the survey, decide on the upstream and downstream limits. Check the length either by pacing or measuring.

In addition, it is helpful to have some supporting information to aid interpretation of the results. Record the width of the river (again, either by pacing or measuring) and the depth. Depth will vary, so record the average of at least three measurements of depth (e.g. 25%, 50% and 75% of the length of a transect).

As availability of light has a big effect on the quantity of algae present, you should also record the extent of any shading along both banks. As a minimum, record either “none”, “moderate” (= occasional trees) or “heavy” (= continuous shade on both banks).
As availability of suitable substrata will also influence the cover of some algal growth forms, you should record the substrate composition at the time of the survey, following the Wentworth scale (Table 2.1).

### 2.2.5. Performing the survey

Systematically examine the river bed of the study reach (e.g. by wading back and forth) in order to identify any algal growths that are present (see 2.1.1). An underwater viewing device such as an “Aquascope” (also known as a “Bathyscope”) or a glass-bottomed bucket may be useful for this. Except in cases where a reliable identification can be made in the field (e.g. *Hildenbrandia rivularis*) small specimens of each growth need to be removed (see 2.1.2). Once you have surveyed the entire length, make an estimate of the percentage of the river bed that each growth occupies. A nine-point cover scale is recommended (Table 2.2), although shorter scales may provide enough information for rapid diagnoses of condition in some circumstances. Table 2.3 helps you convert direct observations of the algae in the field to percent cover. Be aware that there may be more than one algal growth form of a particular type (e.g. green film/filaments) present; these may be distinguished by partly by different shades of colour (e.g. dark green versus light green) or texture (coarse versus slimy). If in any doubt, collect samples of each for later confirmation.

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bedrock</td>
<td>Exposure of underlying solid rock</td>
</tr>
<tr>
<td>Boulder</td>
<td>Loose rocks &gt; 256 mm diameter (roughly the size of a large head)</td>
</tr>
<tr>
<td>Cobble</td>
<td>Loose rocks &gt; 64 ≤ 256 mm diameter (roughly the size of half fist to a large head)</td>
</tr>
<tr>
<td>Gravel/pebble</td>
<td>A combined category:</td>
</tr>
<tr>
<td></td>
<td>Pebbles: &gt; 64 ≤ 256 mm (“conker” to half fist size)</td>
</tr>
<tr>
<td></td>
<td>Coarse gravel: &gt; 16 ≤ 64 mm</td>
</tr>
<tr>
<td></td>
<td>Fine gravel: &gt; 2 ≤ 16 mm</td>
</tr>
<tr>
<td>Sand</td>
<td>Particles &gt; 0.06 ≤ 2 mm</td>
</tr>
<tr>
<td>Silt/mud</td>
<td>Particles ≤0.06 mm</td>
</tr>
<tr>
<td>Clay</td>
<td>Solid surface comprising sticky clay material</td>
</tr>
<tr>
<td>Peat</td>
<td>Predominately or totally peat</td>
</tr>
<tr>
<td>Artificial</td>
<td>e.g. concrete.</td>
</tr>
</tbody>
</table>
2.2.6. Identification of algae

The composition of algal growths can be determined either in the laboratory or, if possible, at the site using a field microscope by following the procedures in 2.1.4 in conjunction with the keys in chapters 3 – 7 and other identification literature, if available.

Most algal growths have a single dominant constituent, along with associated epiphytes and other organisms exploiting the microhabitats that it produces. You only need to identify the dominant organism in order to use RAPPER; information on other taxa present may be useful for interpretation later. Occasionally, growths consist of mixtures of two (occasionally more) species. In such cases, record both at the cover value that equates to half the area of stream bed covered by the combined growth. If one taxon is obviously dominant, whilst another is present in smaller quantities, record the latter as “present” (i.e. cover value = 1).

Table 2.2. The nine-point scale for assessing cover of macroalgae for RAPPER assessments

<table>
<thead>
<tr>
<th>Cover value</th>
<th>Percent cover of stream bed</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 0.1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0.1 &lt; 1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1 &lt; 2.5</td>
<td>low cover</td>
</tr>
<tr>
<td>4</td>
<td>2.5 &lt; 5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5 &lt; 10</td>
<td>moderate cover</td>
</tr>
<tr>
<td>6</td>
<td>10 &lt; 25</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>25 &lt; 50</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>50 &lt; 75</td>
<td>high cover</td>
</tr>
<tr>
<td>9</td>
<td>≥ 75</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.3 How to visualise cover ($m^2$) for 10 m stream or river sections.

“%” refers to the amount of the river bed covered by an algal growth. Estimate the average stream width then look at the corresponding column. The values here indicate the maximum amount of the bed that would be covered for each cover value. If your river is 4 metres wide and there is 5 % cover of Cladophora, then this would correspond to 2 m$^2$ of algae which, if visualised as a single patch, would be 1.4 x 1.4 m in size.

<table>
<thead>
<tr>
<th>Cover value</th>
<th>%</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt;0.1</td>
<td>&lt;0.01</td>
<td>&lt;0.02</td>
<td>&lt;0.03</td>
<td>&lt;0.04</td>
<td>&lt;0.05</td>
<td>&lt;0.06</td>
<td>&lt;0.07</td>
<td>&lt;0.08</td>
<td>&lt;0.09</td>
<td>&lt;0.1</td>
<td>&lt;0.15</td>
<td>&lt;0.2</td>
<td>&lt;0.25</td>
</tr>
<tr>
<td>2</td>
<td>0.1-1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>1-2.5</td>
<td>0.25</td>
<td>0.5</td>
<td>0.75</td>
<td>1</td>
<td>1.25</td>
<td>1.5</td>
<td>1.75</td>
<td>2</td>
<td>2.25</td>
<td>2.5</td>
<td>3.75</td>
<td>5</td>
<td>6.25</td>
</tr>
<tr>
<td>4</td>
<td>2.5-5</td>
<td>0.5</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
<td>2.5</td>
<td>3</td>
<td>3.5</td>
<td>4</td>
<td>4.5</td>
<td>5</td>
<td>7.5</td>
<td>10</td>
<td>12.5</td>
</tr>
<tr>
<td>5</td>
<td>5-10</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>6</td>
<td>10-25</td>
<td>2.5</td>
<td>5</td>
<td>7.5</td>
<td>10</td>
<td>12.5</td>
<td>15</td>
<td>17.5</td>
<td>20</td>
<td>22.5</td>
<td>25</td>
<td>37.5</td>
<td>50</td>
<td>62.5</td>
</tr>
<tr>
<td>7</td>
<td>25-50</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>50</td>
<td>75</td>
<td>100</td>
<td>125</td>
</tr>
<tr>
<td>8</td>
<td>50-75</td>
<td>7.5</td>
<td>15</td>
<td>22.5</td>
<td>30</td>
<td>37.5</td>
<td>45</td>
<td>52.5</td>
<td>60</td>
<td>67.5</td>
<td>75</td>
<td>112.5</td>
<td>150</td>
<td>187.5</td>
</tr>
<tr>
<td>9</td>
<td>&gt;75</td>
<td>&gt;7.5</td>
<td>&gt;15</td>
<td>&gt;22.5</td>
<td>&gt;30</td>
<td>&gt;37.5</td>
<td>&gt;45</td>
<td>&gt;52.5</td>
<td>&gt;60</td>
<td>&gt;67.5</td>
<td>&gt;75</td>
<td>&gt;112.5</td>
<td>&gt;150</td>
<td>&gt;187.5</td>
</tr>
</tbody>
</table>

Note:

0.01 m$^2$ = 10 x 10 cm  
0.02 m$^2$ = 14 x 14 cm  
0.05 m$^2$ = 22 x 22 cm  
0.08 m$^2$ = 28 cm x 28 cm  
0.1 m$^2$ = 32 x 32 cm  
0.2 m$^2$ = 45 x 45 cm  
0.5 m$^2$ = 71 x 71 cm  
0.8 m$^2$ = 90 x 90 cm  
1 m$^2$ = 1 x 1 m  
5 m$^2$ = 2.2 x 2.2 m  
8 m$^2$ = 2.8 x 2.8 m2  
10 m$^2$ = 3.2 x 3.2 m  
20 m$^2$ = 4.5 x 4.5 m  
50 m$^2$ = 7.1 x 7.1 m  
8 m$^2$ = 9 x 9 m
3. IDENTIFICATION OF MACROALGAE: OVERVIEW

3.1 Introduction

Historically, identification of algae has focused on pigment composition and morphology, with other characteristics such as life-cycle, ultrastructure and, increasingly, molecular evidence, contributing to their overall classification. In practice, because algae from many different lineages can be found alongside one another in flowing waters, where they are subject to similar pressures, there is a certain amount of convergent evolution. This means that similar growth forms (e.g. crusts, filaments, gelatinous masses) can be found in evolutionary disparate groups and this, in turn, offers an alternative starting point for identification. This chapter presents an overview of the classification followed by keys that use simple features to classify specimens into the appropriate taxonomic group, each of which is dealt with in a subsequent chapter.

The classification adopted here largely follows that in the Freshwater Algal Flora of the British Isles (John et al., 2011). Readers should be aware that there is still debate about the higher classification levels (phyla, kingdoms) although this should not impact upon the routine identification of algae. Table 3.1 shows the higher classification adopted by AlgaeBase; this differs from that in FAFBI in that Chrysophceae, Xanthophceae and Phaeophyceae are treated as Classes rather than Divisions. The Chromista is broadly consistent with the Heterokontophyta (as used by van den Hoek et al., 1995), but are defined by pigment composition rather than by organisation of flagellae.

The identification guide starts by asking you to look at the properties of your specimen visible with the naked eye and to place it into one of five categories, each representing a different growth form.
<table>
<thead>
<tr>
<th>Taxonomic level</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Empire</td>
<td>Prokaryota</td>
</tr>
<tr>
<td>Kingdom</td>
<td>Eubacteria</td>
</tr>
<tr>
<td>Phylum</td>
<td>Cyanobacteria (blue-green algae)</td>
</tr>
<tr>
<td>Empire</td>
<td>Eukaryota</td>
</tr>
<tr>
<td>Kingdom</td>
<td>Chromista</td>
</tr>
<tr>
<td>Phylum</td>
<td>Ochrophyta</td>
</tr>
<tr>
<td>Class</td>
<td>Xanthophyceae (yellow-green algae)</td>
</tr>
<tr>
<td>Class</td>
<td>Chrysophyceae (yellow-brown algae)</td>
</tr>
<tr>
<td>Class</td>
<td>Phaeophyceae (brown algae)</td>
</tr>
<tr>
<td>Phylum</td>
<td>Bacillariophyta (diatoms)</td>
</tr>
<tr>
<td>Kingdom</td>
<td>Plantae</td>
</tr>
<tr>
<td>Phylum</td>
<td>Rhodophyta (red algae)</td>
</tr>
<tr>
<td>Phylum</td>
<td>Chlorophyta (green algae)</td>
</tr>
<tr>
<td>Phylum</td>
<td>Charophyta (charophytes)</td>
</tr>
</tbody>
</table>
3.2. Preliminary identification

3.2.1 Step 1: decide the growth form of the specimen you want to identify

A. Crusts
Organisms that are tightly attached to the substratum. You may be able to remove small fragments by scratching with a fingernail or blade but you cannot lift the crust in a single piece. There may be evidence of calcification. ..........A

B. Colonies
These form distinct three-dimensional patches on the substratum, ranging from just visible with the naked eye to several centimetres across. They can be removed from the substratum using forceps or a blade .......... B

C. Mats, flocs and films
Prostrate on substratum, loosely-attached or floating to water surface but lacking the distinct outlines of colonies. Individual filaments rarely visible to naked eye. Often “slimy” to the touch .......... C

D. Filaments
Attached to hard substrata; individual filaments are visible with the naked eye; generally ± horizontal to substratum (especially in flowing waters) but, occasionally, ± vertical ................. D

E. Other
Growth forms which do not fit into any of the above categories (see below).
3.2.2 Step 2: determine your specimen’s taxonomic group

The next sections of the key require a microscope with a magnification of at least x100 (ideally x400). In a few cases we can jump straight to the genus but in most we will name the phylum to which the specimen belongs.

A. Crusts

Note: Aquatic lichens are also common on submerged or periodically wetted rocks, especially in oligotrophic waters. They form green, brown or black stains on the rock and can be difficult to distinguish from encrusting algae in the field. If samples are allowed to dry, encrusting lichens can be distinguished by the presence of numerous dot-like reproductive bodies (arrowed in picture), best seen under the low power of a dissection microscope or using a hand lens. These bodies are often of a different colour to the lichen crust and 0.2-0.5 mm in diameter. If the specimen lacks these bodies, a squash preparation of the crust should be examined at 400x magnification under a compound microscope, where the filamentous fungal component will be seen closely associated with the algal cells. Most aquatic lichens contain either green coccoid algae or Cyanobacteria. In the latter case, the algal cells are sometimes greatly modified by the fungus and may require examination by a specialist.

The keys assume that you have ascertained that your specimen is not an aquatic lichen.

First, note the colour of your specimen

1a Red ...........2
1b Brown to almost black ...........3
1c Green ..........GONGROSIRA (p. 62) (CHLOROPHYTA)
1d Blue-green ..........CYANOBACTERIA

2a Bright red patches of irregular shape and various size but always with a distinct outline; on flat and convex surfaces of pebbles and larger substrata ..........HILDENBRANDIA (p. 96) (RHODOPHYTA)
2b Bright red patches of irregular shape and size, lacking a distinct outline, most likely to form in concave surfaces on rock surfaces

......HAEMATOCOCCUS (p. 63)
(CHLOROPHYTA)

2c Bright red patches usually lacking a distinct outline; on hard, stable substrata, cells without distinct chloroplasts, forming filaments, several of which share a single sheath

......SCHIZOTHRIX (p. 43)
(CYANOBACTERIA)

3a Cells without distinct chloroplasts

........CYANOBACTERIA

3b Cells with distinct chloroplasts

......HERIBAUDIELLA (p. 109)
(PHAEOPHYTA)

B. Colonies

First, note the colour of your specimen

1a Pinkish red, brown to almost black

........2

1b Green or blue-green

........4

2a Colonies composed of filaments or unicells; individual cells lacking differentiation into organelles; the cells are usually blue-green in colour although these may be contained within a sheath which may be colourless or contain brown pigments.

........3
(CYANOBACTERIA)

2b Colonies composed of filaments; individual cells contain distinct chloroplasts which range in colour from pinkish-red to olive-green

GO TO 3.3.2
(RHODOPHYTA)

2c Individual cells, not organised into filaments, though there may be extracellular structures such as stalks or tubes present. A yellow-brown chloroplast is visible
within an ornamented silica cell wall  \(\ldots\) DIATOMS

3a Filamentous  \(\ldots\) GO TO 3.1.2

3b Not filamentous  \(\ldots\) GO TO FAFBI

4a Colonies composed of filaments of cells each with distinct chloroplasts  \(\ldots\) GO TO 3.2.2

4b Colonies composed of individual cells each with a distinct chloroplast in a gelatinous matrix, often arranged in twos or fours  TETRASPOR (p. 74) (CHLOROPHYTA)

4c Colonies composed of individual cells each lacking differentiation into organelles  \(\ldots\) GO TO FAFBI

C. Mats, flocs and films

What colour is your mat, floc or film? Use this matrix to decide where to go next:

<table>
<thead>
<tr>
<th>Colour</th>
<th>Cyanobacteria</th>
<th>Diatoms</th>
<th>Chrysophytes</th>
<th>Sewage fungus</th>
<th>Green algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Various: blue-green to brown to almost black</td>
<td>Shades of brown</td>
<td>Shades of brown</td>
<td>Various, from white and grey to dark brown</td>
<td>Green</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Form</th>
<th>Cyanobacteria</th>
<th>Diatoms</th>
<th>Chrysophytes</th>
<th>Sewage fungus</th>
<th>Green algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mostly filamentous, with or without branching</td>
<td>Various</td>
<td>Various; often mucilaginous, feathery growths</td>
<td>Mostly filamentous</td>
<td>Branched / unbranched filaments</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key diagnostic properties</th>
<th>Cyanobacteria</th>
<th>Diatoms</th>
<th>Chrysophytes</th>
<th>Sewage fungus</th>
<th>Green algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of obvious differentiation within cells</td>
<td>Ornamented silica cell wall</td>
<td>Mucilage “filaments” within which cells are arranged peripherally</td>
<td>Absence of photosynthetic pigments</td>
<td>Colour, cell organelles present</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Go to:</th>
<th>Cyanobacteria</th>
<th>Diatoms</th>
<th>Chrysophytes</th>
<th>Sewage fungus</th>
<th>Green algae</th>
</tr>
</thead>
<tbody>
<tr>
<td>p. 27</td>
<td>Note C1</td>
<td>p. 106</td>
<td>Note C2</td>
<td>p. 52</td>
<td></td>
</tr>
</tbody>
</table>
**Note C1:** Diatoms are often the most abundant algae in films covering submerged surfaces in lakes and rivers, though they only occasionally qualify as “macroalgae”. Their identification is beyond the scope of this booklet. See Kelly (2000) and Cox (1996) for introductory guides.

**Note C2:** A large number of heterotrophic organisms fall into the category commonly referred to as “sewage fungus”. Their identification is beyond the scope of this booklet.

### D. Filaments

First, note the colour and form of your specimen

1a Filaments bright to dark green in appearance  
CHLOROPHYTA & XANTHOPHYTA

1b Filaments not green in appearance; colour may vary from pinkish red to olive green to brown

2 Filaments not as above, may be rough to the touch or be mucilaginous with a beaded structure (resembling frog spawn)  
RHODOPHYTA

#### 2a Fragile brown filaments, readily disintegrating on contact, composed of chains of cylindrical cells each containing many yellow-brown chloroplasts  
MELOSIRA (DIATOMS) (p. 104)

#### 2b Filaments not as above

### E. Other types of macroalgal growth form

**Net-like structures**

From a distance these can look like filaments, mats or flocs but, on close inspection, they can be seen to be composed of a mesh of cells. Green in colour

************** HYDRODICTYON (p. 64)
Thalloid (look like green “seaweeds”)

Simple multicellular organisms which lack differentiation into root, stem, leaf or leaves. For the purpose of this booklet, they are sheets of cells, forming thin membranes ... 3.2.3

CHARACEAE

A single main stem from which whorls of branches arise at intervals. May be calcified. Easily mistaken for higher plants.

