Environment Agency

using science to create a better place

Stoneworts: their habitats, ecological requirements and conservation

Integrated catchment science programme

Science report: SC030202

Broads Authority
The Broads - a member of the National Park family

PLANTLIFE

UEA
University of East Anglia

The Environment Agency is the leading public body protecting and improving the environment in England and Wales.

It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

Published by:
Environment Agency, Rio House, Waterside Drive,
Aztec West, Almondsbury, Bristol, BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
www.environment-agency.gov.uk

ISBN: 978-1-84911-035-8

Further copies of this report are available from:
The Environment Agency's National Customer Contact Centre by emailing:
enquiries@environment-agency.gov.uk
or by telephoning 08708 506506.

Author:
Dr Stephen Lambert

Dissemination Status:
Publicly available

Keywords:
Stonewort; Charophyte; Algae; Conservation; Biodiversity; Habitat; Wetland; Restoration; Water quality.

Research Contractor:
Dr Stephen Lambert, School of Biological Sciences, University of East Anglia, Norwich, NR4 7TJ
Email: charophytes@hotmail.co.uk

Environment Agency's Project Manager:
Debbie Cousins, Thames Region

Collaborator(s):
This report is the result of work jointly funded by the Environment Agency, Plantlife International and the Broads Authority.

National Stoneworts Recorder:
Nick Stewart. Email: nfstewart@freeuk.com

Science Project Number:
SC030202

Product Code:
SCHO0309BPSD-E-P

Science at the Environment Agency

Science underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us and helps us to develop monitoring tools and techniques to manage our environment as efficiently and effectively as possible.

The work of the Environment Agency's Science Department is a key ingredient in the partnership between research, policy and operations that enables the Environment Agency to protect and restore our environment.

The science programme focuses on five main areas of activity:

- **Setting the agenda**, by identifying where strategic science can inform our evidence-based policies, advisory and regulatory roles;
- **Funding science**, by supporting programmes, projects and people in response to long-term strategic needs, medium-term policy priorities and shorter-term operational requirements;
- **Managing science**, by ensuring that our programmes and projects are fit for purpose and executed according to international scientific standards;
- **Carrying out science**, by undertaking research – either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques**, by making appropriate products available to our policy and operations staff.

Steve Killeen

Head of Science

Executive summary

Stoneworts, also known as charophytes, are a family of complex-structured algae. They are submerged species that live in a variety of wetland and freshwater or brackish habitats. They derive their common name from the stony external texture that many of the species acquire as a result of encrustation of their outer surface, mainly with calcium carbonate. Stoneworts play a significant role in ecological succession and the community structure of many types of water body. The UK currently supports approximately 30 species. Seventeen of these are currently listed as threatened or endangered in the Red Data Book of British Stoneworts, while 11 are currently listed as priority species on the UK Biodiversity Action Plan. This report is a summary of the relevant sections of a PhD thesis carried out at the University of East Anglia. The thesis investigated the limits of environmental tolerances for British stoneworts with particular reference to water quality and rarer species.

The main aim of this report is to produce a guide to the habitats, ecological requirements and conservation of British stoneworts. It includes chapters on the structure of stoneworts to help with identification, the critical water quality limits of nitrogen, phosphorus and copper, and examples of practical conservation methods. It is intended for use by anyone who works in conservation or water quality as well as those who manage wetland sites.

As a broad guideline, the following are all likely to reduce the probability of stonewort establishment and persistence (Lambert 2007):

- **Nitrogen** in the form of nitrate at concentrations above **0.5 mgl^{-1}** in open water.
- **Phosphorus** as inorganic phosphate at concentrations above **20 μgl^{-1}** in open water.
- **Copper** at concentrations above **50 μgl^{-1}** in the sediment pore water or **100 μgl^{-1}** in open water.

The main threats to stonewort establishment and survival are unmanaged succession, particularly by common reed (*Phragmites australis*), eutrophication, sedimentation and grazing by waterfowl.

