

Bryological assessment for hydroelectric schemes in the West Highlands (2nd edition)





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COMMISSIONED REPORT

Commissioned Report No. 449b

Bryological assessment for hydroelectric schemes in the West Highlands (2nd edition)

For further information on this report please contact:

Dr David Genney
Policy & Advice Officer - Bryophytes, Fungi and Lichens
Scottish Natural Heritage
Great Glen House
Leachkin Road
Inverness, IV3 8NW
Telephone: 01463 725000
Email: David.Genney@snh.gov.uk

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COMMISSIONED REPORT

Summary

Bryological assessment for hydroelectric schemes in the West Highlands – 2nd edition

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Background

Proposals for run-of-river hydroelectric schemes are being submitted each year, but developers and planning consultees are often unclear about when to commission a bryophyte survey as part of the information submitted in a planning application. This project was commissioned by SNH to provide a means of assessing the bryological importance and/or potential of watercourses. This will help to clarify whether a survey is needed for any particular hydroelectric proposal. It will also indicate where hydroelectric schemes could have an adverse impact on the national bryophyte flora. The work was carried out by a team of three bryologists – Ben Averis, Nick Hodgetts and Gordon Rothero – working in close association with Dr David Genney (SNH Policy and Advice Officer for Bryophytes, Fungi and Lichens).

29 nationally uncommon or rarer, humidity-demanding bryophyte species were selected as being of importance for nature conservation and potentially vulnerable to the effects of water abstraction for hydroelectric schemes. Each species was given a score between 1 and 12, based on a combination of its rarity and IUCN threat category: 1 = neither Nationally Scarce nor Nationally Rare; 3 = Nationally Scarce; 6 = Near-Threatened; 9 = Vulnerable; 12 = Endangered. At sites with records of these species, the species scores are summed to give a site score. Where a watercourse has a score of 6 or more points it is considered to be of high national and/or international significance; a hydroelectric scheme at such a site could have an adverse impact on the national bryophyte flora. Where a watercourse has been well surveyed and found to have a score of 0-5 points, the bryophyte flora is considered to be of lower importance and hydroelectric development is unlikely to have a significant impact at a national scale but may be important at a more local scale.

Main findings

- 5629 sites have been classified.
- The majority (90.8%) of classified sites are unsurveyed or only partially surveyed, but many of these (49.2% of sites) have low potential for high bryological interest.
- 136 sites (2.4% of all classified sites) have so far been identified that are of such bryological importance that hydroelectric development could have a significant national impact on humidity-demanding oceanic species.

For further information on this project contact:

Dr Dave Genney, Scottish Natural Heritage, Great Glen House, Leachkin Road, Inverness, IV3 8NW.
Telephone: 01463 725000. Email: David.Genney@snh.gov.uk

For further information on the SNH Research & Technical Support Programme contact:

Publications Unit, SNH, Battleby, Redgorton, Perth, PH1 3EW.
Tel: 01738 444177 or publications@snh.gov.uk

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1 INTRODUCTION

Run-of-river hydroelectric power schemes are operating on many watercourses in Scotland, and proposals for new schemes are being submitted each year. Developers and planning consultees are often unclear about when to commission a bryophyte survey as part of the information submitted in a planning application. [Guidance for applicants on supporting information requirements for hydropower applications](#) (SEPA 2010) encourages developers to review existing data as the first stage in identifying whether a full bryophyte survey is required. Scottish Natural Heritage (SNH) recognises that it will help if, at an early stage during the planning and environmental assessment process, it is possible to obtain answers to the following questions:

- Has the watercourse already been surveyed for bryophytes?
- If it has not yet been surveyed, does a survey need to be commissioned?
- Where a survey has taken place, what implications do the survey results have for a hydroelectric proposal?

This project was commissioned by SNH to provide a means of assessing the bryological importance and/or potential of watercourses in the West Highlands. It deals only with bryophytes in relation to water abstraction for hydroelectric schemes. Other effects of hydroelectric schemes on the bryophyte flora (for example from construction of intakes, pipelines, turbine houses and access routes) and other aspects of natural heritage interest (including cumulative impacts) also need to be considered (SNH 2010, SEPA 2010).

The work was carried out by a team of three bryologists – Ben Averis, Nick Hodgetts and Gordon Rothero, each of whom has extensive experience of bryophytes along watercourses in the western Highlands – working in close association with Dr David Genney (SNH Policy & Advice Officer for Bryophytes, Fungi and Lichens).

A system was developed for the classification of watercourses on the basis of their bryological importance or (for sites that are unsurveyed or only partly surveyed) their bryological potential. When a watercourse is classified using this system, the categorisation indicates (a) whether a bryophyte survey needs to be commissioned for a hydroelectric proposal, and (b) whether water abstraction for a hydroelectric scheme could have an important impact on the national bryophyte flora.

Under this contract, carried out in 2011-12, the classification and assessment system was developed and applied to a total of 5629 watercourse sites in the West Highlands. 2357 were initially classified in the first edition of this report; however, since then an additional 3272 sites have been classified and some changes have been made to the scoring system, with advice and assistance from Ian Bainbridge (SNH Head of Science). This edition incorporates these additions and changes. It presents the rationale of the classification system and a summary of the results of the classification work carried out. The details of the 5629 classified sites are held by SNH in a database and will soon be incorporated into an online planning tool accessible from SNH's [hydro planning and development](#) webpage. Copies of the data may be obtained by contacting SNH.

In this report, nomenclature for the bryophytes follows Hill *et al* (2008). The definition of 'oceanic species' follows Hill & Preston (1998). Definitions of Nationally Rare and Nationally Scarce species are taken from Preston (2006, 2010). The status of species in relation to International Union for the Conservation of Nature (IUCN) threat categories is taken from Hodgetts (2011).

2 GENERAL CONCERNS ABOUT BRYOPHYTES IN RELATION TO HYDROELECTRIC SCHEMES

Scottish Natural Heritage (SNH) recognises the benefits of renewable energy production but is concerned that renewable energy development should not have adverse impacts on the natural heritage. The SNH document [Renewable energy and the natural heritage](#) (SNH 2010) makes this point as follows:

We seek a strategic approach in which renewable energy development is guided towards the locations and the technologies most easily accommodated within Scotland's landscapes and habitats without adverse impact, and which safeguard elements of the natural heritage that are nationally and internationally important.