.......... 3.2.4
4. CYANOBACTERIA (BLUE-GREEN ALGAE)

4.1 Introduction

This is the oldest algal group in evolutionary terms and representatives can be found in a wide range of ecological conditions. Cyanobacteria are, strictly speaking, bacteria as they are prokaryotic (lack a nucleus). They have chlorophyll-\(a\) together with the accessory pigments c-phycocyanin, allophycocyanin, c-phycoerythrin, beta-carotene and several xanthophylls. Different combinations of these, along with other photoprotective pigments such as scytonemin (found in the sheaths of some genera) give a range of colours from blue-green or reddish-brown to almost black. Storage products are laid down within cyanophycin granules and polyglucose. Their cell wall is made from peptidoglycan, a polymer of amino sugars. Cyanobacteria never possess flagella. Many genera are found in benthic habitats in running waters, though they are less common in acid conditions. Several taxa are capable of nitrogen-fixation for which some species have specialised cells called heterocysts. The growth forms found include crusts, mats, endolithic growths, tufts and hemispherical colonies and can vary in size from tiny dark spots barely visible to the naked eye to mats that can cover the whole river bed.

<table>
<thead>
<tr>
<th>Genus (arranged by Order)</th>
<th>See page</th>
<th>FAFBI page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chrococcales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Aphanocapsa</em> Nügeli 1849</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td><em>Aphanothece</em> Nügeli 1849</td>
<td>30</td>
<td>44</td>
</tr>
<tr>
<td><strong>Synechococcales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chamaesiphon</em> A. Braun et Grunow 1865</td>
<td>32</td>
<td>46</td>
</tr>
<tr>
<td><strong>Oscillatoriales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Homoeothrix</em> (Thuret) Kirchner 1898 sensu Komarek et Kann</td>
<td>35</td>
<td>83</td>
</tr>
<tr>
<td><em>Lyngbya</em> (C. Agardh 1924) Gomont 1892</td>
<td>36</td>
<td>85</td>
</tr>
<tr>
<td><em>Microcoleus Desmazières</em> ex Gomont 1892</td>
<td>37</td>
<td>93</td>
</tr>
<tr>
<td><em>Oscillatoria</em> (Vaucher 1802) Gomont 1892</td>
<td>39</td>
<td>95</td>
</tr>
<tr>
<td><em>Phormidium</em> (Kuetzing 1843) Gomont 1892</td>
<td>40</td>
<td>101</td>
</tr>
<tr>
<td><em>Plectonema</em> (Thuret) Gomont 1892</td>
<td>41</td>
<td>106</td>
</tr>
</tbody>
</table>
The key below guides you to the most common genera of Cyanobacteria found in freshwater benthic habitats in the UK. Most of these are filamentous; however, some non-filamentous Cyanobacteria are also found in freshwater benthic habitats: these include *Chamaesiphon*, whose representatives are either crust-forming or epiphytic on other algae. In addition, a number of genera of colonial Cyanobacteria (e.g. *Aphanocapsa, Aphanothece* in which many unicells are embedded in a mucilaginous matrix), are also occasionally found in benthic habitats. These are described in detail in FAFBI.

There have been a number of revisions to the taxonomy of Cyanobacteria in recent years, in particular by Komářák and Anagnostidis (2005). Many of these changes have been driven by new insights obtained by molecular studies and these are described in more detail in FAFBI. However, most of these changes have not affected the larger taxa found in benthic freshwater habitats.

### 4.2 How to identify Cyanobacteria

Before you start to use the keys to genera, you will need to learn some of the terms that are used to describe Cyanobacteria. First of all, the filament actually consists of two distinct components: the chain of cells, termed the **trichome** and a mucilaginous **sheath**. The sheath is not present in all genera, and can be very thin (and, so, hard to see) but in some cases (e.g. *Scytonema*), it is very prominent and is useful for identification. The sheath may also be
coloured by pigments such as scytonemin, which protects the cells from ultra-violet radiation. Mostly, filaments are single, but there are some cases (e.g. *Schizothrix*) where several filaments together form bundles. Note, too, whether the filament is the same width for the entire length or if it gradually narrows towards the apex. In some cases, the filament narrows into a long, colourless *hair*, which plays a role in phosphorus. Mostly, filaments are stationary though a few genera (e.g. *Oscillatoria*) display a gliding motion.

Filaments may be unbranched or show one of two types of branching: **false branches** and **true branches**. True branches occur when the cells within a trichome divide to produce a lateral growth whereas false branches are produced by a rupture of a trichome within a sheath so that the branch is no longer attached to the main stem of the trichome.

![Fig. 4.1. Schematic diagrams showing true branching (a) and single (b) and double (c) false branches.](image)

Another important structure to watch for is the **heterocyst**. These are specialised cells used for nitrogen fixation and are found in the Nostocales and Stigonematales but not the Oscillariales. Heterocysts are either found within the trichome (“**intercalary**”) or at the end of the trichome (“**terminal**”). They are paler than the vegetative cells and have thicker walls. Note, too, the presence of a granule at the end of the heterocyst adjacent to the neighbouring vegetative cell. This is composed of a nitrogen-storage compound called cyanophycin.

![Fig. 4.2. Schematic diagram showing a filament without heterocysts (a) and filaments with intercalary (b) and terminal (c) heterocysts.](image)
Akinetes are thick-walled resting spores found in heterocystous Cyanobacteria. They are generally larger than the vegetative cells and their position, relative to the heterocyst, can be a useful diagnostic character. For example, they are found adjacent to the terminal heterocyst (e.g. some Calothrix spp.) and approximately equidistant between heterocysts in many species of Nostoc.

Fig. 4.3. Schematic diagram showing an akinete between the heterocyst and vegetative cells of a tapering Cyanobacterium filament.

It is always a good idea to record the dimensions of the specimens you are trying to identify. In particular, record the width of the trichome and the filament, and also the length of the cells. Dimensions are rarely useful for naming genera but are important if you want to go on to name the species.

4.3 Key to Cyanobacteria which can form macroscopic growths in freshwater benthic habitats

1a  Crust forming cyanobacteria consisting of single cells within a sheath, often capped with a spherical (or ovoid) exosporous  CHAMAESIPHON (p. 32)
1b  Distinct gelatinous colonies, either free-floating or loosely associated with submerged plants  APHANOCAPSA / APHANOTHECE (p. 30)
1c  Not as above  2

2a  Heterocyst absent  ..... 3
2b  Heterocyst present  ..... 6

3a  Filaments composed of bundles of trichomes sharing a common sheath, often with visible gliding motion, cells  SCHIZOTHRIX (p. 43)
3b  Filaments composed of bundles of trichomes sharing a common sheath, gliding motion absent,  MICROCOLEUS (p. 37)
3c  Filaments not in bundles  4

Trichomes of Microcoleus are typically broader (>5 µm) than those of Schizothrix, though
exceptions occur. In addition, *Hydrocoleum* will key out here. In most cases, material will need to be checked using FAFBI.

4a Filaments tapered & HOMOEOTHRIX (p. 35)

4b Filaments not tapered & ......5

5a Sheath absent, filaments unbranched, cells mostly much shorter than broad, giving the appearance of a stack of coins. & OSCILLATORIA (p. 39)

5b Thin sheath, filaments unbranched, cells usually either as long as wide or isodiometric. & PHORMIDIUM (p. 40)

5c Firm sheath, filaments unbranched, length : breadth various & LYNGBYA (p. 36)

5d Firm sheath, false branches present, length : breadth various & PLECTONEMA (p. 41)

6a No branches, filaments appear like chains of beads within a dense sphere or large jelly-like mass, interspersed by larger heterocysts & NOSTOC (p. 38)

6b No branches, filament appearance various but always with heterocysts present and never embedded within jelly-like mass & ANABAENA

6c Not as above & APHANIZOMENON CYLINDROSPERMUM

Couplet 6b catches various predominately planktonic bloom-forming genera which may occasionally be found in benthic habitats. Their identification is beyond the scope of this book.

7a True branches, filaments lack bead-like appearance & STIGONEMA (p. 44)

7b Not as above & 8

8a Tapered filaments with terminal heterocyst & 9
8b  Filaments not tapered, heterocysts either terminal or intercalary

9a  Filaments found in small bundles, not forming distinct colonies visible with the naked eye; false branches absent or occasional  
    CALOTHRIX (p. 31)

9b  Filaments form mats or cushions visible to the naked eye, but not distinct hemispherical colonies; copious false branches  
    DICOTHRIX (p. 33)

9c  Filaments form distinct hemispherical or sub-spherical colonies; some false branches  
    RIVULARIA (p. 42)

9d  Filaments form circular colonies. Mostly free-floating but occasionally epiphytic; false branches absent or occasional  
    GLOEOTRICHIA (p. 34)

10a All false branches single  
    TOLYPOTHRIX (p. 46)

10b Some false branches arising in pairs  
    SCYTONEMA (p. 44)

4.4 Descriptions of Cyanobacteria genera

“Species” refers to the number of species recorded in Britain and Ireland, based on accounts in FAFBI, along with the ease with which these can be separated. There are few keys in FAFBI for Cyanobacteria; the best option is to use the CD-ROM by Whitton et al. (2000).
4.4.1 Aphanocapsa Nägeli 1849 and Aphanothece Nägeli 1849

Species

14 (Aphanocapsa) and 11 (Aphanothece) although only a few of these are likely to form colonies visible with the naked eye. Use CD-ROM.

Macroscopic appearance

Distinct pale blue-green to green mucilaginous masses, with a firm outer margin, up to 4 cm in diameter, found floating just below the water surface in sheltered margins.

Microscopic appearance

Spherical to ellipsoid or elongate cells, 1-8 µm wide and up to 16 µm long embedded in a mucilage matrix.

Ecology

Don’t confuse with

Several other cyanobacterial genera (e.g. Microcystis) form colonies, though without the distinct outer margin characteristic of Aphanocapsa and Aphanothece.

Look for

Distinct mucilaginous colonies.

Habitat and ecology

Planktonic or loosely associated with vegetation in standing or slowly moving waters. Some species are also associated with damp rock faces and other terrestrial surfaces. Aquatic, macroscopic forms can be found in a wide range of water bodies throughout the year.

Literature

FAFBI; Gutowski & Foerster (2009): pp. 64-70

Fig. 4.4. a. A mucilaginous colony of Aphanocapsa stagnina; b. a microscopic view of the individual cyanobacterial cells embedded in mucilage. Scale bar: 25 micrometres (photos: MGK).
4.4.2 *Calothrix (C. Agardh 1824) Bornet et Flahault 1886*

**Species**

11. Use CD-Rom

**Macroscopic appearance**

Filaments solitary or in small bundles, sometimes aggregated into cushions, mats or crusts, but not the distinct hemispherical colonies associated with *Dichothrix* and *Rivularia*.

**Microscopic appearance**

Trichomes with a heterocyst at the base and getting thinner towards the top enclosed in a firm, often brown-pigmented sheath.

**Don’t confuse with**

*Dichothrix* p. 33 (hemispherical colonies, copious false branches); *Rivularia* p. 42 (narrower trichomes with some false branches; hemispherical colonies).

**Look for**

Unbranched filaments and basal heterocysts.

**Habitat and ecology**

More likely to be found in still than flowing water, but common in freshwater, brackish and marine environments. Field populations almost always have colourless hairs, suggesting an ability to utilise organic phosphorus at times of phosphorus limitation, although hair formation can be suppressed in the laboratory under nutrient rich conditions.

**Literature**

FAFBI; deNicola and deEyto, 2004; Wood *et al.*, 1986; Whitton, 1987;

---

Fig. 4.5. *Calothrix* filaments from a stream in Iceland. Note the basal heterocysts, tapering trichome and distinct sheath (photo: CFC).
4.4.3 Chamaesiphon A. Braun et Grunow 1865

**Species**
10. (13) Use CD-ROM

**Macroscopic appearance**
Dark-brown or almost black spots or patches on rocks.

**Microscopic appearance**
Cells, club-shaped, pear-shaped, ellipsoidal or almost cylindrical, in an open-ended sheath forming “pseudofilaments” which are attached to the substrate with the narrow end and release exospores at the upper end.

**Don’t confuse with**
Several other crustose algae form dark patches on rocks, as does the aquatic lichen *Verrucaria*.

**Look for**
If colonies are scraped from the rocks and placed under the microscope, the prokaryotic cell structure coupled with the open sheaths, often with exospores visible, are the most useful indicators of *Chamaesiphon*.

**Habitat and ecology**
Attached to all sorts of substrata from other algae to large rocks. Fairly wide-spread in fast-flowing rivers. The genus *Chamaesiphon* comprises two sub-genera, one of which includes predominately epilithic taxa whilst the other includes epiphytes such as *C. incrustans* (which is very common on *Cladophora* p. 57). The former group typically form dark patches on stones in fast-flowing rivers. Several species have quite distinct ecological preferences – typically in relatively unpolluted water - but the details are beyond the scope of this booklet. See Whitton (2002) for more details.

**Literature**
FAFBI; Kann, 1973; Pipp and Rott, 1993; Biggs and Kilroy 2000, Gutowski et al. 2015.

Fig. 4.6. *Chamaesiphon polonicus* from Caldbeck. Top left: looking down on colony; other images: side views showing cells in their sheaths and, in a few instances, with exospores (photos: CFC). **Still need habit photograph**
4.4.4 *Dichotheix* [Zanardini 1858] *Bornet et Flahault 1886*

<table>
<thead>
<tr>
<th><strong>Species</strong></th>
<th>5. Use CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macroscopic appearance</strong></td>
<td>Gelatinous, brown layer forming mat, cushion or bushy structure.</td>
</tr>
<tr>
<td><strong>Microscopic appearance</strong></td>
<td>False-branched trichomes with basal heterocysts, tapering trichomes and (often) pigmented sheaths. Several trichomes may share a common sheath below the false branches.</td>
</tr>
<tr>
<td><strong>Ecology</strong></td>
<td>Presence of hair indicates phosphorus limitation.</td>
</tr>
<tr>
<td><strong>Don’t confuse with</strong></td>
<td><em>Calothrix</em> (does not form hemispherical colonies; lacks false branches), p. 31; <em>Tolypothrix</em> p. 46 (trichomes of <em>Tolypothrix</em> do not narrow into hairs). <em>Rivularia</em>, p. 42.</td>
</tr>
<tr>
<td><strong>Look for</strong></td>
<td>Tufts of filaments with abundant false branches.</td>
</tr>
<tr>
<td><strong>Habitat and ecology</strong></td>
<td>Lakes and clean-water streams.</td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td>FAFBI; Biggs and Kilroy, 2000.</td>
</tr>
</tbody>
</table>

Fig. 4.7. *Left: Dichotheix gypsophila* from the River Caher, Ireland (Photo: BnC); *right: microscopic view of Dichotheix* sp. showing false-branches on filaments (compare with Calothrix which lacks false branches) (photo: CFC).
4.4.5 *Gloeotrichia (J. Agardh 1842) Bornet et Flahault 1886*

Species 4. Use CD-ROM

**Macroscopic appearance** Spherical (if free-floating) or hemispherical gelatinous colonies

**Microscopic appearance** Tapering trichomes with basal heterocysts;

**Don’t confuse with** *Calothrix, Rivularia* and *Dichothrix* are predominately benthic, forming hemispherical colonies, rather than planktonic.

**Look for** Spherical colonies.

**Habitat and ecology** Mostly lakes; common in the plankton; some species are also epiphytic. Presence of hair indicates phosphorus limitation.

**Literature** FAFBI; Biggs and Kilroy, 2000.

Fig. 4.8. a. *Gloeotrichia pisum* on the stems of *Potamogeton pectinalis* from Abington Meadows, Northamptonshire (photo; CFC); b. *Gloeotrichia echinulata* colony (approx. 5 mm across) from Talkin Tarn, Cumbria; c. close-up of *G. echinulata* filaments within the colony (photos: MGK). Note the basal heterocysts and absence of false branches.
4.4.6 *Homoeothrix (Thuret) Kirchner 1898 sensu Komarek et Kann*

**Species**
7. Use CD-ROM

**Macroscopic appearance**
Slightly flattened hemisphere, crust or tuft.

**Microscopic appearance**
Trichome slightly tapered, unbranched or showing false branching, usually with obvious sheath. No heterocysts or akinetes.

**Don’t confuse with**
*Lyngbya*, p. 36, (untapered trichomes); *Schizothrix* p. 43 (several trichomes in a single sheath). *Rivularia*, p. 42 but this has heterocysts, *Homoeothrix* does not.

**Look for**
Tapering filaments lacking heterocysts.

**Habitat and ecology**
Standing and flowing waters on rocks or plants.

**Literature**
FAFBI.

---

**Fig. 4.9.**
a: *Homoeothrix crustacea* encrusting a boulder (approx. 40 cm across) from a calcareous stream in Cumbria, U.K.; b: filaments of *H. fusca* from a crust on Whitbarrow tufa stream, Cumbria (scale bar: 100 μm); c: close-up of a single trichome from the same stream. Note the distinctive tapering and absence of a heterocyst (scale bar: 10 μm) (photos: MGK).
4.4.7 *Lyngbya (C. Agardh 1924) Gomont 1892*

**Species**  
21.

**Macrosopic appearance**  
Blue-green to dark brown mats and crusts. A few species (e.g. *L. vandenberghenii*) are endolithic, growing in limestone boulders and cobbles.

**Microscopic appearance**  
Straight, not tapering filaments enclosed within a sheath, cells usually wider than long.

**Don’t confuse with**  
*Oscillatoria*, p. 39, (no obvious sheath, motile trichomes); *Phormidium*, p. 40, (thin sheath).