To slow down succession, particularly by common reed, creating scrapes within the reedbed allows in light and promotes the re-emergence of stoneworts. Regular scraping of ditches that support stoneworts is also good practice, as it allows in light as well as aiding germination by bringing oospores back to the surface. In aggregate sites, conservation methods include creating margins of variable form and gradient, peaks and troughs in the pit bed and submerged islands. Actions to avoid at aggregate sites include planting of common reed, creating islands that attract waterfowl, excessive tree planting on the banks and the addition of topsoil along the margins.

This report is designed to remove some of the mystery surrounding stoneworts as a group, and give some simple pointers as to how to conserve current communities and create habitats suitable for new colonisation.

Acknowledgements

Dr Stephen Lambert (University of East Anglia) – researcher and author

Professor Anthony Davy (University of East Anglia) – PhD supervisor

Funding:

The Environment Agency

Plantlife International

The Broads Authority

Editors:

Debbie Cousins (The Environment Agency)

Professor Anthony Davy (University of East Anglia)

Andrea Kelly (Broads Authority)

Dominic Price (Plantlife International)

Photographs:

Dr Stephen Lambert

Contents

1 Introduction

Stoneworts (also known as charophytes) are a family of complex-structured algae that live in a variety of wetland and freshwater or brackish habitats. These include disused aggregate sites, fenland ditches, dykes, bog pools, lakes, ponds, highland lochs and even cattle tracks. Stoneworts are submerged species, generally preferring water depths between one and ten metres. The plants derive their common name from the stony external texture that many of the species acquire as a result of encrustation of their outer surface, mainly with calcium carbonate.

Stoneworts are found in the following habitats:

Disused aggregate pit

Calcareous fenland ditch

Disused peat digging

Ephemeral coastal pond

Highland loch

Moorland cattle tracks

2 Conservation status and distribution

Earliest fossil records date back 460 million years, and recent DNA evidence has established stoneworts as close to the precursors of all land plants. Today, globally, there are over 400 species, while the UK supports approximately 30 species. However, since the mid-twentieth century their range has decreased significantly and the number of sites with extant populations has declined by over 60 per cent, due to habitat loss and pollution of both surface and groundwaters.

Seventeen species are currently listed as Threatened or Endangered in the Red Data Book of British Stoneworts, while 11 species are currently listed as priority species on the UK Biodiversity Action Plan.

There are five genera of stoneworts in the UK, living in the following conditions:

- *Chara*: base-rich alkaline waters; species often calcium-encrusted.
- *Lamprothamnium*: coastal lagoons.
- *Nitella*: less alkaline, softer waters (pH 6.5 - 7.5), lacking encrustation, and stem without cortex.
- *Nitellopsis*: mesotrophic lakes, lacking encrustation, and stem without cortex.
- *Tolypella*: calcareous ditches and canals.

Main threats

These include:

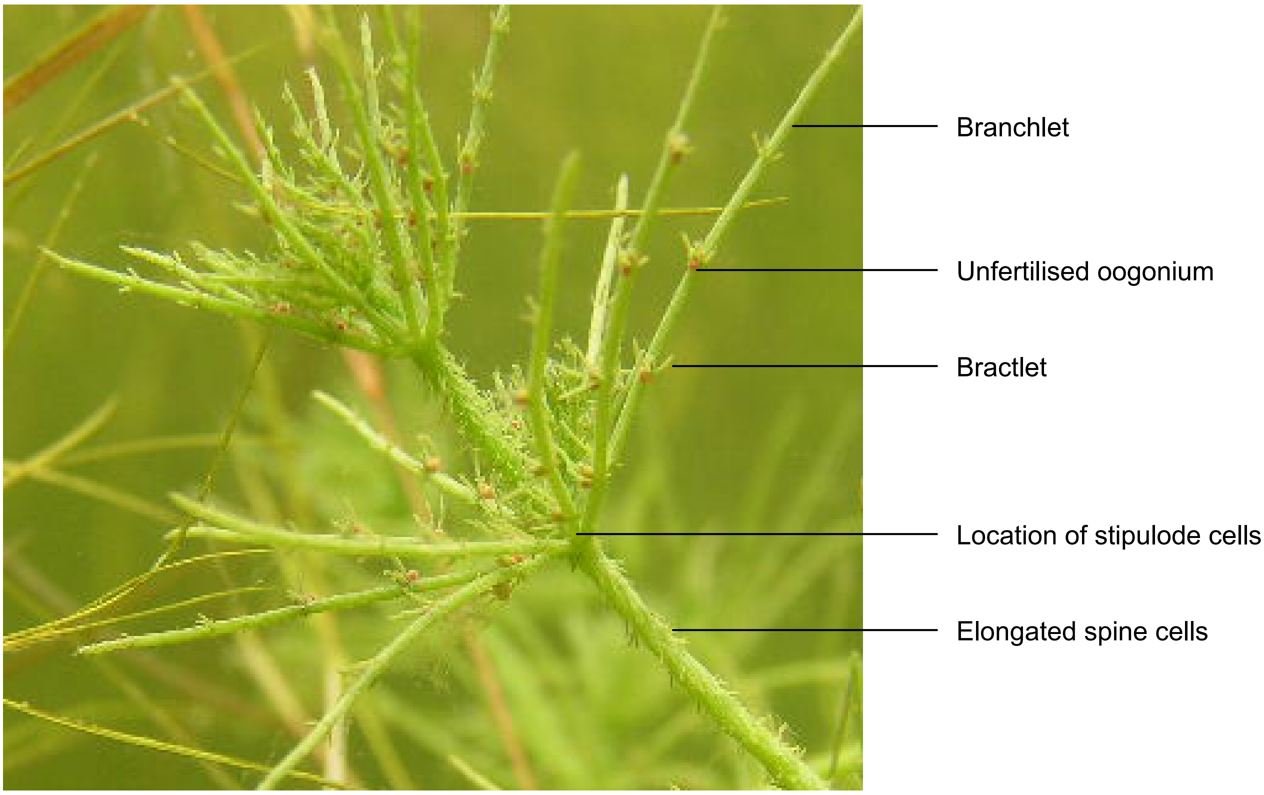
- eutrophication;
- sedimentation;
- unmanaged succession, particularly of common reed (*Phragmites australis*);
- avian grazing, particularly by geese which includes nutrient import.

Eutrophic pond

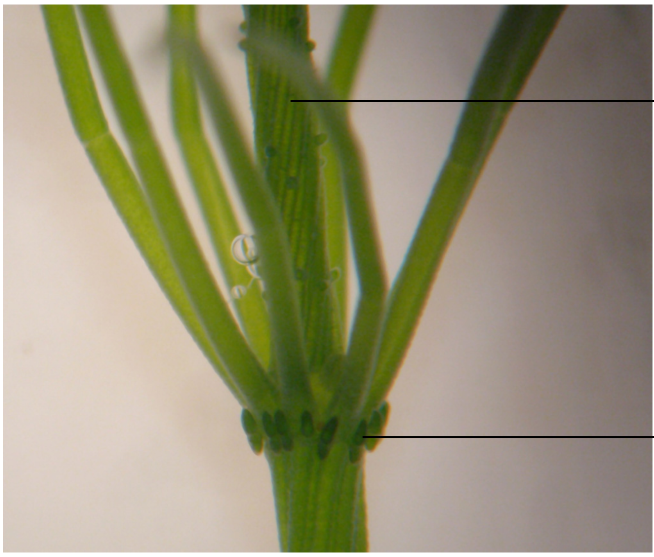
Sedimentation

3 Structure and sensitivities

Being algae, stoneworts do not have true leaves or roots. Instead of leaves they have branchlets arranged in whorls around the stem, and they possess fine rhizoids that anchor the plant into the sediment. Stoneworts have very large cells (up to 20 cm in length), with each branchlet, rhizoid wall and internode being one cell thick. While nutrient uptake can be through the rhizoids, gaseous exchange and most nutrient uptake are by direct transport from the water through the outer cells of the branchlets and stems. This makes stoneworts exceptionally sensitive to water quality, particularly the presence of metals. They are also very sensitive to competition from filamentous algae, which are often promoted by nutrient enrichment, particularly nitrates and phosphates from agricultural and urban run-off.