In a typical run-of-river hydroelectric scheme some of the water is removed from the watercourse at an *intake* and piped downslope to an electricity generating station (turbine house) from where it is piped back into the watercourse at the *outfall*. The quantity of water between the intake and outfall is therefore reduced. Bryophytes (mosses and liverworts) are one of the main groups of concern in relation to this water abstraction, especially in the western Highlands (including the Hebrides). This concern is summarised in the following extract from section 3.5 (*Bryophytes and hydro schemes*) of *Guidance for applicants on supporting information requirements for hydropower applications* (SEPA 2010) and expanded on below:

The western part of the British Isles has international importance for its oceanic bryophyte and lichen floras, with large populations of some species that are uncommon in Europe generally and a few species that are rare or absent in the rest of Europe. Incised river valleys, and particularly rocky ravines that may be suitable for hydropower represent key refugia for these species. Oceanic bryophytes and lichens require high humidity, and a reduction in river flow may result in a negative impact on these species. Many bryophytes of oceanic ravines also depend on new habitat created when rivers are in spate and on frequent periods of inundation. The impact of an application on river corridor humidity and spate flow rates will have to be considered where a site is known or found to be important for its oceanic bryophyte and/or lichen flora. A bryophyte and lichen survey is recommended for any Scottish hydropower application. Information on the bryophyte and lichen flora will be required if conditions 1, 2 and/or 3 below are met:

- 1) *The application relates to a site in western Scotland (West Coast Scotland Important Plant Area or Western Isles)*.*
- 2) *The watercourse is incised and/or a wooded ravine.*
- 3) *The application relates to a site that has been designated for its bryophyte and/or lichen interest e.g. SSSIs or SACs.*

**Important oceanic or riparian bryophyte and lichen communities may be found beyond the oceanic zone defined here, which is why a general bryophyte or lichen survey is always recommended. The West Coast Scotland IPA boundary is available from the Plantlife website (www.plantlife.org.uk).*

2.1 The international importance of oceanic bryophytes in the West Highlands

The concern about bryophytes in relation to hydroelectric schemes focuses particularly on uncommon bryophyte species that are hygrophilous (adapted to wet conditions; living or growing in moist places) and for which watercourses and their environs are vitally important habitats. These potentially vulnerable bryophytes are mainly *oceanic*

species (*sensu* Hill & Preston 1998) that are restricted in Europe to western *oceanic* areas with a wet and equable climate. The western parts of Great Britain and Ireland, and the Faroe Islands, have the most oceanic climate in Europe and are the richest parts of Europe for oceanic bryophytes. Within these areas oceanic bryophytes are commonest in humid habitats: rocks and trees along fast-flowing watercourses, especially in wooded ravines, are particularly important habitats. Many sites in these areas are of international importance for their rich oceanic bryophyte floras. The western Highlands is the richest part of Great Britain for oceanic bryophytes, and contains many of the richest sites for oceanic bryophytes in Europe.

The international significance of bryophyte-rich west Highland woodland is apparent from its classification as Coastal Temperate Rainforest, a biome with a very restricted world distribution as shown in Map 1.

Map 1. World distribution of Coastal Temperate Rainforest.



Map drawn by Ben Averis and based on descriptions from the following sources: Rhind (2003); <http://www.terrestrial-biozones.net/> ; http://en.wikipedia.org/wiki/Temperate_rainforest. Note: this habitat occurs in Cumbria and Wales but these areas are too small to show on this map; the 'cloud forests' in the Azores, Madeira and Canary Islands could also be regarded as a type of Coastal Temperate Rainforest.

Coastal Temperate Rainforest throughout the world is characterised by a great abundance and diversity of bryophytes and Fig. 1 is a west Highland example.



Figure 1. *Bryophyte-rich community in coastal temperate rainforest in the West Highlands*

This luxuriance of bryophytes is a response to the climate of the Coastal Temperate Rainforest biome: very wet (with rain falling on a high proportion of days through the year), combined with an equable temperature regime so that winters are mild and summers are warm but not very hot. Within the Coastal Temperate Rainforest habitats in the West Highlands, conditions are especially humid and bryophyte assemblages especially rich along rocky streams such as the example in Fig. 2.



Figure 2. *Bryophyte-rich flora on rocky streamside, West Highlands.*

Figures 3 and 4 show closer views of typical rock habitats of uncommon hygrophilous oceanic bryophytes along western rocky watercourses.



Figure 3. *Habitats of the liverworts Jubula hutchinsiae (a), and Aphanolejeunea microscopica (b)*



Figure 4 *Habitats of the liverworts Radula voluta (a) and Drepanolejeunea hamatifolia (b)*

Figures 5 and 6 show closer views of some of the uncommon oceanic bryophyte species found along western rocky watercourses.



Figure 5 (a) *Isohetecium holtii* (a moss) and (b) *Aphanolejeunea microscopica* (a liverwort)



Figure 6 (a) *Jubula hutchinsiae* (a liverwort) and (b) *Radula voluta* (a liverwort)

In West Highland woodland the luxuriance and diversity of bryophytes and the occurrences of certain oceanic species or genera are all markers of strong floristic and ecological links with Coastal Temperate Rainforests in such distant areas as western Canada/USA, Chile, New Zealand and Japan. It adds significantly to the ecological interest of these woods and rocky streams that they can be considered to belong in a different world-scale climatic and ecological zone from most other parts of Great Britain.

The conservation importance of these West Highland woods and rocky streams should not be underestimated. These habitats form one of the most notable features of British vegetation and one of Great Britain's greatest contributions to global biodiversity interest. The rocky, bryophyte-rich watercourses are particularly valuable in this respect. Many sites in this area may appear 'average' in a west Highland context but are clearly of high significance at national and international levels – on a par with the better known international importance of Great Britain's breeding seabird colonies. It is important that we this value and aim to maintain the richness of this important area.

The high humidity along a rocky watercourse in a west Highland wood or ravine will be the result of a combination of many factors including the watercourse itself (i.e. spray, splash, periodic submergence etc), rainfall, the infrequency of very hot or very cold temperatures, the shade and shelter provided by tree cover, boulders and ravine

topography, and groundwater seeping down steep streamside banks. The interactions among these factors appear to be extremely complex – probably varying considerably within any site – and are not yet understood in detail. While some of these factors are not directly related to the water in the watercourse itself, there are several factors contributing to the significance of the watercourse. These include greater concentrations of uncommon hygrophilous oceanic bryophytes on rocks and banks close to watercourses (including assemblages on boulders and tree trunks, which do not receive seepage from ravine walls or other streamside banks), the role of stream water in limiting colonisation by (and competition from) commoner bryophytes, and the generally poorer representation of uncommon hygrophilous oceanic bryophytes in ravines and gullies without streams.