**Look for**  
Obvious sheath.

**Habitat and ecology**  
Most often attached to other plants at lake edges and in streams, or endolithic in submerged rocks (see below).

**Literature**  
FAFBI; Biggs and Kilroy, 2000.

---

Fig. 4.10. Left: *Lyngbya vandenberghenii* on and in a cobble from the River Tees at Blackwell Bridge, Co. Durham. (Scale bar: 1 cm; photo: MGK); right: microscopic view of Lyngbya filaments with (inset) sheath indicated with an arrow (photo: CFC)
4.4.8 *Microcoleus Desmazières ex Gomont 1892*

**Species**
3-4 freshwater/terrestrial species. Use CD-ROM.

**Macrosopic appearance**
Mats

**Microscopic appearance**
Unbranched or sparsely-branched filaments consisting of a number of trichomes, often twisted to give a rope-like appearance, within a single, usually colourless, sheath. The trichomes lack heterocysts

**Don’t confuse with**
*Schizothrix* p. 43 (sheathes usually narrower), *Hydrocoleum* (broad trichomes (> 8 µm) with distinctive end cells (see FAFBI p. 84)).

**Look for**
Rope-like bundles of trichomes within a single sheath

**Habitat and ecology**
Standing or slow-flowing waters, also terrestrial habitats including moist soil and quarry bottoms. Can form mats in terrestrial and damp habitats, as well as occurring in fully submerged environments (often associated with vegetation).

**Literature**
FAFBI

---

Fig. 4.11. a. filaments of *Microcoleus* interwoven around a bryophyte leaf from a damp churchyard; b. *Microcoleus* sp. from Nene gravel pits (photos: CFC).
4.4.9 *Nostoc (Vaucher 1803) Bornet et Flahault 1886*

**Species**
16. Use CD-ROM

**Macroscopic appearance**
Gelatinous or leathery structures with a distinct outer layer.

**Microscopic appearance**
A compact, cohesive mucilage with numerous unbranched filaments of bead-like cells and slightly larger heterocysts.

**Don’t confuse with**
*Anabaena* does not have distinct sheath and does not form large rubbery colonies. Growth of a green alga, *Coccomyxa* can have a similar appearance but this species is largely terrestrial in habit. It is not included in the key. Watch out for distinct chloroplasts within the cells.

**Look for**
Distinctive growth form and chains of bead-like cells, rubbery colonies.

**Habitat and ecology**
Found in many habitats, from terrestrial environments to lake edges through to fast-flowing streams and lake edges.

**Literature**
FAFBI; Mollenhauer et al. (1999)

---

Fig. 4.12. Left: *Nostoc commune* growing amidst limestone chips on a driveway in Galloway, South west Scotland. Scale bar (main photo): 5 cm. The detail shows a single colony (photo: MGK); right: *Nostoc commune*, microscopic view showing the chains of bead-like cells. The detail shows a single filament with a heterocyst (arrowed). Scale bar (detail): 5 µm (photos: MGK)
4.4.10 *Oscillatoria (Vaucher 1802) Gomont 1892*

**Species**  
33. (34) Use CD-ROM

**Macroscopic appearance**  
Loose dark green, brown or dark brown mats and flocs which readily break up in the hand.

**Microscopic appearance**  
Cylindrical, motile trichomes without an obvious sheath with cells mostly much wider than long.

**Don’t confuse with**  

**Look for**  
*Oscillatoria* is characterized by strong gliding motility and the absence of a sheath.

**Habitat and ecology**  
Mostly found in still and slow-flowing waters. *Oscillatoria* is a common constituent of lake phytoplankton but a number of species are benthic in habit. These can sometimes detach from the bottom sediments due to the formation of gas bubbles and, in a few cases, have been linked to symptoms of blue-green algal toxicity.

**Literature**  
FAFBI; Anagnostidis and Komarek, 1988; Biggs and Kilroy, 2000; Wehr and Sheath, 2003.

---

Fig. 4.13. a) mats of *Oscillatoria limosa* floating in Upper Lough Erne, Co. Fermanagh (scale bar: 1 cm); b) and c) same mats as viewed under the microscope. Note the absence of an obvious sheath (scale bar: 10µm).
4.4.11 Phormidium (Kuetzing 1843) Gomont 1892

**Species**
22. Use CD-ROM

**Macrosopic appearance**
Gelatinous dark brown, dark green or reddish skin-like mats, which on drying out form thin, paper-like or leathery fragments. Often with a distinctive musty odour.

**Microscopic appearance**
Slightly, to intensely waved trichomes with a thin mucilaginous sheath and cells often as long as or longer than wide. The final part of the trichome may taper and the terminal cell is often distinctive often rounded or narrowing and sometimes possessing a calyptra (membranous cover)

**Don’t confuse with**

**Look for**
Unbranched filaments lacking heterocysts and not strongly motile. Each sheath contains a single trichome (cf *Schizothrix*).

**Habitat and ecology**
Attached to substratum or as floating colonies. *Phormidium* mats can be found across a wide range of nutrient conditions.

**Literature**
FAFBI; deNicola and deEyto, 2004.

Fig. 4.14. *Phormidium autumnale* from the Waterfoot River, Pettigo, Co. Donegal. a) moist purplish-black flakes of a *P. autumnale* mat on an exposed boulder (the hand lens is 7 cm long); b) low magnification view of exposed filaments at the edge of a piece of mat; c) high magnification view of filaments; d) a short trichome in an otherwise empty sheath (scale bar for c) and d): 10 µm.
4.4.12 *Plectonema (Thuret) Gomont 1892*

<table>
<thead>
<tr>
<th>Species</th>
<th>9. Use CD-ROM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macroscopic appearance</strong></td>
<td>Mats and felts on rocks or loosely associated with macrophytes</td>
</tr>
<tr>
<td><strong>Microscopic appearance</strong></td>
<td>Straight trichomes with single or double false branches, enclosed in a firm sheath, no heterocysts; several species are very thin (i.e. &lt; 4 µm wide) but <em>P. tomasininum</em> is 11-22 µm wide.</td>
</tr>
<tr>
<td><strong>Don’t confuse with</strong></td>
<td><em>Lyngbya</em> p. 36 (lacks false branches), <em>Tolypothrix</em>, p. 46 (has heterocysts)</td>
</tr>
<tr>
<td><strong>Look for</strong></td>
<td>Combination of false branching and absence of heterocysts.</td>
</tr>
<tr>
<td><strong>Habitat and ecology</strong></td>
<td>Wide ecological amplitude, including wet ground, seepages and littoral regions of ponds, lakes and streams</td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td>FAFBI</td>
</tr>
</tbody>
</table>

Fig. 4.15....
4.4.13 Rivularia (J. Agardh 1824) Bornet et Flahault 1886

Species 9.

Macroscopic appearance Brown or dark brown hemispherical to subspherical colonies, which sometimes spread out into cushion-shaped growth up to about 2 cm in diameter.

Microscopic appearance Colonies (often calcified) composed of tapering filaments, each with a heterocyst at the base and enclosed within a sheath.

Don’t confuse with Calothrix p. 31, Dichothrix p. 33, Homoeothrix p. 35.

Look for Dark, shiny brown or olive green colonies.

Habitat and ecology Often in streams that receive peat drainage, and the juxtaposition of peat and calcareous geology giving rise to intermittent short bursts of high phosphorus concentrations in an environment that otherwise has low concentrations of available phosphorus.

Literature FAFBI; Livingstone and Whitton, 1984.

Fig. 4.16. Left: Rivularia colonies (maximum size ≈ 1 cm) in an inflow stream to Sunbiggin Tarn, Cumbria, UK. Right: A Rivularia colony, showing the characteristic tapering trichomes. Below: Trichome with terminal heterocyst.
### 4.4.14 Schizothrix (Kuetzing 1843) Gomont 1892

<table>
<thead>
<tr>
<th>Species</th>
<th>16. (17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macroscopic appearance</td>
<td>Upright bundles, flat leathery mat, cushion, hemisphere, bushy or floating flocs. Can cover considerable areas of stream beds, and be of various colours including blue-green, green, pink, red, grey, and brown.</td>
</tr>
<tr>
<td>Microscopic appearance</td>
<td>Straight or slightly wavy trichomes, sometimes with false branching, usually many trichomes within one sheath.</td>
</tr>
<tr>
<td>Don’t confuse with</td>
<td>Some forms of Homoeothrix p. 35, Phormidium p. 40.</td>
</tr>
<tr>
<td>Look for</td>
<td>Groups of narrow (&lt; 3 µm) filaments enclosed in a common sheath.</td>
</tr>
<tr>
<td>Habitat and ecology</td>
<td>Some species grow submerged, but many occur in habitats which fall dry for some time during the year.</td>
</tr>
<tr>
<td>Literature</td>
<td>FAFBI; deNicola and de Eyto, 2004.</td>
</tr>
</tbody>
</table>

![Schizothrix](image)

**Fig. 4.17.** a) Schizothrix growing on a damp rock face near Claerwen reservoir, Powys, Wales; b) a portion of the Schizothrix mat of *S. calcicola*; c) microscopic view of *S. calcicola* showing a bundle of trichomes (photos: CFC).
4.4.15 Scytonema (C. Agardh 1824) Bornet et Flahault 1886

**Species**
6. Use CD-ROM

**Macroscopic appearance**
Yellowish-brown to brown cushion-shaped colonies which can be several centimetres across and which may bear an uncanny resemblance to sheep or horse droppings.

**Microscopic appearance**
Filaments with trichomes in a thick sheath that is usually heavily pigmented. Single or double false branching is present (sometimes only occasional). Heterocysts are usually intercalary but occasionally occur at the end of trichomes.

**Don’t confuse with**
Tolypothrix p. 46 (false branching from heterocysts, not vegetative cells as in Scytonema) and never with double false branches. Plectonema p. 41.

**Look for**
Thick sheath and at least occasional double branches.

**Habitat and ecology**
On wet ground and in shallow, still water; sometimes in outlet of streams and rivers. It can also grow on trees in humid districts. Our experience is that Scytonema is restricted to pristine and near-pristine environments in base-rich areas.

**Literature**
FAFBI; Biggs and Kilroy, 2000.

---

Fig. 4.18. a) Colonies of Scytonema on damp ground in the vicinity of Sunbiggin Tarn, Cumbria, UK (scale bar: 5 cm); b) filament showing the thick, pigmented sheath and a single false branch and basal heterocyst (scale bar: 10 μm); c) another filament, this time showing a characteristic double false branch (scale as for b).
4.4.16 *Stigonema* (C. Agardh 1824) Bornet et Flahault 1886

**Species**

7.

**Macroscopic appearance**

Small dark green, brown or almost black cushions, crusts or turfs when wet.

**Microscopic appearance**

True branching trichomes with rounded cells usually in multiple rows. Heterocysts usually present.

**Don’t confuse with**


**Look for**

True branching;

**Habitat and ecology**

Characteristic of submerged rocks in streams and humid environments which are occasionally submerged.

**Literature**

FAFBI; Biggs and Kilroy, 2000.

4.19. *Stigonema mamillosum*: left: *Stigonema* colonies (arrowed) growing in the “splash zone” just above water level on a boulder in the Atma River in Norway (scale bar: 1 cm); centre: low magnification view of colonies, showing side branches arising from central filament; right: high magnification view of filament.
4.4.17 Tolypothrix (Kuetzing 1843) Bornet et Flauhault 1886

Species 4. Use CD-ROM

Macroscopic appearance Tufts, cushions, mats and felts ranging in colour from dark blue-green to almost black.

Microscopic appearance Long, straight and not tapering blue-green trichomes in a thin, firm, usually colourless sheath. Occasional single (never double) false branches, always starting with a heterocyst.

Don’t confuse with Dichothrix p. 33 (but Dichothrix has tapering trichomes and a thick brown sheath), Plectonema p. 41 (no heterocysts); Scytonema p. 44 (usually heavily pigmented sheath, single or double false branches that do not end in a heterocyst).

Look for Single false branches with heterocysts, lack of double false-branches.

Habitat and ecology Lakes and streams, usually with low levels of pollution and often base rich. Typically on rocks in shallow, agitated water.

Literature FAFBI; Wehr and Sheath, 2003; Biggs and Kilroy, 2000.

4.20 a) Tolypothrix penicillatus growing on the side of a cistern in a calcareous stream near Whitbarrow, south Cumbria. The largest growth is approximately one centimetre across; b) microscopic view. Note the clear sheath and single false branch with a basal heterocyst (scale bar: 10 µm).
5. CHLOROPHYTA AND XANTHOPHYTA

5.1 Introduction

These two groups are combined in the key below because it is often difficult to distinguish them using morphological properties alone. The standard test to distinguish Chlorophyta from Xanthophyta is to add a drop of iodine to the specimens on the slide; green algae (Chlorophyta) have starch as their storage product and this is stained dark brown by the iodine whilst Xanthophyta have chrysolaminarin as their storage product and this does not react with iodine. However, there are sufficiently few filamentous Xanthophyta that are common that it is also possible to write a single key to both groups, with the iodine test reserved for confirming difficult cases. This, indeed, was the practice in the past (see West and Fritsch, 1927), before the distinction between the two groups (equivalent to the difference between mammals and molluscs) was fully appreciated.

The list of taxa is confined to those likely to be encountered in rivers. This means that a number of terrestrial and semi-terrestrial genera (e.g. Apatococcus, Desmococcus, Trentepolia, Trebouxia) have been omitted, along with some desmids (e.g. Pleurotaenium) which occasionally form macroscopic growths in bog pools and similar habitats.

The charophytes are also included in this chapter. These are structurally-complex algae which bear a superficial resemblance to horsetails (Equisetum sp.), consisting of a main branch with, at intervals, whorls of short lateral branchlets. The nature of their relationship to the Chlorophyta has been discussed at length, with them variously being treated as a distinct phylum (“Charophyta”), a class within the Chlorophyta (“Charophyceae”) or an order within a class of the Chlorophyta (“Charales”). They are treated only briefly in this volume, with more details given in Moore (1986) and FAFBI.

5.1.1 Chlorophyta (green algae)

Chlorophyta are the closest algal relatives of higher plants and contain similar pigments, primarily chlorophyll $a$ and $b$ together with carotene and xanthophyll as accessory pigments. Their storage product is usually starch (occasionally lipids) and their cell walls are mostly cellulose. Flagellated cells have from one to many flagella of approximately equal length and apically inserted. This is a large division of algae that are very common in both standing and running waters. Many of the macroalgal representatives are filamentous, forming either branched or unbranched colonies or flocs but a few are thalloid or form crusts. They are usually bright to dark green in colour (occasionally yellow-green).
<table>
<thead>
<tr>
<th>Genus (arranged by Order)</th>
<th>See page</th>
<th>FAFBI page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tetrasporales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tetraspora</em> Link 1809</td>
<td>74</td>
<td>374</td>
</tr>
<tr>
<td><strong>Volvocales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Haematococcus</em> C. Agardh emend. Flowtow 1844</td>
<td>63</td>
<td>399</td>
</tr>
<tr>
<td><strong>Sphaeropleales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Hydrodictyon</em> Roth 1800</td>
<td>64</td>
<td>451</td>
</tr>
<tr>
<td><strong>Oedogoniales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bulbochaete</em> C. Agargh 1817</td>
<td>58</td>
<td>500</td>
</tr>
<tr>
<td><em>Oedogonium</em> Link 1820</td>
<td>69</td>
<td>504</td>
</tr>
<tr>
<td><strong>Chaetophorales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chaetophora</em> F. Schrank 1783</td>
<td>59</td>
<td>528</td>
</tr>
<tr>
<td><em>Draparnaldia</em> Bory 1808</td>
<td>61</td>
<td>530</td>
</tr>
<tr>
<td><em>Gongrosira</em> Kuetzing 1843</td>
<td>62</td>
<td>534</td>
</tr>
<tr>
<td><em>Stigeoclonium</em> Kuetzing 1843</td>
<td>73</td>
<td>547</td>
</tr>
<tr>
<td><strong>Microsporales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Microspora</em> Thuret 1850</td>
<td>66</td>
<td>539</td>
</tr>
<tr>
<td><strong>Ulotrichales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ulothrix</em> Kuetzing 1833</td>
<td>75</td>
<td>553</td>
</tr>
<tr>
<td><strong>Klebsormidiales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Klebsormidium</em> P.C. Silva, Mattox et W.H. Blackwell 1972</td>
<td>65</td>
<td>555</td>
</tr>
<tr>
<td><strong>Cladophorales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Aegagropila</em> Kützing 1843</td>
<td>57</td>
<td>557</td>
</tr>
<tr>
<td><em>Chaetomorpha</em> Kützing 1845</td>
<td>71</td>
<td>560</td>
</tr>
<tr>
<td><em>Cladophora</em> Kuetzing 1843</td>
<td>60</td>
<td>563</td>
</tr>
</tbody>
</table>
Genus (arranged by Order)  
See page  
FAFBI page  

*Rhizoclonium* Kuetzing 1843  
71  
564  

**Prasiolales**  

*Prasiola* [C. Agardh] Meneghini 1838  
70  
567  

**Ulvales**  

*Monostroma* Thuret 1854  
67  
541  

*Ulva* Wulfen 1803 (formaly *Enteramorpha*)  
76  
575  

**Zygnematales**  

*Mougeotia* C. Agardh 1824  
68  
579  

*Spirogyra* Link 1820  
72  
587  

*Zygnema* C. Agardh 1824  
77  
602  

*Zygogonium* Kuetzing 1843  
78  
608  

### 5.1.2 Charophyta

The Charophyta contain the same pigments and storage pigments as Chlorophyta. They have a unique oogamous mode of reproduction, with gametangia developing from the nodal cells of branchlets. More details (including a pictorial glossary) are given in FAFBI. All genera found in the UK belong to a single order, Charales.

