Article

# *Atrichum angustatum* in Britain - its status and conservation

R.V. Lansdown, T.W. Ottley, E. Phillips and F.J. Rumsey discuss current efforts at conserving the only two remaining British populations

## Introduction

Lesser smooth-cap moss (*Atrichum angustatum*) occurs throughout much of Europe from Iceland in the north, south to the Iberian Peninsula and east to Turkey, with populations in the Azores and Madeira (Blockeel *et al.*, 2014), as well as in eastern North America where it is locally abundant (Smith, Merrill & Ireland, 2007). In the British Isles it was formerly known from Ireland, Scotland and Wales and from eight English counties, mainly in south-east England, where Kent and Sussex were always its centre of distribution. It was described in 1806 and then recorded sporadically in Britain until the 1880s after which records increased dramatically until the inter-war period, when there were very few records between 1910 and the 1940s. Subsequently the number of records peaked in the 1950s before declining dramatically until the early 21st century. It was classed as Endangered in the UK at the start of the 21st century (Church *et al.*, 2001) but this was revised to Critically Endangered (Hodgetts, 2011) and soon afterwards it was considered to be possibly extinct in Britain (Porley, 2013) and Ireland (Lockhart, Hodgetts & Holyoak, 2012), where it was last seen in an old sand pit at Trillick, Co. Tyrone in 1957. It is listed under Section 41 of the Natural Environment and Rural Communities (NERC) Act 2006, indicating that it is considered to be a priority species of conservation concern. Here we report on two projects aimed at locating and conserving the remaining populations of *A. angustatum* in Britain.

## Current Distribution and Conservation

### *Cleeve Hill, Gloucestershire*

H.H. Knight was the first botanist to record systematically the bryophyte flora of Gloucestershire. Living in Cheltenham, he was able to document the remarkable bryophyte species diversity of Cleeve Hill and Cleeve Common, which lie just east of the town. From Cleeve Common, 202 species and 21 varieties of bryophyte have now been recorded (Lansdown & Phillips, 2014). One of the reasons for this diversity is that, although most of the common is on the oolitic limestone of the Cotswolds, there are exposures of the extremely acid sands of the Harford Member, which is a layer of sandstone between 2 and 5.5 metres deep (Owen, 2011 citing Angseesing *et al.*, 2002). This forms the uppermost part of the Birdlip Limestone Formation and produces an acidic, sandy

△Fig 1. Harford Sands on Cleeve Hill, exposed when digging holes as receptor sites for *A. angustatum.*

| | number of lamellae | mid-leaf cells (μm) |
|---|---|---|
| *Atrichum angustatum* | | |
| Rose, 1951a | 4-6 | 10-18 |
| Smith, 2004 | 3-4(-7) | 12-18(-20) |
| Cleeve | 4 | 20 |
| Angley Wood | 5-6 | 14-20 |
| *Atrichum undulatum* | | |
| Rose, 1951a | 5-7 | 18-25 |
| Smith, 2004 | 3-6 | 20-40 |

△Table 1. Character comparisons between *A. angustatum* and *A. undulatum*

soil of around pH 5.0 to 6.0 in an otherwise alkaline sequence. Owing to the topography of Cleeve Hill, these acid sands outcrop to produce a relatively large cap on the northern part of Cleeve Common, whereas on the central and southern part of Cleeve Hill the Harford Member is overlain and manifests as a thin band, outcropping between the 270-320 m contours (Owen, 2011). Knight recorded *A. angustatum* "sparingly on sandy ground (Harford Sands)" on Cleeve Hill some time in the early part of the 20th century (Knight, 1914). *A. angustatum* was actively sought on Cleeve Common by C.C. Townsend in 1988 (*in litt.* to K. Hearn) and subsequently by RVL and it was thought to have disappeared with the decline in exploitation of the sands on the common (Lansdown, 2014a).