2.2 Potential effects of hydroelectric schemes on bryophytes in the West Highlands

Water abstraction for a hydroelectric scheme causes a reduction in the volume of water in that part of the watercourse between the intake and outfall locations. The amount of reduction varies: for example in drier conditions when natural water levels are lower, the amount abstracted for hydroelectric generation is typically small, or even halted; the highest proportion of water is generally abstracted when natural flows are between average and high levels.

The effects of hydroelectric schemes on oceanic bryophytes are not known in detail because the monitoring work that has been done so far relates only to the last decade or so at a small number of sites. Demars & Britton (2011) also conclude that it will be very difficult to measure the impact of abstraction on rare bryophytes due to their low frequency, site variability and the unknown timescale over which impacts may occur. However, examination of information available about the habitats of bryophyte species (from sources including Ratcliffe 1968, Hill *et al* 1991, 1992, 1994, Averis 1991, Paton 1999, Porley & Hodgetts 2005 and Atherton *et al* 2010) and small-scale variation in bryophyte assemblages (e.g. Ratcliffe 1968, Averis 1991, 2003, Porley & Hodgetts 2005) suggests that abstraction of water for a hydroelectric scheme can be expected to have the following effects:

- A reduced frequency of splash, spray etc in habitats along and close to the stream, and a potential general lowering of humidity levels;
- A downward migration of humidity zones and their associated bryophyte assemblages;
- A reduced tendency for water action to prevent large common bryophytes from colonising rock surfaces. This might lead to an increased extent of colonisation by large common species and a decreased extent of barer rock surfaces on which small uncommon bryophytes can grow without becoming overgrown by larger commoner bryophytes.

These effects could potentially lead to a reduction in the diversity of uncommon oceanic bryophytes along streams with hydroelectric schemes. This appears likely to have happened at a site in Wales studied by Averis (2003), where the most promising-looking habitat in a deep ravine has been affected by hydroelectric development since the 1920s and was found to be bryologically poorer (with some apparent losses of uncommon oceanic species since the 1920s) than some unaffected areas upstream where the habitats were less likely to be as bryologically rich as those in the ravine.

Mitigation measures that have been considered in relation to bryophytes and hydroelectric schemes include the following:

- *Compensation flow.* This means abstracting less water than is necessary for the most economic electricity generation. This maintains at least a certain minimum volume of water in the stream. The amount of compensation flow will be limited because economic electricity generation will require a minimum abstraction volume. It will also vary depending on the volume of water available in the stream. It is not known whether this can allow a rich oceanic bryophyte flora to be maintained.
- *Spray from pipelines.* This is the release of some piped water as spray from small holes in a pipeline close to the watercourse. However, observations at a site in Wales (Averis pers. obs.) suggest that this provides very particular and localised spray conditions that benefit some commoner non-oceanic bryophytes more than the small uncommon oceanic ones.
- *Translocation of bryophytes.* This means moving populations of uncommon bryophyte species to another watercourse unaffected by hydroelectric development. If bryophytes are moved to a new location there is no guarantee that they will survive there. As they will be damaged if removed from rock or bark surfaces, translocation would probably mean moving the bryophytes and their substrate (for example whole rocks); this would present practical problems and would disturb the natural microhabitats at source and destination sites.
- *Establishment of new tree growth.* This is sometimes proposed as a means of increasing shade and shelter along open, unwooded and relatively bryophyte-poor lengths of watercourse, especially upstream or downstream of the potentially affected sections. In time this may benefit some aspects of the bryophyte flora but there is currently no evidence that it would lead to the development of very rich oceanic bryophyte floras along watercourses in these places.

The appropriateness of mitigation in relation to any development varies according to the balance between the level of conservation importance of the habitat affected and the certainty with which mitigation would allow that level of conservation importance to be maintained. This is shown diagrammatically below:

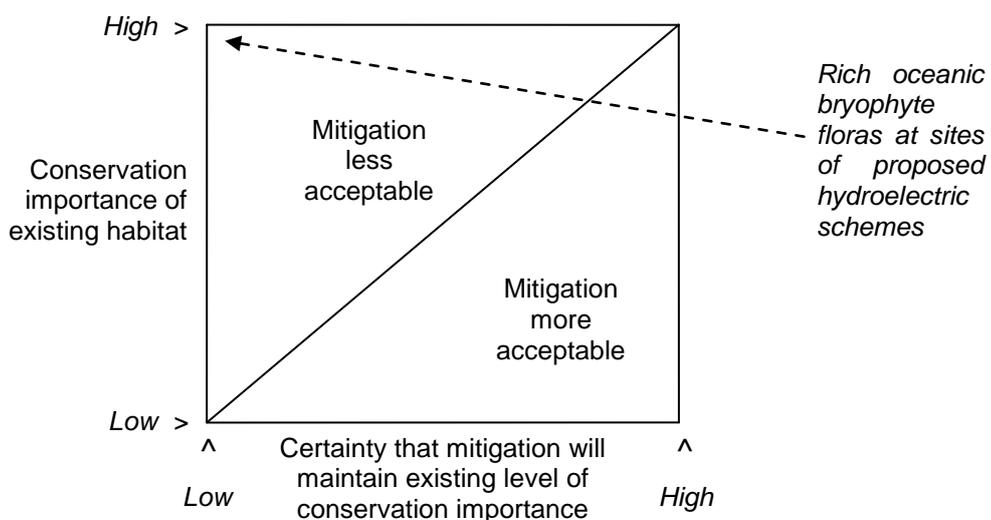


Figure 7. *The balance between existing conservation importance and mitigation activity*

In Fig. 7, mitigation for rich oceanic bryophyte floras in relation to water abstraction for hydroelectric schemes occupies a position at the top left corner: i.e. mitigation of very uncertain ecological benefit used at sites of very high conservation importance. In such situations mitigation is less acceptable as a means of maintaining ecological interest than it would be if its beneficial effects were much more certain and/or if the level of existing conservation importance were lower.

Given the potential vulnerability of uncommon oceanic bryophyte species to hydroelectric schemes, the uncertainty regarding the precise effect of any particular hydroelectric scheme, and the limited scope for mitigation against the effects of water abstraction, the precautionary principle should be adopted as follows:

- To regard hydroelectric schemes on watercourses whose bryophyte floras are not of high national and international importance to be unlikely to have a significant impact on the national bryophyte flora (though some may have impacts of significance at a more local scale).
- To regard hydroelectric schemes at sites with nationally or internationally important assemblages of uncommon humidity-demanding bryophyte species to have the potential to have significant impacts on the national bryophyte flora, and normally to avoid these for bryophyte conservation reasons.