Genus  
See page  
FAFBI page  

*Chara* Linnaeus 1753  
79  
744  

*Nitella* C. Agardh 1824  
81  
756  

*Nitellopsis* Hy 1889  
82  
763  

*Tolypella* (A. Braun) A. Braun 1857  
83  
763  

### 5.1.3 Xanthophyta (yellow-green algae)

Xanthophyta contain the green pigments chlorophyll *a* and *c* together with carotenes and xanthophylls as the accessory pigments. Their storage product is chrysosaminaran and their cell walls are made from cellulose. Any flagellated stages have one or two apically-inserted flagellae of equal length. Only a few genera form growths that are recognizable with the naked eye. They are green or yellow-green in colour which means that they can be confused with taxa belonging to the Chlorophyta; however Xanthophyta have a negative reaction to the iodine test.
<table>
<thead>
<tr>
<th>Genus (arranged by Order)</th>
<th>See page</th>
<th>FAFBI page</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Tribonemates</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Tribonema</em> Derbes et Solier 1856</td>
<td>84</td>
<td>333</td>
</tr>
<tr>
<td><em>Vaucheriales</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Vaucheria</em> de Candolle 1805</td>
<td>85</td>
<td>336</td>
</tr>
</tbody>
</table>

### 5.2 How to identify filamentous Chlorophyta and Xanthophyta

Before you start using the key to filamentous greens and Xanthophyta you will need to understand some of the terms that are used to describe these groups. The most important of these refer to whether or not filaments are branched (and, if so, how they branch), and to the number, shape and location of chloroplasts.

Branching, if present, may be **dichotomous** (i.e. both branches are approximately the same time) or unequal, with smaller branches arising from a single main stem. These side branches may arise **alternately** or in groups of two or more from points along this stem.

![Branching patterns in green algae: a. dichotomous branching; b. side branches arising alternately from a main axis; c. side-branches arising in pairs from main axis.](image)

**Chloroplasts** can be either aligned along the median axis of the cell ("axial") or lie just inside the cell wall ("parietal"). In many cases, the shape of individual chloroplasts can be determined (Fig. 5.2: a-d, f.) but in others, the entire cell seems to be an almost uniform green colour. Such cells have "**reticulate**", or net-like, chloroplasts (Fig. 5.2: e). You may also be able to see darker green patches within the chloroplast: these are pyrenoids, organelles which contain especially high concentrations of enzymes responsible for fixing carbon dioxide. The presence and number of pyrenoids can also be a useful diagnostic feature.
In addition to branching patterns and chloroplast features there are a few properties that are found only in one or a few genera and which can be extremely useful for identifying these. The genus *Oedogonium*, in particular, has a unique type of cell division which results in the formation of “caps” at the apex of some cells. The presence of **cap cells** is a useful diagnostic for *Oedogonium*.

---

**Fig. 5.2.** Types of chloroplast.  
- a. discoid (disc-shaped) parietal chloroplasts;  
- b: lobed parietal chloroplast;  
- c: plate-like axial chloroplast;  
- d. helical chloroplast (parietal);  
- e. reticulate (net-like) chloroplast (parietal);  
- f. stellate (star-like) chloroplasts.

---

**Fig. 5.3.** Schematic diagram showing cap cells in a filament of *Oedogonium*.

Other genera have a tendency to break in the middle rather than at the ends so chains of cells end with distinctive H-shaped fragments.
Fig. 5.4. Schematic diagram showing H-shaped ends in a filament of cells (a), alongside a filament of cells that lacks H-shaped ends (b).

It is always a good idea to record the dimensions of the specimens you are trying to identify. In particular, record the width of the filament, and also the length of the cells. Dimensions are rarely useful for naming genera but are important if you want to go on to name the species.

5.3 Keys to Chlorophyta and Xanthophyta

5.3.1 Key to filamentous green and yellow-green algae

1a Filaments unbranched ........................................ 2
1b Filaments branched ........................................ 9

2a Cap cells present ................................................. OEDOGONIUM (p. 69)
2b Cap cells absent .............................................. 3

3a Filaments terminate in H-shaped fragments. ........................................ 4
3b Filaments do not terminate with H-shaped fragments ........................................ 5

4a Reticulate chloroplast ........................................ MICROSPORA (p. 66)
One to many disc-shaped chloroplasts

TRIBONEMA (p. 84)

Filaments coarse to the touch, reticulate chloroplast,

RHIZOCLONIUM (p. 71)

Not coarse to the touch, often slimy, chloroplasts various but not reticulate.

……. 6

Rhizoclonium can have short uni- or multicellular “rhizoidal branchlets; these are much narrower than cells of the main axis. R. hieroglyphicum, the only species found in UK and Ireland freshwaters has these branchlets only rarely, if at all. Note, too, that Cladophora can be very sparsely branched.

Helical chloroplast

SPIROGYRA (p. 72)

Star-shaped chloroplast(s)

…….. 7

Single flat plate-like chloroplast

MOUGEOTIA (p. 68)

Single parietal chloroplast

……. 8

Two star-shaped chloroplasts, cytoplasm clear

ZYGNEMA (p. 77)

Two oval-shaped chloroplast, cytoplasm may have a purplish tinge.

ZYGOGONIUM (p. 78)

Chloroplast encircling most of cell circumference (usually ≥ 80%), usually not lobed; knee joints absent; up to 70 μm in diameter

ULOTHRIX (p. 75)

Chloroplast encircling only a proportion (usually ≤ 80%) of the cell circumference, usually lobed; knee-joints often present; up to 20 μm in diameter.

KLEBSORMIDIUM (p. 65)

Fig. 5.5. Schematic diagram showing difference between chloroplasts of Ulothrix (a) and Klebsormidium (b).
9a  Coarse robust filaments, not slimy, typically 30 -50 µm wide, either reticulate chloroplast within broad cells or many small disc-like chloroplasts within broad filament lacking divisions into individual cells.  

9b  Slimy, narrower filaments, ≤ 30 µm

*Rhizoclonium* is narrow (≤ 37 µm) but coarse to the touch. It is unbranched but may possess short rhizoidal branchlets. It also has a lower length:breadth ratio (2-5) than *Cladophora* (3-8)

10a  Sparsely to profusely-branched filaments in tufts trailing in the water, up to 30 cm or more in length  
Cladophora (p. 60)

10b  Strongly branched filaments, usually forming mats, with individual filaments typically < 3 cm  
Aegagropila (p. 57)

10c  Cushions up to 20 cm across composed of vertical filaments (sometimes prostrate); microscopic examination reveals long tubular filaments with many disc-like chloroplast. The filaments are easily ruptured, releasing the chloroplasts into the surrounding water.  
Vaucheria (p. 85)

11a  Reticulate chloroplasts, side branches short and terminating in long colourless hairs with a bulbous base.  
Bulbochaetae (p. 58)

11b  Parietal chloroplasts; side branches of various lengths and may or may not end in long colourless hairs. If a hair is present, then the base is not swollen.  

…… 12

12a  Main axis with tufts of branches arising from the main stem.  
Draparnaldia (p. 61)

12b  Dichotomously-branched filaments with no single main axis  
…… 13
13a Films or mats, slimy to the touch but generally not forming distinct colonies or cushion; hairs may or may not be present

STIGEOCLONIUM (p. 73)

13b Forms distinct, firm, gelatinous colonies composed of well branched filaments tapering to fine apices; hairs may or may not be present

CHAETOPHORA (p. 59)

*Gongrosira* is related to *Draparnaldia, Stigeoclonium* and *Chaetophora* but the branched filaments form crusts or cushions impregnated with calcium carbonate.

### 5.3.2. Key to thalloid green algae

1a Thallus tubular and yellow to bright green, most obvious in summer when it is often free-floating or loosely-attached to substrates

ULVA (p. 76)

1b Thallus flat, formed from a single layer of cells

...... 2

2a Membrane-like fronds, up to 15 cm across, attached by a basal disc, composed of cells each with a parietal chloroplast with one or more pyrenoids

MONOSTROMA (p. 67)

2b Membrane-like fronds, up to 20 cm across, attached by a single-celled rhizoid or a few-celled holdfast, with a stipe gradually developing; cells each with an axial star-shaped chloroplast with a single pyrenoid

PRASIOLA (p.57)

### 5.3.3 Key to Characeae

1a Whorls of secondary branches arising from a main stem; nodes and internodes with spines; stems also have outer cortex of cells, which appear as faint parallel lines; stem and branches often calcified

CHARA (p. 79)

1b Whorls of secondary branches arising from main stem but nodes and internodes lack spines, outer cortex lacking; stem and branches may or may not be calcified

...... 2

2a Branchlets undivided

NITELLOPSIS (p. 82)
2b  Branchlets divided

Undivided branchlets are also encountered in *Lamprothamnium*, which is confined to brackish and coastal habitats

3a  Branchlets divided one or more times into single-celled segments of similar length; not calcified. Balls of fertile branches not present. Rarely calcified.  

*NITELLA* (p. 81)

3b  Branchlets divided into multicellular segments of unequal length. Short, fertile branches curve inwards to form loose “balls”. Often calcified.  

*TOLYPELLA* (p. 83)
5.4 Descriptions of Chlorophyta genera

5.4.1 Aegagropila Kützing 1843

Species
1. Aegagropila limnei Kützing 1843  (syn: Cladophora aegagropila (Linnaeus) Trevisan 1845)

Macrosopic appearance
Mat-like growth form in rivers. In some lakes C. aegagropila can form loose-lying growths over soft (sandy or muddy) substrata, which can be dislodged, forming spherical “Cladophora balls” which can accumulate in sheltered bays.

Microscopic appearance
Extensively branched, dark green; thick walled cells.

Don’t confuse with
As balls, not likely to be confused with any other species, but mat-like growths can occur in similar habitats to Cladophora in rivers.

Look for
Soft green balls in shallow waters. Extensively branched filaments.

Habitat and ecology
Along pond and shallow lake margins and in rivers. Found in base-rich conditions; however, A. limnei is absent from heavily enriched rivers where Cladophora glomerata is prolific.

Literature
FAFBI.

Fig. 5.6. Aegagropila limnei: a. “Cladophora ball” from a domestic aquarium (scale bar: 1 cm; photo: MGK); b. microscopic view of a population from the Hebrides (scale bar: 25 µm; photo: CFC).
5.4.2 Bulbochaete C. Agargh 1817

**Species**
18. Reproductive stages required

**Macroscopic appearance**
Epilithic or epiphytic green, branched filaments intermingled with other green algae.

**Microscopic appearance**
Branched filaments of cells with one long hair with a bulbous base and terminal cells with two of these hairs. Chloroplasts parietal and net-like usually with several pyrenoids.

**Don’t confuse with**
*Oedogonium* p. 58 (no hairs), forms of *Chaetophora* p. 59.

**Look for**
Conspicuous bulbous hairs.

**Habitat and ecology**
Attached to plants or other hard substrata. Usually found in standing waters, occasionally in streams and rivers. Huxley and Pentecost (2002) report that it occurs over a wide range of pH and nutrient conditions although it is not found in highly enriched sites. The presence of long, colourless hairs may suggest that *Bulbochaete* is able to use extracellular phosphatases to metabolise organic phosphorus sources in the environment (Whitton, 1988).

**Literature**
FAFBI; Whitton, 1988; Biggs & Kilroy, 2000.

---

![Fig. 5.7.](image)

a. A mass of green algae (predominately Bulbochaete sp) smothering stones on the bed of the River Ehen, December 2014. The effect of the numerous colourless hairs of the algae is to create a translucent “haze” over the top of the mass of green filaments; b. branched filament of *Bulbochaete* from the River Ehen (scale bar: 10 μm; photos: MGK)
5.4.4 Chaetophora F. Schrank 1783

Species 4.

**Macrosopic appearance** Bright green firm jelly-like growths up to 1 cm which can be branched and lobed/nodulated, spherical, hemispherical or tubular.

**Microscopic appearance** Prostrate system of rounded cells and densely-branched erect filaments ending in a bluntly pointed cell or a long hair. Chloroplasts parietal and sometimes band-like.

**Don’t confuse with** *Stigeoclonium* p. 73 (forms streaming tufts, often with a slimy feel).

**Look for** Distinctive jelly-like growths.

**Habitat and ecology** Most commonly found in cool, clean and moderate- to fast-flowing streams, lakes, ponds and bogs. Most field populations have colourless hairs, suggesting an ability to use organic phosphorus sources to overcome phosphorus limitation (Gibson & Whitton, 1987a, b).

**Literature** FAFBI; Gibson & Whitton, 1987a,b; Biggs & Kilroy, 2000; John, 2003.

---

**Fig. 5.8.** *Chaetophora* colonies growing on a submerged twig (scale bar: 1 cm); b., c. microscopic views of *Chaetophora* sp. (photos: CFC).
5.5.6 Cladophora Kützing 1843

Species

1. _Cladophora glomerata_ (Linnaeus) Kützing 1843. A number of other species may be found in brackish and marine habitats, and care should be taken at sites close to the tidal limit.

Macroscopic appearance

Green (or brownish through epiphytes), branched filaments from a few centimetres to a metre or more in length, sometimes smothering almost the entire substratum. The filaments are attached horizontal to the substratum, mostly rocks and usually feel rough rather than slimy.

Microscopic appearance

Branched filaments of elongated cells of granular appearance through net-like parietal chloroplast with pyrenoid, often with many epiphytes. Occasionally, unbranched forms may be encountered.

Don’t confuse with

_Rhizoclonium_ p. 71, _Vaucheria_ p. 85, _Oedogonium_ p. 69

Look for

Robust branched filaments, rough to the touch. The branching should be visible through a hand-lens; if no branching can be seen the material must be checked under the microscope.

Habitat and ecology

Common in standing and flowing, waters of moderate to high alkalinity. Present across the entire nutrient gradient but is most prolific in nutrient-rich water (Whitton, 1970; Dodds et al., 1992). Intolerant to heavy metals (Whitton et al., 1989).

Literature

FAFBI; Biggs & Kilroy, 2000; Bolas & Lund, 1974; Dodds & Gudder, 1992; Parker & Maberley, 2000; Planas _et al._, 1996; Whitton, 1970.

Fig. 5.9. a. _Cladophora glomerata_ smothering a river bed (River Team, Co. Durham) and b. a single cobble from the stream bed; c. microscopic view showing branched filaments (scale bar: 50 µm).
5.5.7 Draparnaldia Bory 1808

Species
1. Draparnaldia glomerata (Vaucher) C. Agardh 1824

Macroscopic appearance
Light green, soft, slimy masses of filaments up to about 50 cm long attached by rhizoids. The ratio of mucilage to filaments can vary considerably (see below).

Microscopic appearance
Thick central filament with densely branching tufts of filaments ending in a blunt cell or a fine, multicellular hair. Cells contain one parietal chloroplast, which is narrower than the cell and extends partially round the cell.

Don’t confuse with
Stigeocolonium p. 73 (lacks a single main stem), Chaetophora p. 59.

Look for
Distinctive microscopic appearance (see below)

Habitat and ecology
Found in streams, ditches, springs, canals and shallow peaty lakes. Field populations almost always have colourless hairs, suggesting an ability to utilise organic phosphorus at times of phosphorus limitation, although hair formation can be suppressed in the laboratory under nutrient rich conditions (Gibson & Whitton, 1987a, b; Whitton, 1988).

Literature
FAFBI; Biggs & Kilroy, 2000; Gibson & Whitton, 1987a,b; Whitton, 1988.

Fig. 5.10. Draparnaldia. a) microscopic view of material from the Terman River, Co. Donegal / Co. Fermanagh showing tufts of side-branches arising from the main stem (scale bar: 10 µm); b – d: variation in growth forms: b) gelatinous mass from a tributary of the River Ribble (scale bar: 1 cm); c) branched form from outflow of Harrop Tarn, Cumbria (scale bar: 1 cm); d) long skeins from the Terman River, Ireland.
5.5.8 Gongrosira Kuetzing 1843

Species 9.

**Macroscopic appearance** Cushion-like or hard, greenish crust ranging from 2 mm to several cm in diameter, often calcified. Nine species are described in FAFBI of which *G. incrustans* is the most common.

**Microscopic appearance** Uniseriate filaments, erect system consisting of sparsely-branched filaments with blunt apices, cells cylindrical or somewhat inflated usually with thick laminated walls and parietal chloroplasts. Calcite crystals are often visible within the matrix of the colony.

**Don’t confuse with** Small forms of *Chaetophora* p. 59.

**Look for** Dense, compact and small green colonies.

**Habitat and ecology** Found on any surface among the marginal shallows of ponds, lakes and rivers, particularly in hard water areas. Insufficient data to establish the nutrient preferences of the genus with any certainty, though our experience is that *Gongrosira* usually prefers unpolluted conditions.

**Literature** FAFBI; John & Johnson, 1989.

Fig. 5.11. *Gongrosira incrustans* from downstream Bonniconlon Village, Srafaungal River, Co. Mayo, Ireland. a) macroscopic view of the small green colonies on a stone; b) low power view of the erect system; c) high power view of the erect filaments (scale bar: 5 µm). Photos: BK.
5.5.9 *Haematococcus C. Agargh emend. Flotow 1844*

**Species**

Macroscopic appearance: Red crust lacking a distinct outline.

Microscopic appearance: Unicells that are elliptical or almost spherical in outline. Cytoplasm contains astaxanthin, a red carotenoid, which obscures cell contents. The red crusts are formed from non-motile aplanospores.

Don’t confuse with: *Hildenbrandia* p. 96 (usually on flat or convex surfaces, colonies have distinct outline).

Look for: Bright red colour in shallow waters.

Habitat and ecology: Common in hard water areas, particularly in small pools, cattle troughs, bird baths etc. that are only intermittently wetted. The bright red colour intensifies when the cells are starved of nitrogen.

Literature: FAFBI.

---

Fig. 5.12. a) *Haematococcus pluvialis* in a dried-out bird bath in London; b) *H. pluvialis* on limestone pavement in the River Nent, Cumbria (photos: MGK); c. microscopic view of resting stages (photo: CFC).
5.5.10 Hydrodictyon Roth 1800

Species
1. Hydrodictyon reticulatum (Linnaeus) Lagerheim 1883

Macroscopic appearance
Free-floating or secondarily attached coenobium in the form of sac-like or plate-like nets of cylindrical cells.

Microscopic appearance
Cylindrical to oblong-oval or spherical cells with thin cell walls and perforated parietal chloroplast with many pyrenoids.