In 2011, in the course of work to document the bryophyte flora of Cleeve Common with the aim of informing management of the common by Cleeve Common Board of Conservators (CCBC), a sward of small *Atrichum* plants was found in the "Masts Field" of the Prestbury Hill Reserve. The reserve, which is managed by Butterfly Conservation, is adjacent to Cleeve Common and shares the common's rather unusual geology, with Harford Sands outcrops at the northern end of the otherwise oolitic limestone field. The *Atrichum* plants were found on the vertical face of a disused rabbit-burrow on these Harford Sands. The biometrics of this population fell in the overlap between those of *A. angustatum* and *A. undulatum* and that justified the submission of a sample to Tom Blockeel (TLB) for confirmation. TLB and RVL both accepted that they were immature *A. undulatum* and apart from a slight nagging uncertainty, the matter was left there. However a short while later David Bell and David Long were seeking material of *A. angustatum* for a major DNA bar-coding project and RVL took the opportunity to send them the material from Cleeve "just to check". To everyone's surprise, "the recently collected sample of putative *A. angustatum* from East Gloucestershire [nested] within the clade of European and North American samples of *A. angustatum*, confirming its identification as the only recent record from Britain" (Bell, Long & Hollingsworth, 2013). The population of *A. angustatum* found on Cleeve Hill initially involved very pale plants of uniform growth which might have been the result of a single

colonisation event or possibly germination resulting from the disturbance of buried spores. These plants had leaves approximately 1.2 mm wide, slightly reddish-tinged, consistently with four lamellae about 6 cells high and with mid-leaf cells measuring 20 $\mu$m. The apparent ambiguity of these plants led Bell, Long & Hollingsworth (2013) to conclude that "The most reliable character to distinguish *A. angustatum* [from *A. undulatum*] is the smaller leaf cell size, 12-18(-20) $\mu$m wide in mid-leaf, compared to 20-40 $\mu$m wide in *A. undulatum*", modifying the cell biometrics given by most authors (Lansdown, 2014a).

This confirmation of the presence of *A. angustatum* on the Prestbury Hill Reserve greatly increased the significance of a pilot study which CCBC had been conducting on Cleeve Common. The pilot study involved the exposure of Harford Sands on the common to encourage re-establishment of some of the acidophiles which formerly occurred on Cleeve Hill but which could not be re-found despite extensive survey effort (Lansdown & Phillips, 2014). Once the relevant consents had been acquired from Natural England and following soil studies employing an auger, a series of shallow hollows was excavated in 2012 at five sites on Cleeve Common (Lansdown, 2012). These holes were monitored for sixteen months to assess natural colonisation by acidophile bryophytes. Although a few desirable species such as *Campylopus pyriformis, Ceratodon purpureus, Dicranella heteromalla, Pleuridium acuminatum* and of note because it had not previously been recorded on Cleeve Common, *Pohlia nutans* colonised the holes, two conclusions were drawn from the pilot study: i) livestock accessing the scrapes had levelled out the profile of the scrapes; and correspondingly ii) much deeper and narrower holes needed to be created into the Harford Sands, so that the humidity of the exposed sand was much greater (Lansdown, 2014b).

▽Fig 2. Digging the potential receptor sites on Cleeve Common.


Taking these conclusions and with funding from the Natural England Species Recovery Programme (SRP) and from CCBC, a further series of holes was excavated at four locations on Cleeve Common in 2014, taking a slightly different approach. These holes were much narrower and deeper, in an attempt to mimic the conditions in the rabbit hole which supported the original population of *A. angustatum*, and were excavated in groups of three to provide a much larger area of potentially suitable habitat.

Whilst this experimental action was being undertaken on the common, a small amount of *A. angustatum*, collected from the population on the Prestbury Hill Reserve in January 2014,

△Fig 3. Planting *A. angustatum* into the holes. △Fig 4. Two alginate beads and a tuft of gametophytes on the back wall of one of the holes.

had been taken into cultivation by Dr Margaret Ramsay at the Royal Botanic Garden, Kew and, funded by the Natural England SRP, bulked up to provide material which could be transplanted into the "artificial rabbit holes". Between January and November 2014, the rabbit hole on the Prestbury Hill Reserve which supported the original *A. angustatum* population became overgrown by vascular vegetation and was lost (Lansdown, 2015a, 2015b). At this point, British *A. angustatum* was thought only to occur *ex situ* in Kew. In November 2014, again with ongoing funding by the Natural England SRP, small alginate beads containing protonema and 'protonema tufts' (developing gametophytes) of *A. angustatum* were planted into the side and back walls of each of the holes. The development of *A. angustatum* in these holes has been monitored since the planting (Lansdown, 2015a; Lansdown & Phillips, 2016).