This is consistent with the SNH recommendation to '*...safeguard elements of the natural heritage that are nationally and internationally important*'

The classification system described in the next section of this report presents a definition of national/international importance of bryophyte floras along watercourses in the western Highlands. It also provides a rationale for dealing with bryophytes for environmental assessment purposes, based on the known bryological richness of watercourses or their bryological potential if they are unsurveyed or only partly surveyed.

3 CLASSIFICATION SYSTEM FOR BRYOLOGICAL ASSESSMENT OF WATERCOURSES IN RELATION TO PROPOSED HYDROELECTRIC SCHEMES

The classification system developed by this project is based on the following information:

- Distribution records of 29 nationally uncommon humidity-demanding bryophyte species;
- Habitat potential for these species at unsurveyed or partly surveyed sites.

3.1 Selection of species

Twenty-nine species were selected for inclusion in this method of assessment. They are species for which all of the following apply:

- They are uncommon in Great Britain (either Nationally Rare, Nationally Scarce or with otherwise markedly restricted distributions as shown by maps in Atherton *et al* 2010 and <http://data.nbn.org.uk>).
- Their occurrences are mainly or entirely in very humid habitats such as watercourses and their environs, sheltered woods, and rocky slopes and ravines, especially in western areas with a wet climate (habitat and distribution details are

shown in various sources, especially Ratcliffe 1968, Hill *et al* 1991, 1992, 1994, Averis 1991, Paton 1999, Atherton *et al* 2010 and the British Bryological Society: Bryophyte data for Great Britain from the British Bryological Society (accessible via <http://data.nbn.org.uk>).

- Rocks and trees close to watercourses, in the zone that could be affected by water abstraction for hydroelectric development, are a particularly important habitat for these species (as shown by information from sources including Ratcliffe 1968, Hill *et al* 1991, 1992, 1994, Averis 1991, Paton 1999 and Atherton *et al* 2010, and many years of personal observations by BA, NH and GR).

Most of these are oceanic species (*sensu* Hill & Preston 1998), but three uncommon non-oceanic riparian species (*Hygrohypnum duriusculum*, *Pohlia scotica* and *Schistidium agassizii*) are also included. These 29 species are listed in Table 1, which also gives information about their conservation status and occurrences in different parts of Great Britain and Ireland.

3.2 Site selection and definition

The study area for this assessment is defined as the West Highlands as far east as the red line in Map 2, including the Inner Hebrides but not the Outer Hebrides.

There were various options regarding the selection of sites for classification in this study. One approach would have been to classify all watercourses shown on the Ordnance Survey 1:50,000 or 1:25,000 map series. There are so many of these that this would be an immense task and geographical coverage would be slow. Instead, a decision was taken to restrict the sites to watercourses shown on the Ordnance Survey 1:250,000 map series. A quick check of some known hydroelectric sites showed that the great majority of past and proposed schemes are on watercourses included in this selection. Therefore this set of watercourses was chosen in order to allow more rapid geographical coverage. A few additional watercourses not shown on the 1:250,000 map were included because they had records of scoring species.

Table 1 . Bryophyte species selected for inclusion in assessment of western Scottish watercourses in relation to proposed hydroelectric schemes

This table includes additional non-Scottish species (in non-bold type) that are similarly uncommon and hygrophilous and for which watercourses with hydroelectric potential are an important habitat.

Species	Moss or Liverwort	Recorded in:				GB rarity status **	IUCN threat level ***	Score ****
		Scotland;	England;	Wales;	Ireland			
<i>Campylopus setifolius</i>	M	S	E	W	I	NS		3
<i>Campylopus subporodictyon</i>	M	S				NR	NT	6
<i>Cyclodictyon laetivirens</i>	M	S	E		I	NR	EN	12
<i>Daltonia splachnoides</i>	M	S		W	I	NR	VU	9
<i>Fissidens polyphyllus</i>	M	S	E	W	I	NS		3
<i>Hageniella micans</i>	M	S	E	W	I	NS		3
<i>Heterocladium wulfsbergii</i>	M	S	E	W	I	NS		3
<i>Hygrohypnum duriusculum</i> *	M	S	E	W	I	NS	NT	6
<i>Isothecium holtii</i>	M	S	E	W	I			1
<i>Paraleptodontium recurvifolium</i>	M	S	E	W	I	NS		3
<i>Platyhypnidium lusitanicum</i>	M	S	E	W	I	NS		3
<i>Pohlia scotica</i> *	M	S				NR	VU	9
<i>Schistidium agassizii</i> *	M	S	E	W	I	NS		3
<i>Sematophyllum demissum</i>	M			W	I	NR	VU	9
<i>Thamnobryum angustifolium</i>	M		E			NR	EN	12
<i>Thamnobryum cataractarum</i>	M		E			NR	EN	12
<i>Trichostomum hibernicum</i>	M	S			I	NS		3
<i>Acrobolbus wilsonii</i>	L	S			I	NS		3
<i>Aphanolejeunea microscopica</i>	L	S	E	W	I			1
<i>Colura calyptrifolia</i>	L	S	E	W	I			1
<i>Drepanolejeunea hamatifolia</i>	L	S	E	W	I			1
<i>Dumortiera hirsuta</i>	L	S	E		I	NR	VU	9
<i>Harpalejeunea molleri</i>	L	S	E	W	I			1
<i>Jubula hutchinsiae</i>	L	S	E	W	I			1
<i>Lejeunea eckloniana</i>	L	S			I	NR	VU	9
<i>Lejeunea flava</i>	L				I			?
<i>Lejeunea hibernica</i>	L				I			?
<i>Lejeunea mandonii</i>	L	S	E		I	NR	EN	12
<i>Lophocolea fragrans</i>	L	S	E	W	I			1
<i>Metzgeria leptoneura</i>	L	S	E	W	I			1
<i>Plagiochila exigua</i>	L	S	E	W	I			1
<i>Porella pinnata</i>	L		E	W	I	NS		3
<i>Radula aquilegia</i>	L	S	E	W	I			1
<i>Radula carringtonii</i>	L	S			I	NR	VU	9
<i>Radula holtii</i>	L				I			?
<i>Radula voluta</i>	L	S	E	W	I	NS		3

* *Hygrohypnum duriusculum*, *Pohlia scotica* and *Schistidium agassizii* do not have oceanic distributions in Europe but are included here because they are so uncommon in Great Britain and Ireland (*H. duriusculum* and *P. scotica* are also Red Data Book species) and are riparian with a high dependence on water flow.