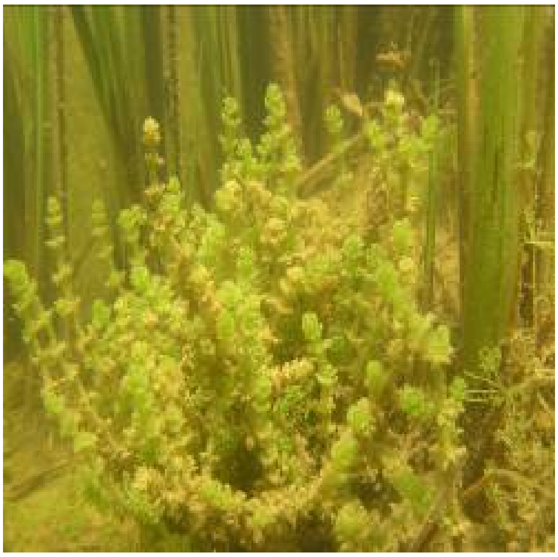


Basic anatomy of a stonewort (*Chara hispida*)



The presence, form and location of stipulode cells are a key identification tool for *Chara* species (Moore 1986).

Whole young *Chara hispida* plant showing rhizoid mass.



Chara canescens thriving in nutrient-free waters in Orton Pits (Cambs.)

Uprooted *Chara hispida* plant showing fine and chemically sensitive rhizoid mass

Stoneworts of the same species exhibit plasticity of morphology (variation in shape and form) according to the habitat and water quality in which they are found.

Chara hispida at Trevassack Quarry, Cornwall (serpentine quarry).

Chara hispida at Orton Pits, Cambridgeshire (clay pit).

Such variation in form from site to site makes correct identification of stoneworts a difficult task. A degree of training is required, even for many who might otherwise consider themselves to be competent botanists. If a stonewort is noted at a site, it is always best to seek professional confirmation of its true identity. This may be done by sending a sample to the National Recorder (Nick Stewart) whose email address is provided on page ii of this document. Collection is simple: two or three stems should be clipped at three branches below the shoot tip, leaving the plant *in situ*. Samples should then be placed in a sealed plastic bag and posted in a cushioned envelope within 24 hours. Placing the sample in a refrigerator until posting will greatly improve the shelf life.

Although they may persist, often as dominants, for many years, stoneworts are pioneer species and will commonly be the first plant community to colonise newly dug ponds, lakes or ditches. As natural succession takes place and sediments age, recent research has shown that the stonewort community structure is likely to change from species that thrive on new, oxidised sediment such as *Chara aspera* to those which have apparently evolved to inhabit deeper, more hypoxic, benthic conditions such as *Nitellopsis obtusa* or *Nitella* spp. Both of these have been shown to persist in lower light and more mesotrophic conditions.

Many stoneworts are spiny (hispid) and it is thought (but not proven) that the spines function for protection and as sites of ion uptake from the water. However many are not. The *Nitella* spp. and *Nitellopsis* spp. are ecorticate (lacking cortex), are not ‘hispid’ and do not deposit calcium salts on the branchlets. This suggests not only a morphological difference but also a metabolic difference between the species.

The spiny *Chara hispida*.

Ecorticate *Nitellopsis obtusa*.

Some stoneworts such as the ditch and clay pond dwelling *Tolypella* spp have several stems.