Despite the modified, deeper and narrower design of the Harford Sands exposures, all hole complexes, with the exception of one in an area of Cleeve Common into which livestock have no access, suffered from sheep entering the holes and either digging or rubbing against the walls, cattle digging in the holes or rabbits making small excavations at the base of some of the walls. Sheep had so damaged one complex of holes (referred to henceforth as the 13th tee complex) by June 2015 that there was no sign of *A. angustatum* and no evidence that the habitat remained suitable (Lansdown & Phillips, 2016). To prevent recurrence of the problem, the complexes of holes were protected using temporary fencing (apart from the 13th tee complex).

Monitoring of the translocated *A. angustatum* has shown that, as of February 2016, establishment of *A. angustatum* on Cleeve Common in the four complexes of holes dug for this project has been successful in that the plant is surviving in all of the hole complexes. All of these suffered losses and re-establishment of gametophyte-stage *A. angustatum* on one or more walls over the recording period. However, the most striking result of the monitoring is that after apparently dying out from some of the holes into which it was introduced, *A. angustatum* was capable of recovery even some months later. Apart from the set of holes to which livestock have no access, at least one hole per complex suffered complete loss of gametophyte-stage *A. angustatum* at some point during the monitoring, and in some cases it subsequently returned. This was most pronounced at the 13th tee complex, where gametophyte-stage *A. angustatum* was not recorded at all following its introduction until

△Fig 5 (top). Monitoring growth of *A. angustatum* in one of the holes within the sheep-protection fence.

△Fig 6 (bottom). *A. angustatum* and *Pleuridium acuminatum* growing on the back wall of one of the holes.

January 2016 (Lansdown & Phillips, 2016). It is noteworthy that extensive grazing is seasonal (summer-only) on Cleeve Common, and sheep were removed from the common on 11th November 2015: between this date and January 2016 the holes would not have been disturbed by livestock. The reappearance of *A. angustatum* from apparently lost holes, combined with the fact that most populations formed swards rather than tufts, strongly suggested that the protonema penetrates quite deep into the substrate. This means that the upper layers of the substrate may be lost, but the plant is capable of recovery from the buried protonema. Even so, the frequent disappearance of *A. angustatum* from hole walls and at times from entire holes is of concern. The evident causes of such loss include damage by stock (which can be controlled) and collapse of lumps of the sand which forms the walls (which cannot) and while *A. angustatum* may survive in the bed of some holes, it does not appear to be able to survive well in such conditions. It cannot yet be said that *A. angustatum* is established as a self-sustaining population on Cleeve Hill because without the degree of protection already installed, it is very possible that most of the planted populations would have been lost. On the other hand, if the viability of protonema quite deep in the substrate is sufficient to last the duration of the grazing season (i.e. the period of livestock disturbance) and provided that livestock disturbance is not so severe as to completely remove the protonema from the walls of the holes, it is possible that dynamism could be achieved, with gametophyte growth appearing through the winter and being destroyed in the summer, as was observed at the 13th tee complex. If this situation were occurring, it would remain to be seen whether it were one of gradual depletion of *A. angustatum* protonema and gametophyte material or whether the populations are indeed

sustainable in the current habitat conditions and with the current management pressure.

Given that *A. angustatum* is dioicious, it is clear that there will be no establishment from spores at the site unless material of the other gender can also be introduced. If any of the population recently re-found in Kent includes the other gender then this becomes a possibility using British material.

## The Weald in south-east England

The discovery of *A. angustatum* and subsequent work to try to assure its future on Cleeve Hill prompted RVL to investigate the status of the species elsewhere in Britain. The need for surveys to attempt to locate remaining populations in the Weald had been recognised as early as the late 1990s and was outlined as a priority by the NHM/EN UK Biodiversity co-ordination project. At that time the species was still extant but declining at its last known site at Slindon in West Sussex. As a consequence, both the local British Bryological Society (BBS) groups and the national meeting of the BBS included searches for *A. angustatum* in sites where it had formerly been recorded, as and when the opportunity arose but without success.

In 2015, funds were obtained from Natural England under their SRP to carry out a search for remnant populations of this species in its former stronghold in south-east England. The aims of this project were to:

1. Derive a list of sites with the longest continuity of records, using records held by the BBS.
2. Contact local bryologists to plan site surveys.
3. Carry out surveys of selected sites, in collaboration with bryologists familiar with the sites.
4. Produce a report to cover the findings of the survey.

Using a combination of the records held by the Centre for Ecology and Hydrology (CEH) and the British Bryological Society (BBS), a short list was drawn up of the sites with the most recent records and those with the greatest continuity of records. This was then reviewed by people with local knowledge of the sites which resulted in the list being further refined and the following sites surveyed:

**Vice County 13 West Sussex**

Rewell Wood, Slindon 4th November 2015, R.V. Lansdown, F.J. Rumsey. T. W. Ottley, J. M. Hutson, J. Norton, S. Rubinstein, D. T. Streeter.

**Vice County 14 East Sussex**

Saxonbury Hill, Eridge Park SSSI 17th February 2016, RVL, FJR, TWO, L. Hutchby, J. Bee

**Vice County 15 East Kent**

Bull Wood, Sissinghurst 26th January 2016, RVL, TWO, P. Williams, DTS

Kingswood 17th February 2016, RVL.

Sissinghurst Park Wood 26th January 2016 RVL, TWO, PW, DTS

**Vice County 16 West Kent**

Angley Wood 26th January 2016, RVL, TWO, PW, 18th February 2016 RVL, FJR

Combwell Wood, Bedgebury 25th January 2016, FJR, TWO, PW, M. Herbert

The overall length of ride surveyed has not been calculated but it is likely to be nearly twenty kilometres, concentrating on areas with past records and lengths of ride which appeared to involve the most suitable habitat. The only population of *A. angustatum* found was on a single ride at Angley Wood which, although believed to have been in existence for over 100 years, appears to have been reworked within the last five years. An approximate estimate of the size of the population suggested there were

△Fig 7. Tom Ottley and Phil Williams at the location of two stands of *A. angustatum* at Angley Wood.

in excess of 400 plants in 13 small separated colonies. *A. tenellum* was also found to be frequent along the same ride.

## Ecology

*Atrichum angustatum* grows on sandy clay soils, which in south-east England are usually a mildly acid loam of "Brown Earth" type (pH 6.0-6.5) derived from either Tunbridge Wells Sand or Wadhurst Clay (Rose, 1951a, 1951b), in areas which remain damp throughout the year, either due to shade or due to the impermeability of the substrate. The majority of records from south-east England are from the High Weald but there are some from woodlands on the loamy greensand of the Hythe Beds and on clay-with-flints on the North Downs plateau. Most records are from rides and woodland banks, although it has also been recorded from heathland and grassland. In the United States a characteristic habitat for this species is mounds of subsoil thrown up by the roots of fallen trees (Smith Merrill & Ireland, 2007). It appears very likely that it depends on factors which supress vegetation succession, such as ride use and maintenance. In the late 20th century and into the early 21st century there was a decline in the traditional intensive management of sites which formerly supported the species (M. Herbert pers. comm.), coinciding with a decline in the species. It is dioicous and sexual reproduction appears to be rare.

Rose (1951a) described *A. angustatum* as most frequently occurring with species characteristic of disturbed ground and some characteristic of seasonally wet habitats, including *Anagallis minima, Aphanes inexpectata, Atrichum undulatum, Ceratodon purpureus, Diplophyllum albicans, Fissidens bryoides, Gnaphalium uliginosum, Jungermannia gracillima, Lythrum portula, Nardia scalaris, Pogonatum nanum, Radiola linioides* and *Scapania nemorea*. None of these species was found in association with *A. angustatum* at Angley Wood but many were found in different combinations at different sites. At Angley Wood, *A. angustatum* occurred mainly in a zone slightly set back from the bare ground of the main part of the ride but still sparsely vegetated. All stands were associated with *Agrostis capillaris* while other frequent associated species were *Agrostis stolonifera, Atrichum tenellum, Calluna vulgaris, Carex pilulifera, Hypochaeris radicata, Pleuridium acuminatum, Polytrichastrum formosum, Potentilla erecta, Prunella vulgaris, Rubus* sp. and *Veronica officinalis.* The association

with *Atrichum tenellum* is of note; it occurred in the same zone along the track and often within a few centimetres of *A. angustatum*. The ecology of these two species appears to have much in common but *A. tenellum*, although scarce, is still fairly widespread in the UK. This latter species has been shown to produce rhizoidal tubers (Arts, 1987) which may play a role in dispersal and survival in unsuitable conditions. It is not clear whether *A. angustatum* is capable of producing rhizoidal tubers, but if not this is another possible reason why it has been unable to survive the changes in management of sites where it formerly occurred.

The data derive from a small area in a single site and cannot be considered representative of any overall relationship with a particular phytosociological class of habitat. However phytosociological data collected from *A. angustatum* stands at Angley Wood would appear to be reasonably well aligned with a form of U1e *Festuca ovina - Agrostis capillaris - Rumex acetosella* grassland, *Galium saxatile - Potentilla erecta* sub-community (Rodwell, 1991) with a slightly higher representation of inundation-tolerant plants than is typical. It is likely that such communities develop in disturbed areas of many heathlands on which drainage is impeded, suggesting that the habitat alone is not critical for *A. angustatum* although the processes driving the development or maintenance of the habitat may be.

## Discussion

It is not possible to be certain, but it appears likely that *A. angustatum* now exists as only two populations in Britain, one on a ride at Angley Wood in West Kent and the other a reintroduced population on Cleeve Common in East Gloucestershire. Material from both of these populations is in *ex situ* cultivation at the Natural History Museum (BM). It is certain that the population on Cleeve Common is of one sex, but it is possible that both sexes occur at Angley Wood. It is vanishingly unlikely, even if these two populations are of different sexes, that sexual reproduction could occur between them; thus it is unlikely that the Cleeve Common population will persist without management. It would be ideal if both sexes could be represented at both sites to increase the chance of fruiting and therefore of dispersal in both areas by spores.

Available records show a dramatic decline at least from the mid-20th century; however, it is not clear when the decline began. If this decline began before the species was recognised, it may have been due to the changes in management of many woods in response to changing demand for timber. If the decline is recent, then it may be mainly linked to the abandonment of traditional forestry practices, possibly linked to the increased use of mechanised vehicles, replacing horses which would have dramatically changed the nature of substrate disturbance resulting in corresponding changes in the vegetation.

It is also possible that infrequent sexual reproduction in this species makes it vulnerable to extinction. Thus, for example, if an unrelated factor leads to the increased isolation of populations, then this increased isolation could reduce the possibility of sexual reproduction, which would lead to a loss of populations, creating a feedback loop. With this possible linked decline in sexual reproduction, *A. angustatum* would have been unable to survive the period of declining exploitation of woodland in a dormant phase and so has been lost from most of the sites where it once occurred without being able to return if management led to the restoration of suitable habitat.

Of the sites surveyed in 2015/16, the following are not considered to merit work to

△Fig 8. *Atrichum angustatum* at Angley Wood.

attempt to restore in the short-term: Rewell Wood near Arundel, Crowborough Warren, Bull Wood near Sissinghurst and Sissinghurst Park Wood, although if the situation changes at any of these sites it may be worth considering management. Sites which should be considered priorities for management work to attempt to restore are Saxonbury Hill (within Eridge Park SSSI), Kingswood (Maidstone) and Combwell Wood. Other sites which need to be surveyed are Chingley Wood, Chobham Common, Hassocks, King's Wood (Challock), St. Leonard's Forest, Wepham Wood and Worth Lodge. Based on the results of this survey and ongoing conservation work at Cleeve Hill in Gloucestershire, the main outstanding questions which might be answered by a study of the population at Angley Wood are whether this population produces rhizoidal tubers, whether this population includes both sexes and what form do natural population dynamics take in this species. The first question can best be answered by *ex situ* study of plants in conditions likely to maximise the chance of tuber production, the second question by a combination of *ex situ* study and field examination and the third by detailed recording. A baseline for monitoring was taken as part of this study and a monitoring protocol proposed.

**Acknowledgements**

On Cleeve Hill, we are profoundly grateful to Cleeve Common Board of Conservators for their continuing support in all our work to conserve rare bryophytes on Cleeve Common, to Butterfly Conservation for their support with conservation work linked to the Prestbury Hill Reserve, to Paul Hackman of Natural England for his help and support with all our conservation work, to David Stevenson for doing most of the hard work and making other aspects possible and Chantal Brown for helping with the pilot study excavations. In south-

east England we would like to thank Phil Williams and Louise Hutchby for their help in organising access to sites, some of which would simply have been inaccessible without their help. Ron Porley was the catalyst for work on this species and established the groundwork necessary for parts of this project to happen. We would also thank Oliver Pescott for providing a copy of the CEH data holdings, Jeff Duckett, Jan Hendy, Geoffrey Kitchener and Howard Matcham for information which helped toward site visits and surveys. We would also like to thank Mark Herbert, Jacqui Hutson, John Norton, Sue Rubinstein and David Streeter for their help and company on surveys and John Bee for information and access to Saxonbury Hill. Last but not least, we are very grateful to Jonathan Cox for his help with administration of the contract, as well as initiating contact with a number of people.

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