Don’t confuse with
Cladophora p. 60 (although a close examination with naked eye or hand lens should be sufficient to reveal the net-like structure of Hydrodictyon p. 64).

Look for
Green net-like structures.

Habitat and ecology
Usually free-floating in ponds, small lakes or secondarily attached in slow-moving rivers, streams and irrigation ditches (e.g. Jubilee River, Thames Region). The characteristic habitat is eutrophic standing or running waters; however, there are exceptions (e.g. upland wetlands around Sunbiggin Tarn, Cumbria). There are reports that Hydrodictyon has become more widespread in recent years, reaching nuisance quantities in some situations. Longer, warmer summers are suggested as one possible reason (John et al., 2001).

Literature
FAFBI, Flory & Hawley, 1994;

Fig. 5.13. a. Mat of Hydrodictyon reticulatum from the lower River Tweed (photo: MGK). b. macro and c. microscopic views of coenobia of H. reticulatum from Thrapston Lake, Northampton (photos: CFC).
5.4.11 Klebsormidium P.C. Silva, Mattox et W.H. Blackwell 1972

Species 8.

**Macroscopic appearance** Bright-green to yellow-green flocs and filamentous flocs, slimy to the touch.

**Microscopic appearance** Uniseriate, unbranched filaments of cylindrical or barrel-shaped cells with single parietal chloroplasts only encircling a proportion of cell circumference (normally less than 80%) although this can be hard to determine. Several species have characteristic ‘knee joints’ (see Fig. 39).

**Don’t confuse with** Ulothrix p. 75 (chloroplast encircles a larger proportion of the cell circumference).

**Look for** Narrow, unbranched filaments, chloroplast structure, knee joints.

**Habitat and ecology** *Klebsormidium* occurs in a wide range of environments, including terrestrial and sub-aerial habitats, highly acid streams and heavy metal-enriched environments.


![Fig. 5.14. a) Klebsormidium rivulare growing in the entrance of an abandoned lead mine at Nenthead, Cumbria; b) filaments of *K. flaccidum* (photo: Fabio Rindi).](image)
5.4.12 Microspora Thuret 1850

Species 9.

Macroscopic appearance Long, deep-green filaments, often entangles around other algae or vascular plants.

Microscopic appearance Uniseriate, unbranched filaments of quadrate, cylindrical or slightly swollen cells, which have a tendency to break in the middle leaving H-shaped fragments. Single, parietal, usually net-like chloroplast without pyrenoids.

Don’t confuse with Tribonema p. 84.

Look for H-fragments at the end of broken filaments. Microspora has only one chloroplast per cell, while Tribonema has several. Microspora normally tests positively for starch.

Habitat and ecology Usually found at low nutrient concentrations. Often found dominating associations of filamentous algae at stream sites with heavy metal contamination and in acid waters. Often abundant in winter.

Literature FAFBI; Biggs & Kilroy, 2000; Foster, 1982; John, 2003.

Fig. 5.15 Microspora flocculosa from the Drish River a metal-polluted river in Co. Tipperary, Ireland. Inset a) a short filament showing the parietal chloroplasts particularly clearly; inset b) an isolated ‘H-piece’. Scale bar: 10 µm.
5.4.13 Monostroma Thuret 1854

Species 2.

Macroscopic appearance Thalli up to about 10 cm in length, organized as a number of overlapping lobes.

Microscopic appearance Appears initially sack-like, and later as a single-layered, membrane-like plate of cells, each with a single, parietal, cup-shaped chloroplast with one pyrenoid.

Don’t confuse with Ulva p. 76 (tubular thalli, resembling empty sausage skins); Prasiola (p. 70)

Look for Bright green rosette-like lobes.

Habitat and ecology Found in ponds and rivers, extending into brackish waters. More often in lowland areas and appears to be tolerant of elevated nutrient concentrations.

Literature FAFBI; John, 2003.

Fig. 5.16. a. Monostroma bullosum from a flooded field near Chichester, low magnification view; b. Monostroma sp., low magnification view; c. M. bullosum, high magnification view showing arrangement of cells within thallus (photos: CFC).
5.4.14 **Mougeotia C. Agardh 1824**

**Species**  
26. Reproductive stages required

**Macroscopic appearance**  
Yellow-green to bright-green flocs (in standing water) or filamentous flocs (in running water) (both types of growth form are visible in Fig. 36a). Mucilaginous to the touch.

**Microscopic appearance**  
Uniseriate, unattached filaments of cylindrical cells with plane end walls and generally one flat or sometimes slightly twisted plate-like chloroplast occupying most of the cell length with pyrenoids in row(s). *Mougeotia capucina* has purple sap.

**Don’t confuse with**  
*Ulothrix* p. 75 which has much shorter filaments and encircling chloroplasts.

**Look for**  
Mucilaginous flocs composed of unbranched filaments each with a single plate-like chloroplast.

**Habitat and ecology**  
Most of our records from rivers were associated with low inorganic phosphorus concentrations. It is also a common genus in littoral areas of lakes, again predominantly where inorganic phosphorus concentrations are low. *Mougeotia* can develop tolerance to heavy metals.

**Literature**  
FAFBI; Patterson & Whitton, 1981.

---

Fig. 5.17. a) *Mougeotia* in the outflow of an abandoned lead mine at Nenthead, Cumbria. b) and c) filaments of *Mougeotia* showing the flat chloroplast and conspicuous pyrenoids in two different orientations. The chloroplast rotates on its axis depending upon light intensity (Scale bar: 10 µm).
5.4.15 *Oedogonium* Link 1820

**Species**

66. Reproductive stages required

**Macroscopic appearance**

Yellow-green filaments, epilithic or epiphytic. Not slimy to the touch.

**Microscopic appearance**

Unbranched filaments of cylindrical cells, usually at least slightly asymmetric, with parietal, net-like chloroplast, usually with several pyrenoids. Cell division leads to the formation of “caps”, visible as ring-like structures, at certain places along the filament. These are often stained brown with deposited manganese and iron compounds.

**Don’t confuse with**

*Bulbochaete* p. 58 which has bulbous hairs in addition to cap cells. Coarse filaments can be mistaken for *Cladophora* (which is branched rather than unbranched) and other Cladophroaceae

**Habitat and ecology**

Grows in a wide range of habitats, in both acid and alkaline waters and in nutrient poor and nutrient rich conditions. Difficult to make generalisations about the genus but too little is known about the ecology of individual species.

**Look for**

The cap cells are the most characteristic feature.

**Literature**

FAFBI;
### 5.4.16 Prasiola [C. Agardh] Meneghini 1838

<table>
<thead>
<tr>
<th>Species</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macroscopic appearance</strong></td>
<td>Small, papery thallie, consisting of irregular greenish strands attached to soil or stones</td>
</tr>
<tr>
<td><strong>Microscopic appearance</strong></td>
<td>Single layer of cells, each 5-20 µm wide with an axile chloroplast and pyrenoid</td>
</tr>
<tr>
<td><strong>Don’t confuse with</strong></td>
<td><em>Monostroma</em> (p. 67)</td>
</tr>
<tr>
<td><strong>Habitat and ecology</strong></td>
<td>Prasiola is a largely terrestrial genus, included here to rule out possible confusions with Monostroma. It favours locations with high nitrogen concentrations, including the base of walls and lampposts frequented by dogs</td>
</tr>
<tr>
<td><strong>Look for</strong></td>
<td>Thalli composed of a single layer of cells</td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td>FAFBI, Rindi et al. (2007)</td>
</tr>
</tbody>
</table>

---

**Fig. 5.19** To follow
5.4.17 *Rhizoclonium Kuetzing 1843*

**Species**
1 (*R. hieroglyphicum*)

**Macroscopic appearance**
Coarse, unbranched green filaments, 10-37 µm wide, 2 – 5 times longer than wide

**Microscopic appearance**
Unbranched filaments, sometimes with short rhizoidal branches. Cells multinucleate and with a net-like chloroplast with several pyrenoids.

**Don’t confuse with**
*Cladophora* p. 60, which is regularly branched but which is occasionally very sparsely branched and can appear unbranched unless examined carefully. *Chaetomorpha* is a largely marine/brackish genus which is occasionally found in freshwaters. This forms unbranched filaments which are significantly wider (120 – 300 µm) than those of *Rhizoclonium*.

**Look for**
Narrower than *Cladophora* p. 60 and kinks and bends along the filament.

**Habitat and ecology**
Infrequent in freshwaters. Found at margins of streams and rivers, ponds, ditches and drains often between aquatic macrophytes and other algae, usually in enriched sites. Principally a marine genus with only few freshwater representatives.

**Literature**
FAFBI;

Fig. 5.20. *Rhizoclonium hieroglyphicum*: left: microscopic view of filament at two different focal planes; b. low magnification view of filament showing rhizoidal branches arising from main axis (photos: Chris Carter)
5.4.18 Spirogyra Link 1820

Species 49. Reproductive stages required

Macroscopic appearance Yellow-green to bright-green, very slimy flocs made out of fine filaments, often with gas bubbles near the surface.

Microscopic appearance Cells organised in unbranched filaments usually without epiphytes, cells from as wide as long to many times longer than wide with one or more (up to 16) chloroplasts with pyrenoids forming helices near the cell wall.

Don’t confuse with Other genera which form mucilaginous flocs (Zygnema p. 77, Mougeotia p. 68).

Look for Helical chloroplasts.

Habitat and ecology Typically in slower-flowing, unshaded areas of streams and rivers and in ponds and ditches, most abundant in spring and autumn. Most of our records are from environments with low to moderate nutrient concentrations. Some species are restricted to hard waters, but majority occur in soft waters.

Literature FAFBI; Biggs and Kiltroy, 2000.

Fig. 5.21  a. flocs of Spirogyra in a pond in Coxhoe, Co. Durham; b., c. filaments of a Spirogyra species with a single chloroplast from the same pond in Co. Durham; d. a multi-chloroplast Spirogyra from the River Ehen, Cumbria (scale bar: 10 µm; photos: MGK).
5.4.19 *Stigeoclonium* Kuetzing 1843

**Species**
9. both prostrate and erect system required for identification

**Macroscopic appearance**
Bright-green to yellow-green mucilaginous flocs.

**Microscopic appearance**
*Stigeoclonium* consists of a network of prostrate filaments from which a number of erect filaments arise. It is, however, difficult to see this three-dimensional structure under the microscope. Filaments are branched and consist of cells with chloroplast partially lining cell wall. Branching depends on species and can be sparse, but filaments always taper and often end in a thin hair.

**Don’t confuse with**
*Klebsormidium* p. 65 and *Ulothrix* p. 75 (both unbranched); *Draparnaldia* p. 61 (has a single main axis rather than dichotomous branches).

**Look for**
Branched tapering filaments.

**Habitat and ecology**
Common in moderate to fast-flowing streams. *Stigeoclonium* occurs right across the nutrient gradient in rivers. *Stigeoclonium tenue*, in particular, is associated with nutrient-rich and even organically-polluted water, and is tolerant to heavy metals (Harding and Whitton, 1976; Kelly & Whitton, 1989). *Stigeoclonium* is most common in spring when its mucilaginous growths can turn streambeds a vivid green.

**Literature**

Fig. 5.22. a) *Stigeoclonium tenue* on the bed of the River Nent, Cumbria, April 2007; b) microscopic view (low power) of *Stigeoclonium* from Pitsford (Northamptonshire) showing the branched filaments; c) macroscopic view of *S. tenue* attached to a submerged stone from the River Wear at Frosterley (scale bar: approximately 1 cm); d) high power view showing parietal chloroplasts (scale bar: 10 μm).
### 5.4.20 Tetraspora Link 1809

<table>
<thead>
<tr>
<th><strong>Species</strong></th>
<th>3.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macroscopic appearance</strong></td>
<td>Pale green jelly-like masses loosely attached to submerged surfaces including rocks, can be several centimetres across.</td>
</tr>
<tr>
<td><strong>Microscopic appearance</strong></td>
<td>Spherical cells, approximately 6 – 12 µm in diameter and often arranged in twos or fours. A single parietal chloroplast fills most of the cell. There is a single pyrenoid but no eyespot. Note too the presence of ‘pseudocilia’ – long, flagella-like protrusions from the cell.</td>
</tr>
<tr>
<td><strong>Don’t confuse with</strong></td>
<td>Some other green algae – e.g. Draparnaldia p. 61 – can occasionally form jelly-like growths but is easily distinguished by its filamentous appearance. Ophrydium p. 111.</td>
</tr>
<tr>
<td><strong>Look for</strong></td>
<td>Single cells in jelly matrix, with pseudocilia.</td>
</tr>
<tr>
<td><strong>Habitat and ecology</strong></td>
<td>Rocks, submerged plants, twigs, but can also become free-floating in streams and littoral zones of lakes, particularly in late winter and spring.</td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td>FAFBI.</td>
</tr>
</tbody>
</table>

---

Fig. 5.23. a) *Tetraspora gelatinosa*. a and b) macroscopic views from an ornamental lake at Turlough, Co. Mayo; c) microscopic view of a population from Windermere (scale bar: 10 µm).
5.4.21 Ulothrix Kuetzing 1833

Species

Macroscopic appearance Bright-green patches or filaments on submerged surfaces, slimy to the touch.

Microscopic appearance Unbranched filaments of cells, which are usually longer than wide, with one parietal chloroplast forming a band which encircles more than 80% of the cell.

Don’t confuse with Klebsormidium p. 65 which is usually a smaller plant with different chloroplast form.

Look for Parietal chloroplast going more or less fully around the whole cell.

Habitat and ecology Flowing and standing freshwaters, very common especially in winter and early spring. Records occur across a wide nutrient gradient in both rivers and lakes.

Literature FAFBI; Biggs & Kilroy, 2000; Graham et al., 1985;

Fig. 5.24. a.) Ulothrix zonata covering the bed of the River Wear, Wolsingham, February 2009 (photo: MGK); b.) microscopic view of Ulothrix sp. (photo: CFC)
5.4.22 *Ulva Wulfen 1803*

**Species**  
1. *Ulva flexuosa* Wulfen 1803 (syn: *Enteromorpha flexuosa* (Wulfen) J. Agardh 1883

**Macroscopic appearance**  
Filamentous, thread-like, usually branched, tubular or sac-like, attached or free-floating.

**Microscopic appearance**  
Wall only one cell thick, cells with one parietal, plate-like chloroplast.

**Don’t confuse with**  
*Monostroma* p. 67. Superficially similar but never tubular.

**Look for**  
Bright green tubular thalli (like empty sausage skins).

**Habitat and ecology**  
Cosmopolitan, usually marine, but a few freshwater taxa; can be a nuisance alga in semi-enclosed bays and slow-flowing rivers. Often favouring hard eutrophic water.

**Literature**  
FAFBI; Hayden *et al.* (2003).

---

**Fig. 5.25.** a. *Ulva flexuosa* clogging a fenland drain (Great Eau, Lincolnshire, UK (photo: MG)); b. close-up of thalli of *U. flexuosa* from the River Wear, Durham. (photo: MGK).
5.4.23 Zygnema C. Agardh 1824

Species
14. Reproductive stages required

Macroscopic appearance
Bright-green (sometimes yellow-green) flocs made of slimy filaments.

Microscopic appearance
Unbranched filaments of cells, which are usually longer than wide, with two star-shaped chloroplasts.

Don’t confuse with
Other genera which form mucilaginous flocs (Mougeotia p. 68, Spirogyra p. 72) and Zygogonium (p. 78).

Look for
star-shaped chloroplasts

Habitat and ecology
Standing waters and slower-flowing areas of streams and rivers. Most of our records for Zygnema are from water bodies with low or moderate nutrient concentrations. It is found in acid as well as circumneutral and alkaline waters.

Literature
FAFBI; Biggs & Kilroy, 2000.

Fig. 5.26. a. growth of Zygnema in shallow water on quarry floor, Whitbarrow, Cumbria (photo: MGK); b. microscopic view of Zygnema (possibly Z. stellinum) (photo: CFC).
5.4.24 *Zygogonium Kuetzing 1843*

**Species**  
14. Reproductive stages required

**Macrosopic appearance**  
Bright-green (sometimes yellow-green) flocs made of slimy filaments.

**Microscopic appearance**  
Two irregular oval-shaped chloroplasts. The cytoplasm of *Zygogonium* often has a purplish tinge and thick cell walls.

**Don’t confuse with**  
Macroscopic growths may be confused with other genera which form mucilaginous flocs (*Mougeotia* p. 68, *Spirogyra* p. 72); microscopic growths may be distinguished from *Zygmena* by the oval, rather than star-shaped chloroplasts, and the purplish tinge to the cytoplasm.

**Look for**  
Oval or star-shaped chloroplasts.

**Habitat and ecology**  
*Zygogonium* is mostly found in terrestrial habitats – particularly wet ground in acid environments, and occasionally in standing waters and slower-flowing areas of streams and rivers.

**Literature**  
FAFBI; Biggs & Kilroy, 2000.

---

**Fig. 5.27.** a. *Zygogonium ericetorum* growing on damp ground close to Hadrian’s Wall, Northumberland, UK (photo: MGK). The indentations are made by sheep’ hooves, breaking through the crust which formed as the flocs dried; b. microscopic structure, showing the two oval-shaped chloroplasts per cell, photographed at two different focal planes. Scale bar: 10 µm (photo: CFC).
5.5 Descriptions of Charophyta genera

5.5.1 Chara Linnaeus 1753

Species 16 native species plus 2 introduced species. Use FAFBI or Moore (1986). Several species can be identified from vegetative features alone, but some require reproductive organs to be present.

Macroscopic appearance Macroscopic branching thallus, up to 40 cm long, and sometimes longer, with a central “stem” from which whorls of “branchlets” arise. The main axis and branches are overlain by cortex cells which appear as lines along the axis. Some of these cortex cells develop into spines which can make the stems and branches rough to the touch. The stems and branches are also usually calcified. Fresh plants have a smell that has been compared by different people to sweetened garlic, sweat and cucumbers!