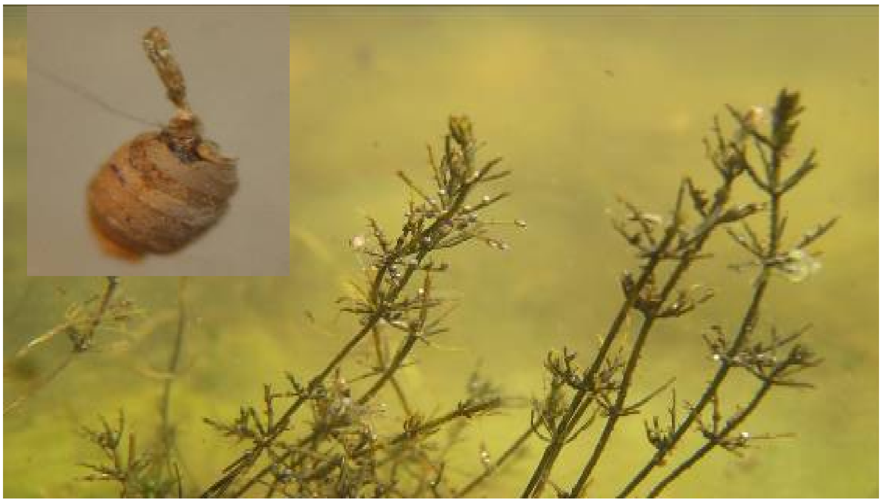
Tolypella prolifera: multicorticate but no calcium encrustation.

4 Reproduction

Sexual reproduction is by oospores, which form when the eggs within the female oogonia are fertilised by the male antherozoids, which are released from the male antheridia. These reproductive organs (gametangia) are typically situated above (female) and below (male) the branchlet arm. In some cases such as in *Chara connivens,* male and female parts are on separate plants (dioecious) while in others they are on the same plant (monoecious). Reproduction is stimulated by light and temperature increase and generally occurs when waters reach 14º C. Post fertilisation, the oospores darken and germination can take place within 24 hours of deposition in correct conditions. Burial of the oospores in soft deep sediments has been shown to be a key cause of stonewort community decline. However, disturbance of such buried oospores may also instigate the regeneration of a former stonewort community.

Unfertilised oogonia of *Chara fragifera*.

Female and male plants of *Chara connivens.*



Darkened fertilised oospores of *Chara intermedia* still *in situ* on the plant and (inset) germinating *Chara intermedia* oospore (day 1) showing the emerging protonema.

In several species reproduction can also be vegetative, by the production of propagules known as bulbils that are formed at rhizoid-bearing joints. These can persist in the substrate and germinate when conditions improve.

5 Water quality

A common factor for stoneworts is that, although there appears to be differential tolerance between species, as a group they are highly sensitive to water quality. This fact is possibly due to their algal structure and ancestral development. Recent research at the University of East Anglia has shown that stoneworts are particularly sensitive to a range of freshwater pollutants commonly associated with agricultural run-off and urbanisation. They are particularly sensitive to heavy metals such as copper, and to the effects of competition induced by dissolved nitrates and phosphates.

Critical water quality limits

Recent research at the University of East Anglia has shown that there is differential tolerance to water quality within and between stonewort species. However, based on a 'presence or absence' study of 123 water bodies at 49 important historical stonewort sites, the following approximate concentrations were shown to reduce the probability of stonewort establishment and persistence (Lambert 2007):

- **Nitrogen** in the form of nitrate at concentrations above **0.5 mgl^{-1}** in open water.
- **Phosphorus** as inorganic phosphate at concentrations above **20 μgl^{-1}** in open water.
- **Copper** at concentrations above **50 μgl^{-1}** in the sediment pore water or **100 μgl^{-1}** in open water.

In addition, the probability of stoneworts occupying a site is dependent on maximum concentrations of cobalt, manganese and silicate as well as minimum concentrations of calcium, chloride, magnesium, sodium and sulphate.

Salinity was also investigated, with growth and photosynthetic function being affected by changes in salinity. Saline ingress as a result of managed retreat and rising sea levels may therefore be another limiting factor in stonewort survival.