** GB rarity status (for species with 100 or fewer 10km sq. records in GB post-1950): NS = Nationally Scarce (16-100 10km sq. records); NR = Nationally Rare (<16 10km sq. records)

*** IUCN threat categories: NT = Near-threatened; VU = Vulnerable; EN = Endangered

**** Species scoring system: 1 = not NS or NR; 3 = NS; 6 = NT; 9 = VU; 12 = EN; ? = species recorded in Ireland but not in Great Britain, so no score can be worked out until rarity and threat categories for Ireland are finalised.

Where a watercourse had distinct sections with different assessments, it was split into two or more sites. The mid point of each section was used to indicate the area covered by each site. For example, the upper section of the Allt na Brachd (NM 858 775) has no bryophyte information but is open and unlikely to support an important oceanic bryophyte population. However, the lower section becomes incised and flows through a woodland site known to support an important oceanic bryophyte population. The watercourse is therefore split into two sites NM87-08 and NM87-09, with different assessments.

3.3 Scoring system

Each of the species assessed by this method is given a score between 1 and 12 (Table 2). These scores are based on a combination of the species' rarity in Great Britain as originally defined by the British Red Data Book for vascular plants (Perring and Farrell 1983), developed for bryophytes by Preston (2006, 2010), and the degree of threat according to the IUCN categories (IUCN 2010, Hodgetts 2011). The species scoring system developed as follows:

Table 2 . Species scoring system for Scottish hygrophilous bryophytes

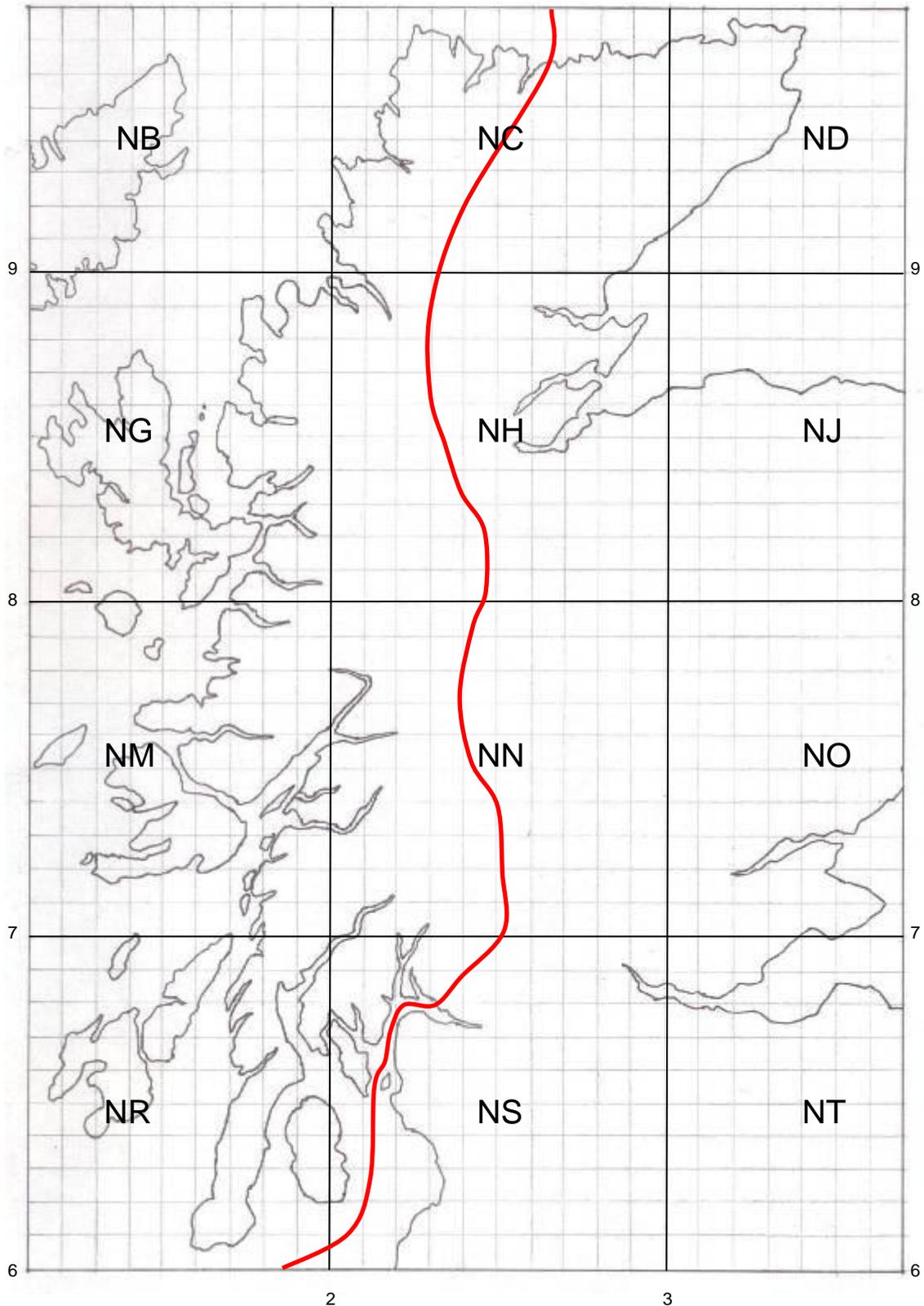
Species score	Description
1	Neither Nationally Scarce nor Nationally Rare
3	Nationally Scarce
6	Near-Threatened (most are Nationally Rare; one is Nationally Scarce)
9	Vulnerable (all of these are Nationally Rare)
12	Endangered (all of these are Nationally Rare)

Nationally Scarce = 16-100 10km square records in Great Britain post-1950.
 Nationally Rare = 1-15 10km square records in Great Britain post-1950.