Microscopic appearance

Don’t confuse with Nitella (p. 81, Nitellopsis (p. 82) and Tolypella (p. 83) (lack calcification, cortex and whorls of branchlets.

Look for Robust “horsetail”-like plants which are rough to the touch due to spine cells and calcification.

Habitat and ecology Mostly found in calcareous ponds and lakes, although there are some records from flowing waters, and some species (e.g. C. virgata) extend into acid waters too. Some species also tolerant of brackish conditions.

Literature FAFBI; Moore, 1986; Lansdown, 2008.

Fig. 5.28. a. Habit photo showing Chara [contraria] sp in a shallow pond at Pitsford Water; b. mature plant of Chara hispida from Yardley Chase, Northants, showing branches and whorls of branchlets arising from main axis (photos: CRC).
Fig. 5.29. Macroscopic view of *Chara intermedia* showing spine cells and cortex cells (photo: CFC).
5.5.2 Nitella C. Agardh 1824

Species 7 native species plus one introduced species. See FAFBI and Moore (1986)

Macroscopic appearance Thallus consisting of main axis and branches, with whorls of branchlets arising at intervals. Branchlets fork one to several times into segments of equal length. Simpler in appearance than Chara, lacking cortex cells, spine cells and calcification.

Microscopic appearance Laterally compressed (flattened) oospore

Don’t confuse with Chara (p. 79; cortex and spines present), Nitellopsis (p. 82; branchlets undivided), Tolypella (p. 83; unequal length segments of branchlets)

Look for Habitat and ecology Associated with soft water (often acid) pools, lakes and, occasionally, rivers

Literature FAFBI; Moore, 1986; Lansdown, 2008.

Fig. 5.30 a. A tuft of Nitella flexilis (approximately 20 cm long) in the River Ehen, Cumbria (photo: MGK); b. single shoot of N. flexilis (photo: CFC).
### 5.5.3 *Nitellopsis* Hy 1889

<table>
<thead>
<tr>
<th><strong>Species</strong></th>
<th>1 (<em>N. obtusa</em> (Desvaux) J. Groves 1919)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Macroscopic appearance</strong></td>
<td>Robust thallus, often calcified but lacking cortex cells and spine cells. Branchlets of variable length and undivided.</td>
</tr>
<tr>
<td><strong>Microscopic appearance</strong></td>
<td>-</td>
</tr>
<tr>
<td><strong>Don’t confuse with</strong></td>
<td><em>Chara</em> (p. 79; cortex and spines present), <em>Nitella</em> (p. 81; branchlets divided, uncalcified), <em>Tolypella</em> (p. 83; unequal length segments of branchlets)</td>
</tr>
<tr>
<td><strong>Look for</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Habitat and ecology</strong></td>
<td>Alkaline to slightly brackish lakes</td>
</tr>
<tr>
<td><strong>Literature</strong></td>
<td>FAFBI; Moore, 1986; Lansdown, 2008.</td>
</tr>
</tbody>
</table>

---

**Fig. 5.31.** Internode of *Nitellopsis obtusa* from the Norfolk Broads showing characteristic branching pattern (i.e. branchlets dividing into segments of unequal length (photo: CFC).
5.5.4 Tolypella (A. Braun) A. Braun 1857

Species

Macrosopic appearance
Robust thallus, often calcified but lacking cortex cells and spine cells. Long sterile branches with whorls of shorter fertile branches which curve inwards to form loose balls or clusters. Branchlets divided into segments of unequal length.

Microscopic appearance
-

Don’t confuse with
Chara (p. 79; cortex and spines present), Nitella (p. 81; “balls” of fertile branches absent), Nitellopsis (p. 82; branchlets of unequal length)

Look for

Habitat and ecology
Hard water ponds, ditches, canals, occasionally also in rivers. Also found in brackish conditions.

Literature
FAFBI; Moore, 1986; Lansdown, 2008.

Fig. 5.32. Tolypella prolifera from near Peterborough, showing characteristic arrangement of fertile branches (photo: CFC).
5.6 Descriptions of Xanthophyta genera

5.6.1 Tribonema Derbes et Solier 1856

**Species** 5.

**Macroscopic appearance** Light green masses of filaments.

**Microscopic appearance** Fine, unbranched filaments with cells longer than wide and usually slightly barrel-shaped. Cell wall overlapping in the middle of each cell leading to the formation of H-shaped structures when filaments break apart. Several disc shaped yellow-green chloroplasts.

**Don’t confuse with** *Microspora* (p. 68) with a single, though sometimes reticulate chloroplast, and usually stains black-brown with iodine.

**Look for** H-shaped cell wall structures at the end on filaments, disc shaped chloroplasts.

**Habitat and ecology** Open situations in streams and rivers. No clear preference for nutrients.

**Literature** FAFBI; Biggs & Kilroy, 2000.

Fig. 5.33. a. *Tribonema* flocs floating on the surface of a pond near Acle, Norfolk (photo: GP); b. microscopic view of *Tribonema* filaments. Note parietal chloroplasts and “H”-shaped cell ends (photo: CFC).
5.6.2 *Vaucheria de Candolle 1805*

**Species**

20. Reproductive stages required

**Macroscopic appearance**

Vertical (sometimes prostrate) filaments forming dark green felt-like mats or cushions up to 20 cm across. This appearance is caused by the positively phototrophic behaviour of the terminal parts of aerial filaments. The texture is a bit like tough wool.

**Microscopic appearance**

One large branched cell with many disc-like chloroplasts lining the cell wall. Often with diatoms as epiphytes.

**Don’t confuse with**

*Cladophora* (p. 60; horizontal filaments, with obvious true branches and cross walls).

**Look for**

Absence of cross-walls, delicate and large cylindrical cells.

**Habitat and ecology**

On rocks and fine sediments in ditches, rivers, streams and lakes. Wide ecological amplitude, extending into brackish conditions.

**Literature**

FAFBI; Biggs & Kilroy, 2000.

---

![Image of Vaucheria](image1).  Note the absence of cell walls. The broad filaments are often kinked and are easily damaged, losing their chloroplasts and leaving an empty tube. Scale bar: 100 µm.
6. RHODOPHYTA

6.1 Introduction

A few freshwater Rhodophyta are bright red in colour, but they can also be olive-green or brown. They contain the green pigment chlorophyll \(a\) (chlorophyll \(d\), too, in some cases) along with accessory pigments of different colours. \(R-\) and \(C-\)phycocyanin and allophycocyanin are bluish whilst \(R-\) and \(B-\)phycoerythrin are red. Alpha- and beta-carotene as well as several xanthophylls are orange. Their storage product is Floridean starch and their cell walls contain cellulose, xylans and several sulphated polysaccharides. Rhodophytes never exhibit any flagellate stages. Many Rhodophytes also have a narrow protoplasmic channel between cells, the “pit connection” (which is closed by a “pit plug”); this can sometimes be a useful means of distinguishing red algae from morphologically-similar organisms.

A few genera can be very abundant in streams. The growth forms found include branched gelatinous tufts, branched or unbranched filaments (often appearing like thick knobbly hairs), short branched tufts appearing like a felt on rocks, moss etc. and crusts varying in colour from olive-green to brown and red.

<table>
<thead>
<tr>
<th>Genera (arranged by order)</th>
<th>See page</th>
<th>FAFBI page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bangiales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Bangia</em> Lyngbye 1819</td>
<td>91</td>
<td>128</td>
</tr>
<tr>
<td><strong>Batrachospermales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Batrachospermum</em> Roth 1797</td>
<td>92</td>
<td>167</td>
</tr>
<tr>
<td><em>Lemanea</em> Bory 1808</td>
<td>97</td>
<td>175</td>
</tr>
<tr>
<td><em>Paralemanea</em> Vis et Sheath 1992</td>
<td>97</td>
<td>175</td>
</tr>
<tr>
<td><em>Sheathia</em> Salomaki &amp; M.L. Vis 2014</td>
<td>92</td>
<td>(167)</td>
</tr>
<tr>
<td><em>Sirodotia</em> Kylin 1912</td>
<td>92</td>
<td>178</td>
</tr>
<tr>
<td><strong>Achrochaetales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Audouniella</em> Bory 1823</td>
<td>90</td>
<td>165</td>
</tr>
<tr>
<td><strong>Stylonematales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chroodactylon</em> Hansgirg 1885</td>
<td>95</td>
<td>163</td>
</tr>
</tbody>
</table>
6.2 How to identify red algae found in freshwater benthic habitats

Some genera of freshwater Rhodophyta (e.g. *Hildenbrandia, Batrachospermum*) can be identified with the naked eye; others can be partially identified by eye but may require a microscope to confirm their identity. Much of the terminology used for green and yellow-green algae (see above) also applies to Rhodophyta; the main difference, for practical purposes, is the photosynthetic pigments. In Chlorophyta, these are predominately chlorophylls a and b, along with some accessory pigments (carotenoids and xanthophylls). In Rhodophyta, there are phycobiliproteins which are responsible for the range of hues, from red through to olive- or blue-green. The range of colours is similar to that found in Cyanobacteria; however, in Rhodophyta the pigments are found in chloroplasts.

Red algae, like all other algae and plants, exhibit “alternation of generations” – i.e. there are distinct haploid and diploid phases of the life cycle. Whereas, in higher plants, the diploid phase is dominant and the haploid phase is reduced to the pollen and anthers, in red algae, it is the haploid phase that is usually most obvious, but in a few genera there are separate haploid and diploid phases that can be difficult to tell apart. In the case of *Audouinella*, the haploid gametophyte stage produces male and female sexual cells which fertilise to form a diploid carposporophyte, which remains attached to the gametophyte stage. This diploid phase is known as the “chantransia” stage, and was once regarded as a separate species. Similar gametophyte stages are found in several other freshwater red algae too. Not only are the haploid and diploid phases of *Audouinella* hard to differentiate, it is also very difficult to differentiate the chantransia stages of different species from one another. For this reason, simple filaments lacking carposporophytes should be designated simply as “chantransia”. In some red algae the diploid spore does not produce the haploid phase immediately on germination but forms another plant producing more spores, the ‘tetrasporophyte’, so there are actually three distinct stages (“triphasic”).

6.3 Key to common freshwater Rhodophyta

1a Bright red crust of irregular shape and size on upper surface of boulders

HILDENBRANDIA

(p. 96)
1b Does not form a crust

2a Branched monoaxial filaments composed of cells with either blue or red-coloured parietal ribbon-like chloroplasts; carposporophytes present on short side-branches. Form tufts and mats on submerged rocks (sometimes also on plants)

AUDOUINELLA (p. 90)

2b As above, but lacking carposporophytes

“CHANTRANSIA” (p. 94)

2c “Pseudofilament” with false branching set in mucilaginous matrix

CHROODACTYLYON (p. 95)

2d Either filaments that are multiaxial for at least part of their length or filamentous thalli. Various growth forms

........... 3

3a Coarse, robust filamentous thalli, sparsely branched, with nodules at intervals

..... 4

Not as above

..... 5

4a Reproductive structures visible as dark patches around the nodes

LEMANEA (p. 97)

4b Reproductive structures visible as dark rings around the thallus

PARALEMANEA (p. 97)

5a Mucilaginous filaments with a beaded structure; resembling “frog spawn” in appearance and texture, up to 40 cm long, varying in colour from olive green, violet, grey to brownish.

..... 6

5b Not as above

..... 7

6a Distinct carposporophytes composed of a mass of gonimoblast filaments

BATRACHOSPERMUM (p. 92)

6b Indistinct carposporophyte composed of indeterminate SIRODOTIA (p. 92)
gonimoblast filaments

6c  Carposporophyte absent

B. TURFOSUM (p. 92)

See description of *Batrachospermum* for comments on the recently-described species *Sheathia*.

7a  Unbranched red-coloured filaments, < 10 cm long, uniaxial at base, becoming multiaxial in upper portions

BANGIA (p. 91)

7b  Branched, multiaxial filaments, olive-green, dark brown, reddish or black, covered with dense coat of finer filaments

….THOREA (p. 100)
6.4 Descriptions of Rhodophyta genera

6.4.1 Audouinella Bory 1823

Species 2.

Macroscopic appearance Various. It can form ‘felt-like pink-brown tufts’ on rocks, but these can be overgrown by diatoms, imparting a darker brown hue to the growths or (if the diatoms are prolific) appear as part of a thick, hummocky biofilm.

Microscopic appearance Branched filaments growing from a basal holdfast with cells on branches usually barrel-shaped, not as long as and more rounded than cells on the main filament which are cylindrical. Chloroplasts several parietal and ribbon-like.

Don’t confuse with Chantransia stages of other red algae (p. 94; lack carpogonia).

Look for Eukaryotic cells similar in colour to Cyanobacteria due to the presence of phycobiliproteins. Distinct branching pattern (see below).

Habitat and ecology Common in clean flowing waters both growing on rocks and as an epiphyte. Most prolific in winter and growths visible to the naked eye are not seen in the summer. Found across a wide range of water hardness.

Literature FAFBI; Biggs and Kilroy, 2000.

Fig. 6.1. a. Audouinella hermanii on submerged boulder in the River Ehen, Cumbria, UK (photo: MGK); b. vegetative filaments and c. carpogonium (sporangium) of the same population of A. hermanii (photos: CFC).
6.4.2 Bangia Lyngbye 1819

<table>
<thead>
<tr>
<th>Species</th>
<th>1 (B. atropurpurea).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macroscopic</td>
<td>Up to 15 cm long filaments.</td>
</tr>
<tr>
<td>appearance</td>
<td></td>
</tr>
<tr>
<td>Microscopic</td>
<td>Unbranched, red-coloured filaments at maturity, uniaxial at the base and multiaxial in the upper portions.</td>
</tr>
<tr>
<td>appearance</td>
<td></td>
</tr>
<tr>
<td>Don’t confuse with</td>
<td>Audoinella (p. 90) has branched filaments and cylindrical or barrel-shaped cells.</td>
</tr>
<tr>
<td>Look for</td>
<td></td>
</tr>
<tr>
<td>Habitat and ecology</td>
<td>Usually found on hard surfaces at moderately shaded locations in alkaline, ion-rich waters. Whitton et al. (1981) found this taxon to be resistant to high levels of heavy metal pollution, especially zinc. Can occur in eutrophic waters.</td>
</tr>
<tr>
<td>Literature</td>
<td>FAFBI.</td>
</tr>
</tbody>
</table>

Fig. 6.2.  a. macroscopic view of Bangia atropurpurea filaments growing epiphytically on Cladophora glomerata; b. and c. microscopic views of uni- and multiaxial filaments (photos: CFC).
### 6.4.3 Batrachospermum Roth 1797 (including Sheathia Salomaki & M.L. Vis 2014) and Sirodotia Kylin 1912

| **Species** | 7 (*Batrachospermum*). Reproductive stages required. These are almost always present, with the exception of *B. turfosum*, which does not reproduce in the UK or Ireland. A new genus, *Sheathia*, consisting of species formerly included in *Batrachospermum*, was recently described (Salomaki et al., 2014); however, the changes have not yet been adopted by FAFBI, so we continue to include all *Sheathia* species within *Batrachospermum*. |
| **Macroscopic appearance** | Mucilaginous filaments, up to 40 cm long, with beaded appearance, varying from blue-green, olive, violet, grey to brownish. |
| **Microscopic appearance** | Thick central filament with whorls of branched filaments of barrel-shaped cells. The main axis of *Batrachospermum* consists of just cylindrical cells whilst that of *Sheathia* consists of both cylindrical and bulbous cells (Fig. 6.3). This “heterocortification” is one of the defining morphological characters of *Sheathia*. |
| **Don’t confuse with** | Young *Batrachospermum* can look like *Audouniella* (p. 90). *Sirodotia suecica* is a closely-related species that has been found in the UK. It is distinguished from *Batrachospermum* by the absence of a distinct carposporophyte (a reproductive stage). See FAFBI for more details. |
| **Look for** | Beaded, heavily branched filaments (usually a dull olive-green colour) which slip easily through the fingers. |
| **Habitat and ecology** | Clean, cool streams and rivers, especially in or near springs. Occasionally in ponds and bogs. Our observations indicate a general preference for low nutrients, although there are occasional records of mass growths in situations where nutrients are known to be elevated. *B. turfosum* is associated with acid/peaty areas. *Batrachospermum* may occasionally be found with epiphytic growths of another freshwater red alga, *Balbiania investiens*. |
| **Literature** | FAFBI; Biggs and Kilroy, 2000. |
Fig. 6.3. High magnification views of the main axis of *Batrachospermum* (B) and *Sheathia* (S). Note the presence of bulbous cells in *Sheathia*.

Fig. 6.4. a: Tufts of *Batrachospermum gelatinosum* (approx 20 cm long) in Beckhead Spring, Cumbria; b: macroscopic view of specimen of *Batrachospermum* from inflow stream to Sunbiggin Tarn, Cumbia (scale bar: 1 cm); c: detail of filament structure of *B. gelatinosum* showing whorls of branches arising from main stem; d: close-up of single branchlet (scale bar: 10 µm). (photos: MGK)
6.4.4 “Chantransia”

Species
This is not a “species”, but a collective term for the haploid (gametophyte) phase of the life cycle of some freshwater red algae. It is included here to prevent confusion with *Audouinella*.

Macroscopic appearance
Various

Microscopic appearance
See description for *Audouinella*. However, chantransia phases always lack carposporophytes, although they are able to produce non-motile “monospores” (see figure 6.4).

Don’t confuse with
*Audouinella* (p. 90)

Look for

Habitat and ecology
Various; similar to that of the sporophyte from which they are derived.

Literature

---

Fig. 6.5. “Chantransia” stages of freshwater red algae: a. tuft of chantransia on .... ; b. monospores on a chantransia filament; c. chantransia filaments (photos: CFC).
6.4.5 *Chroodactylon* Hansgirg 1885

**Species** 1 (*Chroodactylon ornatum*)

**Macroscopic appearance** Filaments within mucilaginous matrix

**Microscopic appearance** “pseudofilaments” (i.e. linear arrangement of cells but not attached to one another) with false branches set within a mucilaginous matrix.

**Don’t confuse with**

**Look for** Distinctive dark green-blue patches on submerged stones.

**Habitat and ecology** Filaments are found in hard waters, especially ponds, associated with *Chara, Cladophora* and *Rhizoclonium*.

**Literature** FAFBI

---

![Fig. 6.6. *Chroodactylon ornatum* at two different magnifications, showing pseudofilaments with false branching in mucilaginous matrix (photos: CFC).](image-url)
6.4.6 Hildenbrandia *Nardo 1834*

**Species**

1 (*Hildenbrandia rivularis*)

**Macrosopic appearance**

Thin crusts looking like patches of bright pinkish-red paint on stone substrata.

**Microscopic appearance**

Cells cuboidal to polygonal in vertical files usually arising from a basal layer.

**Don’t confuse with**

*Haematococcus* (p. 63), a green alga, forms red patches in dried-out calcareous hollows, due to production of a photoprotective pigment, astaxanthin. However, *Haematococcus* patches differ from *Hildenbrandia* as they lack a distinct outline and because the alga can be easily scratched off the rock surface with a fingernail.

**Look for**

Distinctive red patches on submerged stones.

**Habitat and ecology**

Epilithic in standing and flowing waters. Occurs right across the nutrient gradient. The presence of stable substrata and reasonably clear water is probably more important than the nutrient concentration per se. Usually found on non-calcareous rocks.

**Literature**

FAFBI.

---

Fig. 6.7. *Hildenbrandia rivularis* from River Avon, Hampshire. Photo: TC.
6.4.7 Lemanea Bory 1808

Species 2.

Macroscopic appearance Sparsely branched filaments with a coarse, wiry feel with thickened nodes at intervals. The whole plant is streamlined in appearance and can grow up to 40 cm long.

Microscopic appearance The thallus is hollow and lacks cortical filaments. Spermatangia develop as patches associated with the nodes. Carposporophytes develop inside the thallus, and can be very dense.

Don’t confuse with Paralemanea torulosa (p. 97) is unbranched and has distinct bands of spermatangia, rather than patches, plus cortical filaments around a central axis running along the inside of the thallus.

Look for Coarse olive-green filaments in tufts.

Habitat and ecology Grows under a wide range of conditions most commonly in spring with preference for low nutrient concentrations, although populations are sometimes found even in nutrient-rich water. Typically in fast-flowing, circumneutral but not hard waters. Tolerant of heavy metal pollution.

Literature FAFBI; Eloranta, 2002; Sheath, 2003; Eloranta and Kwandrans, 1995; Harding and Whitton, 1981.

6.4.8 Paralemanea Vis & Sheath 1992

Species 1. (Paralemanea torulosa)

Macroscopic appearance Similar to Lemanea (see above)

Microscopic appearance A thick corticated filament runs along the length of the thallus: this can be observed with a hand lens or low power microscope. The corresponding filament in Lemanea is much more difficult to see. Spermatangia occur as rings around the thallus rather than as discrete patches.

Don’t confuse with Lemanea (p. 97)

Look for Cortical filaments and spermatangia in bands

Habitat and ecology Little is known about its ecology; it is presumed to be similar to that described for Lemanea. It can occur alongside Lemanea and is almost certainly under-recorded in the UK and Ireland.

Literature FAFBI; Vis & Sheath, 1992.
Fig. 6.8.  

a. *Lemanea fluviatilis* from the River Wear, Co. Durham; b.-d. *Lemanea fluviatilis* from the River Ehen, March 2014. b. low-power image showing the knobby stems; c. close-up of a single stem showing the spermatangia patches associated with these protruberences (scale bar: 20 micrometres); d. close-up of a patch of spermatangia (photos: MGK).
Fig. 6.9. *Paralemanea nodosa* from the Dreisam, Freiburg im Breisgau, Germany; a. view of a single filament showing the band of spermatangia; b. torn end of thallus showing the thick corticated filament emerging (photos: CFC).
6.4.9 Thorea Bory 1808

Species 1. *(Thorea hispida)*

Macroscopic appearance Branched multiaxial filament giving rise to numerous secondary branches. Filaments are typically about 0.5 mm in diameter but can be up to 2 mm, and up to 1 metre long.

Microscopic appearance

Don’t confuse with Very distinctive, unlikely to be confused with other species of algae

Look for Lax filaments with covering of dense hairs

Habitat and ecology In lowland regions of England, typically in stretches where water is relatively fast flowing. Rare.

Literature FAFBI, John et al., 1989

Fig. 6.10. a. Macroscopic view of filaments of *Thorea hispida* from a tributary of the Ouse in Cambridgeshire; b. cross-section of filament of *T. hispida* showing secondary branches arising from the multiaxial central filament (photos: CFC).
7. OTHER GROUPS

7.1. Diatoms (Bacillariophyta)

Diatoms get their typical brown-green colour from a combination of chlorophyll $a$ and $c$, carotenes and xanthophylls, principally fucoxanthin. They have the polysaccharide chrysolaminarin as their storage product and a cell wall formed from silica. They are often the most abundant and diverse photosynthetic constituents of biofilms in both standing and running waters and over 2000 species have been recorded from Britain and Ireland. However, few genera form distinct growths that are recognizable with the naked eye. Those that are likely to be encountered in rivers and streams are: *Melosira varians*, *Gomphonema* spp and relatives, and *Didymosphenia geminata*, which form brownish growths that feel like damp cotton wool to the touch. Identification of freshwater diatoms is beyond the scope of this book; see Kelly (2000) and Cox (1996) for introductory guides in English; Hofmann *et al.* (2011) is a single volume introduction to the most common diatoms in Europe (in German).

<table>
<thead>
<tr>
<th>Genus (arranged by Class)</th>
<th>See page</th>
<th>FAFBI page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coscinodiscophyceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Melosira varians</em> Agardh 1827</td>
<td>104</td>
<td>*</td>
</tr>
<tr>
<td><strong>Bacillariophyceae</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Didymosphenia</em> (Lyngbye) M. Schmidt 1899</td>
<td>102</td>
<td>*</td>
</tr>
<tr>
<td>Other diatoms</td>
<td>105</td>
<td>*</td>
</tr>
</tbody>
</table>

* Diatoms are not included in FAFBI
7.1.1 Didymosphenia (Lyngbye) M. Schmidt 1899

Species
1 (Didymosphenia geminata)

Macroscopic appearance
Forms brown, hemi-spherical colonies on rocks which grow and coalesce with neighbouring colonies to such an extent that they can, under some circumstances, smother the entire stream bed. The colonies feel like damp cotton wool.

Microscopic appearance
Diatom with heteropolar valves, large and robust, symmetrical to apical axis and broadly capitate at both apices. Cells wedge-shaped in girdle view. Striae strongly punctate. Short terminal spines can sometimes be seen at the head pole. No pseudosepta. 2-5 stigmata occur on one side of the central area.

Don’t confuse with
Smaller diatoms such as Gomphonema (see below).

Look for
Distinctive sarcophagus-shaped cells.

Habitat and Ecology
Upper surface of rocks in upland streams (occasionally also in littoral zone of lakes) mostly in northern and western Britain and Ireland from spring to autumn. Uncommon but, where it does become established, the branched mucilaginous stalks, on which the frustules are supported, can smother the substratum. Colonies start to grow in the spring, spreading to cover the entire substratum by summer and which, in turn, act as a substratum for other diatoms and filamentous green algae. The mass growths are often sheared away from the substratum by high flows and bear an uncanny resemblance to raw sewage as they float downstream. Many accounts considered D. geminata to be a species of pristine water; however, there is evidence that it is also able to tolerate moderate anthropogenic enrichment.

Literature
Ellwood & Whitton (2007); Whitton et al. (2009); Bothwell et al. (2014); Elwell et al. (2014).

Fig. 7.1. Didymosphenia geminata from the River Coquet, Northumberland, May 2006. The colonies smother most of the upper surface of substrata and this biomass will continue to develop throughout the summer. Individual colonies feel like damp cotton wool to the touch. The penknife is 9 cm long.
Fig. 7.2. *Didymosphenia geminata* from River Coquet, Northumberland, May 2006. Live cells. a) medium-magnification view of colony. Note the high proportion of mucilaginous stalks to cells. b) valve view and c) girdle view of single cells, viewed under high magnification. Scale bar (b and c): 10 µm.
7.1.2. *Melosira Agardh 1827*

**Species**

1 (*Melosira varians*). Occasional records of brackish water forms (e.g. *M. nummuloides*) at inland locations, but associated with saline conditions.

**Macroscopic appearance**

Fragile brown filaments, readily disintegrating on contact.

**Microscopic appearance**

Filaments composed of chains of cylindrical cells each containing many yellow-brown chloroplasts.

**Don’t confuse with**

*Melosira nummuloides*, a brackish water form, has cylindrical cells but with domed, rather than virtually flat ends.

**Look for**

Chains of cylindrical cells containing many chloroplasts.

**Habitat and Ecology**

Macroscopic growths are common in shallow areas of enriched lowland rivers with slow to moderate velocities particularly during the summer.

**Literature**

Cox (1996); Kelly (2000)

---

Fig. 7.3. Filaments of *Melosira varians* smothering the bed of a shallow, enriched river (River Browney, Co. Durham) in summer with (inset) a microscopic view of a chain of cells of *Melosira varians*. Scale bar: 10 µm.
7.1.3 Other diatoms

Species > 2000.

Macroscopic appearance Forms brown or yellow-brown mucilaginous colonies or delicate filaments.

Microscopic appearance Composed of diatoms and associated stalks. Macroscopic growths are typically dominated by a single species (often Gomphonema or Cymbella, although occasionally other genera with a number of other taxa are also present in lower numbers.

Don’t confuse with Hydrurus (p. 106) consists of slimy colonies of non-pigmented cells which bear a superficial resemblance to diatom growths from a distance.

Look for Characteristic silica cell-walls and yellow-brown pigmentation.

Habitat and Ecology Diatoms are present in all freshwater habitats, with preferences varying from species to species. Macroscopic growths can form on upper surfaces of rocks, and on leaves and stems of submerged plants; they are particularly obvious in spring.

Literature Cox (1996); Kelly (2000);.

Fig. 7.4. a) Gelatinous growths on a cobble in Blackleas Burn, Co. Fermanagh, April 2007 (scale bar: 5 cm) which, when observed under the microscope, was composed of a near monoculture of stalked Gomphonema olivaceum (b and c). Scale bar: 10 μm.
7.2 Chrysophyta

Chrysophytes get their yellow-brown colour from a combination of chlorophyll \( a \) and \( c \) together with carotenes and xanthophylls, including fucoxanthin. Along with the Xanthophyta and Bacillariophyta they store surplus carbon in the form of the polysaccharide chrysolaminarin. Their cell walls are made from cellulose and any flagellated stages have one or two flagellae of unequal length. Only a few genera form growths that are likely to be seen with the naked eye. None are common in Britain or Ireland, and all are most likely to be encountered in upland areas in northern Britain and Ireland during the winter.

<table>
<thead>
<tr>
<th>Genus (arranged by order)</th>
<th>See page</th>
<th>FAFBI page</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hydrurales</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Chrysonebula</em> J.W.G. Lund 1953</td>
<td>106</td>
<td>308</td>
</tr>
<tr>
<td><em>Hydrurus</em> C. Agardh 1824</td>
<td>107</td>
<td>310</td>
</tr>
<tr>
<td><em>Phaeodermatium</em> Hansgirg 1889</td>
<td>108</td>
<td>310</td>
</tr>
</tbody>
</table>

### 7.2.1. Chrysonebula *J.W.G. Lund 1953*

**Species**  
1 (*C. holmesii*)

**Habitat**

**Macroscopic appearance**  
Prostrate colonies covering stones, often like a layer of pale yellow jelly. Pale whitish mucilage.

**Microscopic appearance**  
Colonies contain calcium carbonate crystals; cells of variable shape arranged irregularity with 1-2 chloroplasts per cell.

**Don’t confuse with**  
Not easily confused with anything else.

**Look for**

**Habitat and Ecology**  
Grows on rocks in fast-flowing rivers with hard-water in late winter under low flow conditions. In the UK it is associated with upland pristine or near pristine environments. It can also be prolific in metal-rich environments.

**Literature**  
FAFBI.

Fig. 7.5..
7.2.2 *Hydrurus C. Agardh 1824*

**Species**
1 (*H. foetidus*)

**Macroscopic appearance**
Epilithic, mucilaginous, branched and bushy to feathery, dark brown thalli up to 30 cm long which has a foetid smell when rubbed between the fingers.

**Microscopic appearance**
Cells are arranged peripherally within the mucilage.

**Don’t confuse with**
Filamentous growths of diatoms.

**Look for**
Long hair-like strands in running water.

**Habitat and Ecology**
Attached to submerged rocks in mountain streams. Most abundant in winter.

**Literature**
FAFBI.

---

Fig. 7.6. a. A stone smothered in *Hydrurus foetidus* from the River Atma, Norway (photo: MGK); b. and c. microscopic views of thalli of *H. foetidus* (photos: CFC)
7.2.3 *Phaeodermatium Hansgirg 1889*

**Species**
1 (*Phaeodermatium rivulare*)

**Habitat**

**Microscopic appearance**
Angular cells arranged in layers, each with a single chloroplast.

**Don’t confuse with**
*Hydrurus foetidus* (foetid smell, bushy appearance) and *Chrysonebula* p. 80 (rounded cells)

**Look for**
Angular cells.

**Ecology**
Little is known about this species except that it is found on submerged stones in streams and lake littoral zones, particularly in winter, disappearing by early spring. The habitats from which it has been recorded suggest a preference for unpolluted water.

**Literature**
FAFBI, Canter-Lund & Lund, 1995

---

*Fig. 7.7. Phaeodermatium from 13 m depth in a lake in Sweden. Photo: RB*
7.3 Phaeophyta

Most brown algae are found in marine or estuarine environments and only a few species are found in fresh water. They contain Chlorophyll $a$ and $c$, beta-carotene and fucoxanthin together with several other xanthophylls. Their storage product is laminarin or mannitol. Cell walls are made from cellulose, alginic acid, and sulphated mucopolysaccharides. Any flagellated stages have two laterally inserted flagella of unequal length. Only five freshwater genera have been found so far, of which only *Heribaudiella* is widespread in the UK. It forms small dark brown spots on rocks and is very easily overlooked or confused with other encrusting algae or lichens. Two other genera of freshwater brown algae have been recorded from Britain and Ireland, but both are rare and, judging by accounts in FAFBI, are unlikely to form conspicuous growths.

<table>
<thead>
<tr>
<th>Genus (by order)</th>
<th>See page</th>
<th>FAFBI page</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Heribaudiellales</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Heribaudiella</em> Gomont 1896</td>
<td>109</td>
<td>357</td>
</tr>
</tbody>
</table>

7.3.1 *Heribaudiella* Gomont 1896

Species 1 (*H. fluviatilis*)

Macroscopic appearance Thallus forming olive-brown to dark-brown crusts with an irregular-rounded outline, but with distinct margins.

Microscopic appearance A basal system of frequently branched filaments and an erect system of tightly packed filaments of 8-15 cells with 4-10 oval or discoid chloroplasts each.

Don’t confuse with *Chamaesiphon* (p. 32)
Lichens (p. 113) (e.g. *Polyblastia*, *Verrucaria aethiobola*, *V. hydrela*). *Audouinella* (p. 90) also has eukaryotic cells that can be confused with *Heribaudiella*, but look for the characteristic “pit connections” between cells that Phaeophyta lack.

Look for Habitat and ecology Epilithic in streams and rivers, and in the littoral zones of lakes. Wehr and Stein (1985) report preferences for well-buffered circumneutral water with low nutrient concentrations.

Literature FAFBI; Wehr & Stein, 1985
Fig. 7.8. *Heribaudiella fluviatilis*. a: colonies growing on submerged boulders in a river in Norway (photo: SS); b. microscopic view of filaments (photo: CFC)
7.4. Other organisms

Several other groups of organisms may be mistaken for macroscopic algae. In some cases (e.g. *Ophyridium*, freshwater sponges), this is due to the presence of endosymbiotic algae.

### 7.4.1. *Ophyrydium versatile* Ehrenberg 1830

<table>
<thead>
<tr>
<th>Macroscopic appearance</th>
<th>Gelatinous colonies from less than 2 cm to over 30 cm, often starting off as spheres but becoming irregular in form as they become larger.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microscopic appearance</td>
<td>Single-celled ciliate that live at the edge of gelatinous colonies. Cells are 300 µm -400 µm long when extended and 100 µm-200 µm when contracted. Green through many green algae (400-500 <em>Grasiella</em> coccoids) living inside <em>Ophyrydium versatile</em> cells. The jelly also provides a habitat for several other organisms including diatoms.</td>
</tr>
<tr>
<td>Don’t confuse with</td>
<td>Gelatinous mats of cyanobacteria or diatoms, motile ciliate protozoan cells. <em>Tetraspora</em> (p. 74).</td>
</tr>
<tr>
<td>Look for</td>
<td>Very soft pale green colonies</td>
</tr>
<tr>
<td>Habitat and Ecology</td>
<td>Slightly acidic bogs and ponds; colonies may be lying on top of the sediment in shallow waters, drifting in the water column or attached to aquatic plants. <em>Ophyrydium</em> individuals or zooids are capable of separating from their holdfast roots in the gel and swimming freely to populate other areas. These free swimmers are called telotrochs. They usually attach themselves to suitable substrates such as aquatic plants and then return to the immobile zooid form.</td>
</tr>
<tr>
<td>Literature</td>
<td>Patterson (1996).</td>
</tr>
</tbody>
</table>

Fig. 7.9. *Ophyrydium versatile* from Harrop Tarn, 2001. The jelly-like masses smothering the submerged stalk are green in colour in young, more spherical colonies but are brown later on due to the presence of diatoms within the jelly matrix, scale bar 1 cm. Inset: two cells of *Ophyrydium*. Scale bar 100 µm.
7.4.2. *Porifera* - *Freshwater Sponges*

**Species**
13 species belonging to six genera have been reported from freshwaters in the UK, and five species from four genera in Ireland.

**Habitat**
More common on the underside of rocks than on the surface of them in clean rivers, lakes and large ponds.

**Macroscopic appearance**
Form crusts of variable form and size with a surface pierced by many small holes on any hard substrate. They range in colour from yellowish-white to brownish-red, but are sometimes green due to inter- and intracellular algae that become more abundant under conditions of strong light.

**Microscopic appearance**
Unspecialized tissues made out of two layers with a gelatinous non-cellular matrix in between containing characteristic siliceous spicules.

**Ecology**
Most sponges die off in winter.

**Don’t confuse with**
Growths of green algae such as *Chaetophora* (p. 59).

**Look for**
Spicules

**Literature**
Eggers & Eiseler (2007); Cocchiglia et al. (2013)

---

**Fig. 7.10. Aquatic sponges. a: macroscopic view of a sponge from Aughrusbeg Lough, Co. Galway, Ireland; b: microscopic view of sponge spicule (scale bar: 100 µm).**
7.4.3. Freshwater Lichens

Rocks and pebbles submerged in shallow water are frequently covered with dark-coloured crusts and in many cases, their identification cannot be verified in the field. Samples should be returned home and allowed to dry out before identification is attempted. If possible, collect small pebbles no more than an inch (25 mm) thick as these may be examined directly under a dissection microscope, otherwise they will need to be broken with a hammer and chisel. Most dark crusts can be categorised into four broad categories: amorphous organic matter such as peat staining; deposits of iron and manganese oxyhydroxides; lichens or algae.

Most aquatic lichens forming dark crusts possess fruit bodies termed perithecia. These are usually black and appear as small raised domes or pimples. They tend to be regularly dispersed on the surface of the lichen thallus and range from about 0.2-1 mm in diameter and are best seen with a dissection microscope at a magnification of x10. The lichen thallus consists of algae embedded in a fungal matrix. Sample a small part of the crust under a microscope in a ‘squash’ preparation, where the material – no more than a block measuring about 0.5 mm square - is soaked and squashed under a cover slip. It should reveal abundant algae among a filamentous fungal mycelium. Lichen thalli, when dried, often show a mosaic-like cracking and this is less often observed in encrusting algae. A large number of aquatic lichens occur in Britain, mostly belonging to the genera Verrucaria, Polyblastia and Thelidium. They prefer clear, unpolluted waters and are often associated with free-living algae. Smith et al. (2009) is the standard guide to British and Irish lichens whilst Dobson (2011) provides a more accessible introduction.

Peat-stained rocks and those encrusted with dark minerals can be easily mistaken for aquatic algae and lichens. They can be distinguished to some extent by their lack of a distinct edge or margin, though some encrusting algae also lack this, so microscopic examination will still be required. Microchemical tests are available to identify these crusts, but often, small algal colonies will grow over them and thus easily overlooked.
8. INTERPRETATION

8.1 Introduction

This chapter describes the RAPPER (“Rapid Assessment of Periphyton Ecology in Rivers) interpretation framework, designed to give a rapid insight into the condition of streams and rivers based on the composition of algae that are visible to the naked eye. The ecological principles behind RAPPER are given in 1.3 and Kelly et al. (2016); this section shows how results of surveys performed according to 2.2 can be interpreted.

RAPPER is based on the assumption that taxa that are well-adapted to survival in nutrient-stressed conditions will be out-competed when limiting nutrients are abundant (Biggs et al., 1998). Such taxa are referred to as “stress-adapted” (“S”) taxa within RAPPER. As a low concentration of inorganic nutrients is the typical state of natural systems in the absence of anthropogenic pressures, these taxa are mostly associated with high and good status. A second group, “competitive” (“C”) taxa, are widespread, but typically only dominate when resources that constrained population growth are abundant (Biggs et al., 1998). Increased availability of inorganic nutrients, therefore, leads to C taxa out-competing S taxa, resulting in a shift in community structure away from the natural (“expected” or “reference”) state. Abundance of C taxa at a site is, therefore, a good indication that the site is no longer at high or good status, leading to potential impairment of ecological services. A few genera, whose representatives span a wide range of nutrient conditions, or for which few data were available, were placed in a third class, “unclassified” (“U”).

8.2 Application of RAPPER to survey results

All genera in a sample first need to be allocated to the appropriate RAPPER category: “S”, “C” or “U” using Table 8.1. The cover value of competitive (“C”) taxa also needs to be calculated. If one “C” taxon is present, the cover value can be used directly. If two or more are present, then the cover value that equates to their sum is used. At this stage, information on the thickness of growths is not used in assessments, but this may change in the future.

Use Table 8.2 to allocate your sample to the appropriate category: “not at risk”, “maybe at risk” or “at risk”.

Example 1: a survey of a tributary of the River Browney (Stockerley Burn, Bogle Bridge, NZ 132 502), County Durham in August 2014 revealed a single macroalga, Cladophora glomerata covering a large area of the stream bed (cover value: 8), with some strands of Vaucheria mixed in. Using Table 8.2, this survey suggests that the stream is “at risk” of eutrophication as both Cladophora and Vaucheria are “C” species. This is, indeed, the case, as the site is 1 km downstream of a sewage works and typically has > 1 mg L\(^{-1}\) reactive P.
Example 2: the River Ehen, about 2 km below the outflow of Ennerdale Water (NY 081 152) has a few growths of *Nitella flexilis* (cover value = 2), and some green algal growths (cover value = 4) composed of a mixture of *Bulbochaete* and a thin *Mougeotia* species, in roughly equal proportions. All three genera are “S” taxa, so the site is presumed to be “not at risk” of eutrophication based on Table 8.2. This reflects the low concentrations of nutrients that are observed in the river (although occasional peaks associated with spates do occur).

Table 8.1 (next page). List of macroalgal taxa and indicator values for RAPPER. The diatoms *Didymosphenia geminata* and *Melosira varians* have been included, although they are not used for classification.

Notes:

1. Predominately epiphytic taxa are excluded when determining the category to which a genus belonged (so, for example, *Chamaesiphon incrustans* was not considered when deciding the category to which *Chamaesiphon* belongs)

2. *Batrachospermum* includes *Sheathia* spp.

3. Square brackets indicates provisional assignments (based on Schneider & Lindstrøm (2011))

4. *Stigeoclonium* is recorded as “S” if hairs are present; otherwise “U”

Table 8.2. Matrix of periphyton taxa indicative of risk of eutrophication and likely ecological status. “S taxa”: taxa associated predominately with high and good status; “C taxa”: taxa associated predominately with moderate, poor and bad status.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Not at risk</th>
<th>Maybe at risk</th>
<th>At risk</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Likely status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S taxa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C taxa</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low abundance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate or high cover</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low abundance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate or high cover</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;25%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;25%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cyanobacteria</td>
<td>S (“stress-adapted”)</td>
<td>C (“competitive”)</td>
<td>U (“unclassified”)</td>
</tr>
<tr>
<td>---------------</td>
<td>----------------------</td>
<td>-------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>[Aphanocapsa]</td>
<td>Oscillatoria</td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Aphanothece]</td>
<td>Microcoleus</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calothrix, Chamaesiphon</td>
<td></td>
<td>Phormidium</td>
<td></td>
</tr>
<tr>
<td>Dichothrix Homoeothrix</td>
<td></td>
<td></td>
<td>Plectonema</td>
</tr>
<tr>
<td>Lyngbya</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nostoc</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rivularia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Schizothrix</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scytonema</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stigonema</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tolypothrix</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rhodophyta</td>
<td>Audouinella</td>
<td>Bangia</td>
<td></td>
</tr>
<tr>
<td>Batrachospermum</td>
<td></td>
<td>“chantransia”</td>
<td></td>
</tr>
<tr>
<td>Lemanea</td>
<td></td>
<td>Chroodactylon</td>
<td></td>
</tr>
<tr>
<td>Paralemaneae</td>
<td></td>
<td>Hildenbrandia</td>
<td></td>
</tr>
<tr>
<td>[Sirodotia]</td>
<td></td>
<td>Thorea</td>
<td></td>
</tr>
<tr>
<td>Chlorophyta</td>
<td>Bulbochaete</td>
<td>Cladophora</td>
<td>Aegagropila</td>
</tr>
<tr>
<td>Chaetophora</td>
<td>Hydrodictyon</td>
<td>Chaetomorpha</td>
<td></td>
</tr>
<tr>
<td>Draparnaldia Gongrosira</td>
<td>Rhizoclonium</td>
<td>Haematococcus</td>
<td></td>
</tr>
<tr>
<td>Klebsormidium</td>
<td>Ulva</td>
<td>Microspora,</td>
<td></td>
</tr>
<tr>
<td>Mougeotia Spirogyra</td>
<td></td>
<td>Monostroma</td>
<td></td>
</tr>
<tr>
<td>(Stigeoclonium + hairs)</td>
<td></td>
<td>Oedogonium,</td>
<td></td>
</tr>
<tr>
<td>Tetraspora</td>
<td></td>
<td>(Stigeoclonium - hairs)</td>
<td></td>
</tr>
<tr>
<td>Ulothrix:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zygnema</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zygoconium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charophyta</td>
<td>Chara</td>
<td>Nitellopsis</td>
<td></td>
</tr>
<tr>
<td>Nitella</td>
<td></td>
<td>Tolypella</td>
<td></td>
</tr>
<tr>
<td>[Heribaudiella]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phaeophyta</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Xanthophyta</td>
<td>Vaucheria</td>
<td>Tribonema</td>
<td></td>
</tr>
<tr>
<td>Chrysophyta</td>
<td>Hydrurus</td>
<td>Chrysonebula</td>
<td>Phaeodermatium</td>
</tr>
<tr>
<td>Bacillariophyta</td>
<td>(Didymosphenia)</td>
<td>(Melosira)</td>
<td></td>
</tr>
</tbody>
</table>
7. GLOSSARY

aerophil  Thriving in the presence of air; air-loving.

biofilm  An aggregation of auto- and heterotrophic microorganisms on submerged surfaces, along with an associated matrix of extracellular polymeric substances.

calcification  Encrustation or impregnation with calcium carbonate

caps  Series of transverse rings at the apex of some cells of the *Oedogoniales* due to a unique type of cell division

chloroplast forms:  See Fig. 7.1.

axial  Aligned along the median axis of a cell (Fig. 7.1c)

parietal  Lying just inside the cell wall (Figs 7.1a and b). Helical (Fig. 7.1d) and reticulate (Fig. 7.1e) chloroplasts are also parietal.

reticulate  Net-like (Fig. 7.1e). Note that the net-like character of the chloroplast is often difficult to discern with a light microscope, and the chloroplast often appears to fill the entire cell.

![Fig. 7.1. Types of chloroplast.](image)
a: discoid (disc-shaped) parietal chloroplasts; b: lobed parietal chloroplast; c: plate-like axial chloroplast; d: helical chloroplast; e: reticulate (net-like) chloroplast; f: stellate (star-like) chloroplasts.

coenobium / coenobia  A colony whose number of cells is determined at the time of formation.

diatom  Unicellular microscopic alga with a cell wall of silica.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>endolithic</td>
<td>Living within a rock</td>
</tr>
<tr>
<td>epilithic</td>
<td>Living on the surface of a rock</td>
</tr>
<tr>
<td>epiphytes</td>
<td>Organisms living on the surface of a plant</td>
</tr>
<tr>
<td>epiphytic</td>
<td>Living on the surface of a plant</td>
</tr>
<tr>
<td>eukaryotic</td>
<td>Having cell(s) with (a) membrane-bound nucleus(i)</td>
</tr>
<tr>
<td>false branching</td>
<td>Branches formed by lateral growth of one or both ends of a broken trichome (cf true branching)</td>
</tr>
<tr>
<td>flagellum / flagella</td>
<td>A fine, thread-like extension of the cytoplasm, involved in propulsion.</td>
</tr>
<tr>
<td>heterocyst</td>
<td>Cells specialised in nitrogen fixation within trichomes of Cyanobacteria. They usually look paler due to the lack of pigments and have thicker walls than adjacent cells.</td>
</tr>
<tr>
<td>intercalary</td>
<td>Inserted between other elements or parts of a structure, here especially cells of algal filaments</td>
</tr>
<tr>
<td>invertebrates</td>
<td>An animal, such as an insect or mollusc, that lacks a backbone or spinal column</td>
</tr>
<tr>
<td>lichen</td>
<td>A symbiotic association between a fungus and an alga</td>
</tr>
<tr>
<td>macroalga(e)</td>
<td>Those algae that can be recognised and at least partially identified with the naked eye</td>
</tr>
<tr>
<td>macrophytes</td>
<td>Larger plants of fresh water which are easily seen with the naked eye, including all aquatic vascular plants, bryophytes, stoneworts (Characeae) and macro-algal growths</td>
</tr>
<tr>
<td>metaphyton</td>
<td>Algae usually loosely attached to a surface, but easily becoming detached and then forming floating masses</td>
</tr>
<tr>
<td>mucilage</td>
<td>Colloidal material made out of complex polysaccharides</td>
</tr>
<tr>
<td>mucilaginous stalks</td>
<td>Holdfasts made out of colloidal material</td>
</tr>
<tr>
<td>multiaxial</td>
<td>Having more than one axis; developing in more than a single line or plain</td>
</tr>
<tr>
<td>multicellular</td>
<td>Consisting of more than one cell</td>
</tr>
<tr>
<td>multiseriate</td>
<td>Made up of more than one row of cells</td>
</tr>
<tr>
<td>nitrogen fixation</td>
<td>The conversion of atmospheric nitrogen into compounds, such as ammonia</td>
</tr>
<tr>
<td>parietal</td>
<td>Adjacent to or lying just inside the cell wall</td>
</tr>
<tr>
<td>phosphatase</td>
<td>Any of a group of enzymes that act as a catalyst in the hydrolysis of organic phosphates</td>
</tr>
<tr>
<td>photo(auto)trophic</td>
<td>An organism capable of synthesizing its own food from inorganic substances using light as an energy source</td>
</tr>
<tr>
<td>phylum</td>
<td>A primary division of a kingdom</td>
</tr>
<tr>
<td>prokaryotic</td>
<td>Without a distinct, membrane-bound nucleus or membrane-bound organelles,</td>
</tr>
</tbody>
</table>
with DNA that is not organized into chromosomes

prostrate  Growing flat along the surface

pseudoparenchymatous  Closely adherent filaments which look superficially like a parenchyma (= tissue)

pseudosepta  A septum (= partition of primary wall material) like structure

punctate  Consisting of dots/points

pyrenoid  Organelle associated with chloroplasts of many algae, which contains high amounts of carbon dioxide fixing enzyme

rhizoid  Single-celled or filamentous organ of attachment

sensu lato  In the broad sense. Used to compare the traditional ‘broad’ concepts of genera such as Lemanea with modern, more restricted concepts. cf. sensu stricto.

striae  Longitudinal lines or ridges

thallus  A plant body undifferentiated into stem, root, or leaf

trichome  Linear arrangement of prokaryotic cells within the Cyanobacteria; trichome becomes synonymous with filament in sheath-less forms, otherwise the trichome and the sheath together form a filament.

true branching  A secondary outgrowth or subdivision of a main axis (cf false branches)

uniaxial  With one axis

uniseriate filament  Arranged in a single series or row

WFD  Water Framework Directive

whorl  An arrangement of three or more leaves, petals, or other organs radiating from a single node
9. REFERENCES


APPENDIX A. RAPPER SURVEY SHEET

<table>
<thead>
<tr>
<th>River:</th>
<th>Substrate composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site name:</td>
<td>Bedrock</td>
</tr>
<tr>
<td>NGR:</td>
<td>Boulder</td>
</tr>
<tr>
<td>Sampler:</td>
<td>Cobble</td>
</tr>
<tr>
<td>Date:</td>
<td>Pebble</td>
</tr>
<tr>
<td>Location code:</td>
<td>Gravel</td>
</tr>
<tr>
<td>Width (m):</td>
<td>Sand</td>
</tr>
<tr>
<td>Depth (m):</td>
<td>Silt / clay</td>
</tr>
</tbody>
</table>

| Sewage fungus present? Y/N | Any other evidence of organic pollution? Y/N |

<table>
<thead>
<tr>
<th>Type (e.g. crust, mat etc.)</th>
<th>Abundance</th>
<th>Thickness</th>
<th>Lab. ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Abundance scale used (circle one)</th>
<th>3 point</th>
<th>9 point</th>
<th>(see reverse of sheet)</th>
</tr>
</thead>
</table>

Are you confident of field identification? Y / N

If you are unable to identify the alga in the field, take a sample for lab identification. Make sure that the sample is clearly labelled with site details.

<table>
<thead>
<tr>
<th>Shading (circle one)</th>
<th>None</th>
<th>Moderate</th>
<th>Heavy</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Current velocity (circle one)</th>
<th>No / minimal</th>
<th>Slow</th>
<th>Rapid</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Time since last spate (circle one)</th>
<th>&lt; 14 days</th>
<th>&gt; 14 days</th>
<th>Not known</th>
</tr>
</thead>
</table>

In your opinion, are there any other pressures affecting this site (e.g. metals, flow regulation)?

Note any other factors that may affect plant and algal growth at the site.

In your opinion does the site show evidence of eutrophication? Y / N
### Abundance scales

<table>
<thead>
<tr>
<th>Cover value</th>
<th>9 point scale</th>
<th>3 point scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 0.1</td>
<td>&lt; 5</td>
</tr>
<tr>
<td>2</td>
<td>0.1 &lt; 1</td>
<td>5 &lt; 25</td>
</tr>
<tr>
<td>3</td>
<td>1 &lt; 2.5</td>
<td>≥ 25</td>
</tr>
<tr>
<td>4</td>
<td>2.5 &lt; 5</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5 &lt; 10</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>10 &lt; 25</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>25 &lt; 50</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>50 &lt; 75</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>≥ 75</td>
<td></td>
</tr>
</tbody>
</table>

Algal growth forms present (continued from first page)

<table>
<thead>
<tr>
<th>Type (e.g. crust, mat etc.)</th>
<th>Abundance</th>
<th>Thickness</th>
<th>Lab. ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>