6 Stoneworts' important role in aquatic ecosystems

Stoneworts are often the earliest colonisers of newly formed water bodies and perform a number of important roles in aquatic ecosystems.

These include:

- Enhancing water clarity by reducing flow rates and hence aiding sediment deposition.
- Forming dense mats and hence aiding sediment stabilisation via rhizoid linkages.
- Providing habitat for both anaerobic and aerobic microbes.
- Providing daytime shelter for phytoplankton-grazing zooplankton.
- Providing habitat for mollusc and other invertebrate populations.
- Providing a substrate for fish spawning and shelter for fish fry.
- Acting as a 'nutrient sink' for organic nutrients, because of their high biomass.

7 Conservation methods

Proven restoration methods vary according to the type of habitat and may therefore be site-specific. Dykes, gravel pits, shallow lakes, clay pits, quarries or lochs may all require a different method or combination of methods.

The principal aims of conservation/restoration are generally to:

i. reduce the annual nutrient budget of the site;
ii. remove surface fluid sediments built up through eutrophic die-off;
iii. remove or reduce competitive vegetation.

The following are some examples of successful conservation methods at a variety of sites.

Mechanical clearance

At Eye Green in Peterborough, a late-succession site, it was found to be more economical to excavate new pits rather than restore the site by mud-pumping or vegetation removal.

Recently dug pits at Eye Green rapidly colonised by the endangered *Chara canescens*

Such pits may have a life-span of up to 20 years before succumbing to succession, dependent upon their annual nutrient load from groundwater and the surrounding catchment.

Ditch/dyke scraping

Regular scraping of ditches (for example every four to five years) is good for stoneworts as it allows full successive life cycles and opens the canopy allowing light to penetrate. It also aids germination by bringing oospores back to the surface of the sediments and aerates the top layers of sediments. Recent research has shown that this stimulates oospore germination for species such as *Tolypella intricata, T.prolifera, Chara vulgaris* and *C. hispida*.

Ditch clearance where the bucket scraped 5 cm into the sediment at a site in the Upper Thurne in The Broads, allowed re-emergence of *Tolypella prolifera.* Scraping too often however, such as annually, may prevent completion of the natural life cycle.

Ditch clearance in the Upper Thurne, The Broads.

Re-emergence of *Tolypella prolifera*.

Peat scrapes

Advanced succession of stonewort sites by common reed (*Phragmites australis*) may be mitigated by the creation of scrapes within the reedbed, allowing light in and promoting the chance of re-emergence of stoneworts.

A peat scrape at Cors Erddreiniog (Anglesey Fens) providing conditions for the extremely rare *Nitella tenuissima* to re-emerge.

Sediment removal

Removal of the surface nutrient-enriched layers of sediments, using mud-pumping for example, can expose buried oospores which subsequently germinate given the right water quality conditions. In addition, removal of silt from the site avoids nutrient leaching back into the system, and has proven very successful in some of the shallow broads.

Aggregate extraction sites

Some simple recommendations for restoration projects at aggregate extraction sites include the following positive actions, as well as actions that should be avoided.

Positive actions

1. Create margins of variable form and gradient to encourage habitat diversity, which will encourage diversity of pioneer species.
2. Allow natural colonisation where possible, but if planting is necessary, try to locally source all new marginal plants. If not possible, all imported plants should be of UK provenance and must be checked for any non-native species so as not to introduce them to the site.
3. Create peaks and troughs in the pit/lake bed that will encourage a diversity of shallow and deep-water plant species. In time this will also create variance in sediment quality from wind-washed shallows to sediment accruing in deeper locations.
4. Create submerged islands away from the margins that are too deep (more than one metre) at normal summer water lows for birds to alight on, but will encourage mid-water colonisation by stonewort species commonly found in shallow waters such as *Chara aspera*, *C. canescens* and *C. curta*.
5. Create a diversity of substrates such as sands, gravels and sub-soils of different grades/sizes.