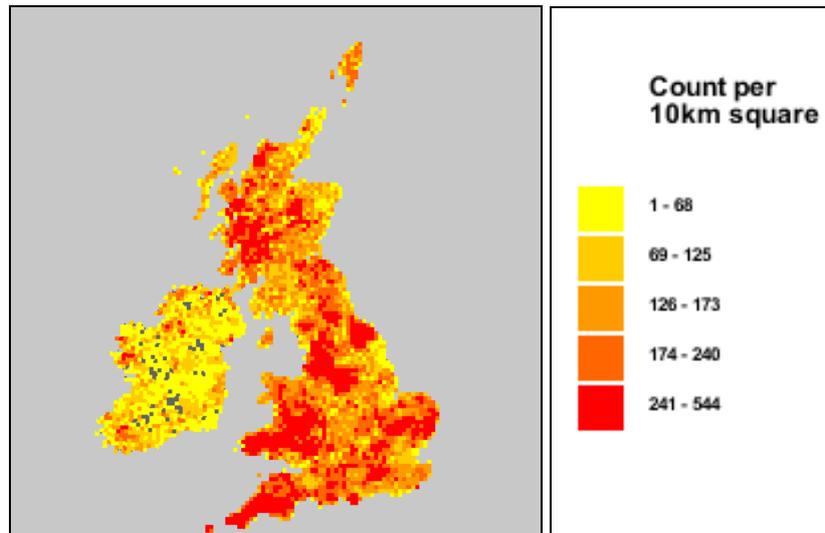
Records of these selected species are available online at <http://data.nbn.org.uk>. For much of the western Highlands the appropriate records were provided to us in Microsoft Excel spreadsheets by Dr Chris Preston of the Biological Records Centre (BRC); this helped greatly with the process of locating records from particular sites. Many of the records of these species in the West Highlands were made by the authors; this also helped with the process of data collation. Bryophytes are comparatively well recorded in the West Highlands and most other western parts of Great Britain, as shown by Map 3, which is based on bryophyte data from the British Bryological Society, held by the UK Biological Records Centre and available online at <http://tinyurl.com/7mjkx5t>.

Map 2. Geographical coverage of watercourse classification work in 2011/12.

All watercourses shown on the Ordnance Survey 1:250,000 map series in the area to the west of the red line (but not in the Outer Hebrides) have been classified. The red line marks the approximate eastern limit of the area richest in oceanic bryophytes.



Map 3. Recorded bryophyte species diversity in Great Britain and Ireland.



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It therefore seems unlikely that any of these species will in future turn out to be much more common and widespread in Great Britain (or in the West Highlands).

At sites with records of any of these species, all scores for those species recorded at that site are summed to give a **site score**. Each site was placed into one of five categories (A – E) based on its site score and (if unsurveyed or partially surveyed) its bryological potential. These five categories are described in Table 3.

Where a watercourse has a site score of 6 or more points (i.e. category A) it is considered to be of high national and international importance, and a hydroelectric scheme could have a significant impact on the national bryophyte flora. Sites in category B have a flora that is similarly rich but might not all be along the watercourse, so further survey is needed to check this. Where a watercourse is well surveyed and has a score of 0-5 points (i.e. category C), the bryophyte flora is considered to be less important and hydroelectric development is unlikely to have a significant national/international impact on humidity-demanding oceanic bryophyte assemblages, though the bryophyte flora might be of special importance at a more local scale.

The separation between category D (unsurveyed or partially surveyed, and appearing to have high bryological potential) and category E (similar but with lower bryological potential) was made by assessing Ordnance Survey 1:50,000 and 1:25,000 maps in combination with detailed aerial photographs. To be in category D a watercourse would need to have at least some of the following features: a steep watercourse gradient, a northerly aspect, ravine topography and woodland cover. Sites in category E are generally open, with more gentle slopes either side of the watercourse, a gentle stream gradient and little or no woodland cover.

A flowchart is provided in Annex 1 to summarise how categories are assigned and what type of survey, if any, will be required (see also Table 3). Further survey of category A or B sites may also be useful, from a developer's perspective, to ascertain whether a scheme can be built that will avoid abstraction from important sections of the watercourse.

Table 3 Categories used to classify West Highland watercourses by their bryological significance, for use in relation to proposed hydroelectric schemes

Category number	Category description
A	The site has been surveyed and has a score of 6 or more points indicating a rich, nationally/internationally important flora of uncommon hygrophilous bryophyte species. The whole site is associated with a particular watercourse (for example the site is a ravine), so the records contributing to the site score are all relevant for consideration in relation to a proposed hydroelectric scheme. Therefore no further survey should be necessary in order to evaluate site importance in relation to a proposed hydroelectric scheme; the score of 6 or more points indicates that the site is of such bryological importance that hydroelectric development could have a significant national/international impact on humidity-demanding oceanic bryophyte assemblages.
B	The site has been surveyed and has a score of 6 or more points (i.e. a rich flora of uncommon hygrophilous species), but the watercourse and its environs form only a part of the site. The site species list may include records made well away from the watercourse, and this watercourse may be one of two or more watercourses within the site. Some of the records contributing to the site score may not therefore be from this particular watercourse and may not be relevant for consideration in relation to a proposed hydroelectric scheme. Survey of this particular watercourse is therefore required, to assess its richness.
C	The site has a score of between 0 and 5 points, and the survey of the watercourse area was sufficiently thorough that it seems unlikely that further survey will produce enough additional records of uncommon hygrophilous species to raise the site score to 6 or more points. No further survey should be necessary in relation to a proposed hydroelectric scheme. With a score of <6 points the site is of low to medium bryological importance and hydroelectric development is unlikely to have a significant national/international impact on humidity-demanding oceanic bryophyte assemblages. However, the following points should be noted for a hydroelectric scheme at a site in this category: (1) the bryophyte flora may be of local importance, for example including a species that is rare locally or is at the edge of its geographical range; (2) the watercourse may be important for other groups such as invertebrates; (3) the ecological acceptability of a proposed scheme might be reduced if many other watercourses in the local area already have hydroelectric schemes (i.e. few unmodified watercourses left in the area concerned).
D	The site has a score of between 0 and 5 points and is either unsurveyed or only partially surveyed, but maps and aerial photographs show topography and/or woodland that suggest potential for a site score exceeding 6 points. Further survey of the watercourse area is required in relation to any hydroelectric proposal.
E	The site has a score of between 0 and 5 points and is unsurveyed (score = 0 points) or in a few cases partially surveyed, and maps and aerial photographs show a gentle watercourse gradient and/or little or no ravine topography or woodland, so it seems unlikely that the bryophyte flora present will score as much as 6 points. Photographs of the site should be taken (looking upstream at regular intervals along the watercourse), and from these the appearance and bryological potential of the habitats should be assessed by a bryologist (or other ecologist using guidance supplied by bryologists) and a decision made on whether the habitat has sufficient potential to require a bryophyte survey.

3.4 Spreadsheet system for recording data

The following information was submitted to SNH on a Microsoft Excel spreadsheet in which each site occupied a row and each species occupied a column:

- Site code number (column A): this was written as the OS 10 km grid square code (e.g. NM64) followed by a hyphen and a two-digit number to identify the site within that 10 km square (e.g. NM64-01, NM64-02, NM64-03 etc).
- Site name (column B)
- 100 km grid square (2-letter code) (column C)
- Easting (4-digit number, the first digit being that of the 100 km easting) * (column D)
- Northing (4-digit number, the first digit being that of the 100 km northing) * (column E)
- Species occurrences (columns F to AH): the number '1' entered in each cell where appropriate, to denote the occurrence of a particular species at a particular site
- Number of species (total number of scoring species recorded at each site) (column AI)
- Site score (sum of species scores for each site) (column AJ)
- Site category (A-E as described in Table 3) (column AK)
- Initials of tabulator (BA, NH or GR) (column AL)

** The grid reference of each site was recorded to c.100 m accuracy, referring to a point approximately halfway along the length of watercourse in question.*

4 SUMMARY OF THE RESULTS OF WATERCOURSE CLASSIFICATION WORK IN 2011-12

4.1 Main results (number of sites, geographical coverage etc)

In total, 5629 watercourse sites were classified using the above-described system. Map 2 shows the geographical coverage of this work. The site data are available from SNH through the online planning tool or, if requested, as a Microsoft Excel spreadsheet. Table 4 provides a breakdown of the number of sites by category.

Table 4 Classification of watercourse sites by bryological significance category

Category	Number of sites	No. of sites as a percentage of all 5629 sites
A	136	2.4 %
B	90	1.6 %
C	291	5.2 %
D	2344	41.6 %
E	2768	49.2 %

The majority of watercourses are still either unsurveyed or only partly surveyed (i.e. categories D and E). Many of these unsurveyed or partially surveyed sites appear to have low potential for high bryological importance (i.e. category E).

A total of 136 sites (2.4% of all assessed sites in the West Highlands) have so far been identified as being in category A. These are of national/international importance for their rich floras of uncommon hygrophilous bryophytes, and hydroelectric development could have a significant impact on our national bryophyte flora. Map 4 shows that these sites are widespread through the West Highlands but are most numerous in mainland Argyll (from West Loch Tarbert northwards), western Lochaber (west of Loch Linnhe), the Knoydart-Torrion area, the island of Mull and the south-eastern part of Skye.

There are large areas of the western Highlands in which few or no category A sites have yet been recorded, especially the eastern parts (approaching the red line in Maps 2 and 4), the extreme north, north-west Skye, Coll, Tiree, Colonsay, Kintyre, Arran and much of Islay and Jura.

Analysis of the data shows that category B sites are mostly in these same areas of the West Highlands as those with many category A sites, and that sites in each of categories C, D and E are very widespread in the West Highlands.

A breakdown of sites by site score is shown in Table 5.

Table 5: Classification of watercourse sites by bryological site score

Site score	No. of sites	Site score	No. of sites
0	5004	16	2
1	107	17	3
2	75	18	4
3	109	19	1
4	49	20	2
5	60	21	0
6	60	22	1
7	36	23	0
8	18	24	2
9	31	25	1
10	18	26	0
11	12	27	0
12	7	28	0
13	12	29	1
14	6	30	0
15	7	31	1

4.2 Implications of reclassification (using recent survey data) of sites formerly in categories D and E

In late 2011 and early 2012, at a late stage in the process of collating site information onto the spreadsheet, 59 sites originally assigned to categories B (2 sites), D (35 sites) and E (22 sites) were reclassified to categories A (8 sites) and C (51 sites) using newly available data from recent surveys. These category changes are summarised below:

Table 6 Post-assessment reclassification of 59 sites following new survey in 2011/12.

Old category	New category	Number of sites
B	A	2
D	A	6
D	C	29
E	C	22

This gives some indication of the proportions of category B, D and E sites that might, from future surveys, be reclassified as categories A and C. However, it should be noted that this is only a small sample, especially for category B (2 sites, both of which were reclassified to category A).

Of the 35 sites previously in category D, six (17%) are now in category A and the remaining 29 (83%) are in category C. This could be taken to suggest that about 17% of all category D sites would, from a more focused survey, turn out to belong to category A. However, the proportion of category D sites that would, if surveyed thoroughly, have a rich enough bryophyte flora to be in category A, probably varies from area to area within the West Highlands. It is probably much less than 17% in the West Highlands as a whole. It would probably be highest in particularly rich 'core' oceanic bryophyte areas such as Loch Sunart, the Kinlochourn area and the Loch Creran area (the six category D→A sites being in these areas). It would probably be low in eastern areas (approaching the red line in Maps 1-2), in the extreme north, in north-west Skye, Kintyre and Arran (very few category A sites are known in these areas so far), on Tiree, Coll and Colonsay and western parts of Islay and Jura (areas with no known category A sites and only a very few category D sites).

All of the 22 sites previously in category E are now in category C. This suggests that the assessment of sites as category E based on maps and aerial photos has worked well.

Much of the bryophyte survey carried out in the West Highlands in recent years has focused especially on known or suspected 'good' sites. Many of these were either known to be bryologically rich or to include rare species, or were suspected to have very high potential to be bryologically rich. The proportion of surveyed sites which have been assessed as category A is therefore probably unrepresentative of the proportion of all sites which would fall into category A. We suspect the surveyed sites hold a disproportionately high number of sites in category A compared with category C. Among the 427 sites in categories A and C combined, 32 % are in category A and 68% in category C. The proportion of category A sites (as a percentage of categories A and C combined) will probably reduce in future, as it seems likely that more surveys across a wider range of sites will increase the number of category C sites much more than the category A sites.

4.3 Results in a wider Scotland and Great Britain context

This assessment applies to the West Highlands (west of the red line in Maps 2 and 4) including the Inner Hebrides. No comparable systematic assessment has been carried out elsewhere in Great Britain, but an examination of the available species distribution maps and data (mainly from <http://data.nbn.org.uk> and a spreadsheet of data for sites in Wales supplied by Sam Bosanquet of the Countryside Council for Wales) has allowed us to identify sites in other parts of Great Britain which score 6 or more points in this assessment system. The results are summarised in Table 7 (including those for the West Highlands, for completeness and comparison).

Table 7 Distribution of riverine bryophyte sites across Great Britain scoring 6 or more points

Area	Number of sites
West Highlands, including the Inner Hebrides	136 sites (from 2011-2012 classification work)
Outer Hebrides	1 site (in South Uist)
East Highlands	11 sites (9 of these with only one scoring species: the non-oceanic moss <i>Hygrohypnum duriusculum</i>)
Southern Scotland	1 site (in Ayrshire)
Northern England	11 sites (7 in the Lake District, 2 in the Cheviots, 1 in the Vale of Eden and 1 in the North Pennines)
Wales	about 35 sites
South-west England	about 20 sites
South-east England	1 site (<i>Dumortiera hirsuta</i> site in Sussex)

It is interesting that the 11 east Highland sites are so far east, but it is relevant here to note that nine of them have just one scoring species – the non-oceanic moss *Hygrohypnum duriusculum* which, being Nationally Scarce and Near-threatened, scores 6 points. The other two east Highland sites also have *H. duriusculum* as well as a very few oceanic species and, at one site, the non-oceanic *Schistidium agassizii*.

There are probably at least 60 sites of comparable richness in Ireland, most of them in the west, but much work would be needed on the bryophyte records to produce an accurate estimate, and the rarity and IUCN threat categories for Ireland have not yet been finalised.

5 FURTHER WORK

The data for the 5629 classified sites will be incorporated into the SNH Geographical Information System (GIS) and made publicly available on their [hydro planning and development](#) website as an online planning tool for use when dealing with hydroelectric scheme planning. It will be updated periodically to include the results of future surveys.

As already mentioned, future surveys will mean that some sites currently in categories B, D and E will be reclassified to categories A and C. It is expected that there will be more reclassifications to category C than to category A (see previous section of report).

It would be worth carrying out similar bryological assessment work in relation to hydroelectric schemes in other parts of Great Britain – especially other western areas – and also in Ireland. Indeed, staff of Natural England and the Countryside Council for Wales are currently considering methods of bryological assessment for hydroelectric schemes in their areas. If this west Highland classification system is used in future in other parts of Great Britain, the numbers of category A sites would be approximately as detailed in Table 7 above (Results in a wider Scottish and Great Britain context).

6 ACKNOWLEDGEMENTS

This project was commissioned by Scottish Natural Heritage. The SNH Project Officer was Dr David Genney (SNH Policy & Advice Officer for Bryophytes, Fungi and Lichens, based at SNH Inverness). BA, NH and GR are very grateful to DG for all his help and encouragement with this project, and the provision of maps and other useful information. IB is thanked for his suggestions about details of the classification system and for his support and encouragement of this work. DG circulated a draft of this report to several other SNH colleagues from whom useful feedback was obtained.

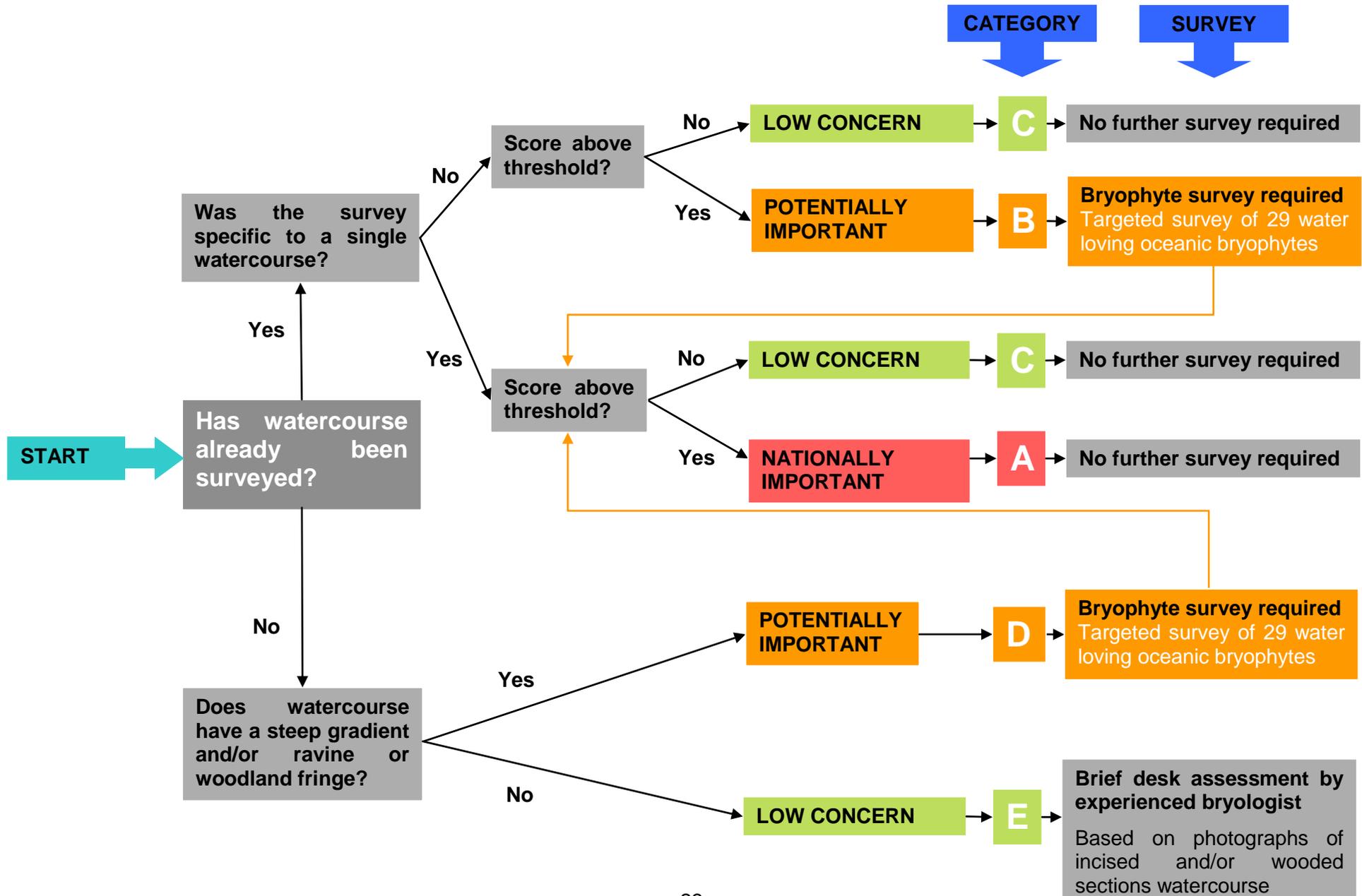
We also thank the British Bryological Society (BBS) for allowing us to use their data held by the Biological Records Centre (BRC) and Dr Chris Preston (BRC) kindly provided us with BBS database records of scoring species in a format suitable for use in this project.

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Annex 1: Decision route to identify importance, category and bryophyte survey requirements for oceanic watercourses.



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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

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