Actions to avoid

1. Do not line marginal habitat with topsoil, which is often nutrient-rich and hence would encourage dominant, competitive species. It may also contain unknown human chemical additives.
2. Do not plant the margins (or any locations) with common reed (*Phragmites australis*), which has been shown to be the fastest coloniser and hence the most strident competitor for marginal habitat. Low-growing species such as hard rush (*Juncus inflexus*) at three plants per metre are far more effective at binding the banks against wave and in-wash erosion without creating ‘marching succession’.
3. Avoid strimming bank-side vegetation as this can leave drowned stands that may decay and promote anoxia and nutrient release from localised sediments.
4. Do not create islands with shallow margins that might become roosts for geese or other nutrient-importing wildfowl.
5. Avoid excessive tree planting at the margins as this (a) limits light and (b) gives rise to benthic detritus via leaf litter that buries oospores.
6. Manage the habitat and fishery to avoid high numbers of benthic fish species such as carp as they can uproot aquatic plants and also stir up sediment which can smother submerged plants. If fish species are to be stocked to create a balanced ecosystem, only stock with low numbers of native fish species such as rudd, perch and pike. All fish stocking and removals will require written consent from the Environment Agency.

8 Conclusion

Stoneworts have existed and been evolving for over 400 million years. Left to their own devices, in natural waters, most species are remarkably robust at both community and population level through their prolific regeneration, reproduction and growth rates. They thrive on being 'left alone' in relatively undisturbed habitats. However, rapid changes in the quality of our freshwaters driven by the intensification of agriculture in the latter half of the 20th century, in combination with the loss of habitat through human demand for land, has left many of the more fragile species under severe threat of extinction.

This report is designed to remove some of the mystery surrounding stoneworts as a group, and give some simple pointers as to how to conserve current communities and create habitat suitable for new colonisation.

References

LAMBERT, S.J., 2007. *The ecological range and tolerance limits of British stoneworts (Charophytes).* Unpublished PhD thesis, University of East Anglia.

MOORE, J.A., 1986. *Charophytes of Great Britain and Ireland*. Botanical Society of the British Isles (Handbook No.5).

STEWART, N.F. AND CHURCH, J.M., 1992. *Red Data Books of Britain and Ireland: stoneworts*. Joint Nature Conservation Committee.

Glossary

Antheridium: globular usually orange male sexual organ, produced at branchlet nodes.

Antherozoid: motile male gamete.

Benthic: on or in the bed of a body of water.

Bractlet: a single-celled process subtending from the oogonium in females plants of dioecious species of *Chara*, replacing antheridium.

Branchlet: the laterals of limited growth produced in whorls at the axial stem nodes.

Bulbil: energy-storing agglomeration of starch containing cells developed on the rhizoids and stem nodes of some stoneworts. Propagules for vegetative reproduction.

Cortex: the outer covering of longitudinally arranged cells in certain species of *Chara*, which gives the axes a striped or ridged appearance.

Dioecious: the male and female gametangia are produced on separate male and female plants of the same species.

Ecorticate: lacking cortical cells around the stem as in *Nitella.*

Gametangia: male and female sexual organs.

Hypoxic: low oxygen content beneath that considered aerobic.

Monoecious: the male and female gametangia are produced on the same plant of a species.

Multicorticate: multiple rows of cortical cells making up the stem cortex.

Oogonium: the ovoid female sexual organ. This is opaque, usually green (when immature) or brown or black (when fertilised), and develops into an oospore covered with spirally arranged cells.

Oospore: diploid spore that is the main agent of dispersal and reproduction.

Protonema: juvenile form that emerges from the oospore at germination and gives rise to a new charophyte plant.

Rhizoid: colourless hair-like filament growing from the plant base into the substrate, with the dual function of absorption and anchorage.

Spine-cells: single-celled processes growing out from the node cells of the stem cortex in some *Chara* species.

Stipulode: a single or double ring of single-celled processes growing out from the base of the branchlet whorls.

We are The Environment Agency. It's our job to look after your environment and make it **a better place** – for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.

Published by:

Environment Agency
Rio House
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 0870 8506506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk