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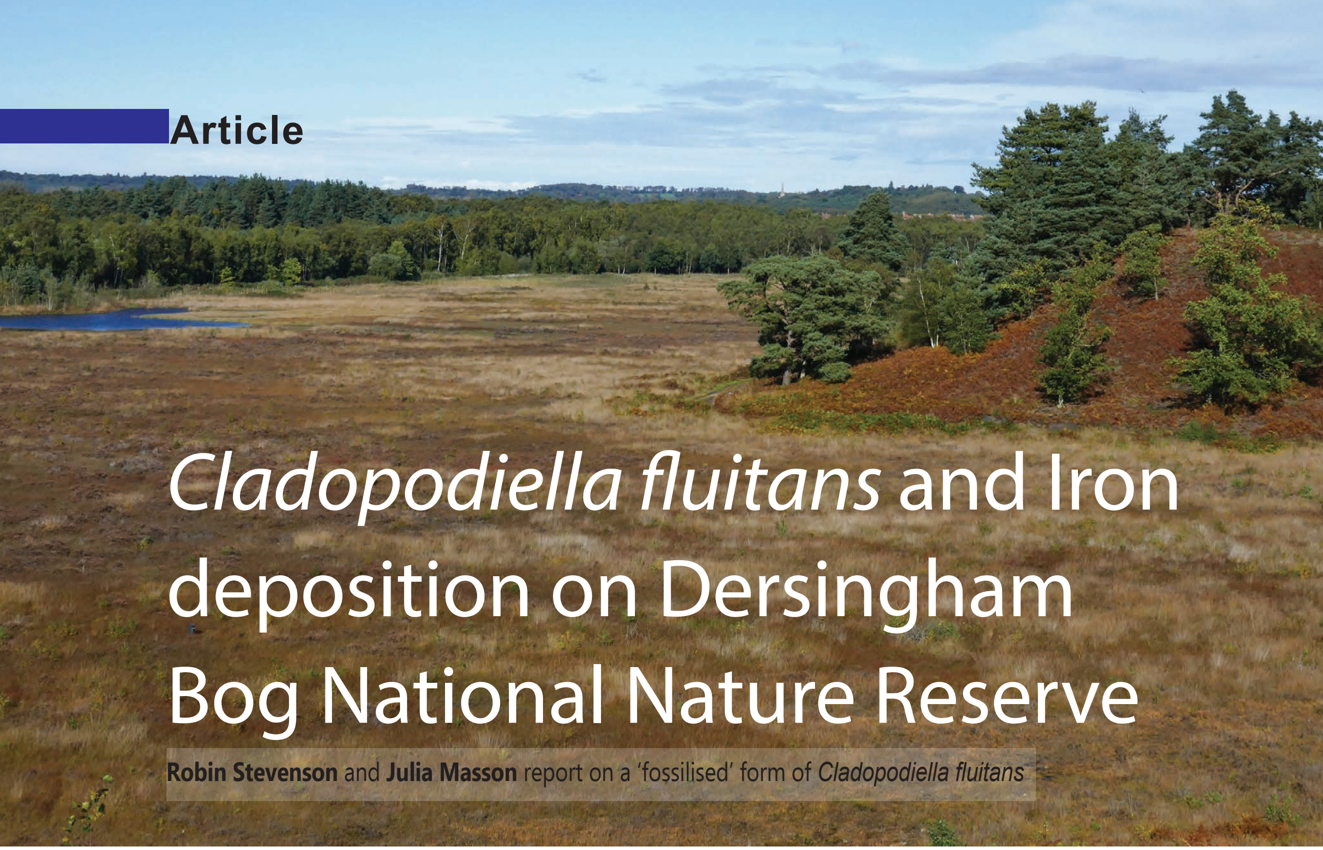

Cladopodiella fluitans and Iron deposition on Dersingham Bog National Nature Reserve

Robin Stevenson and **Julia Masson** report on a 'fossilised' form of *Cladopodiella fluitans*

△Fig 1. View across Dersingham Bog NNR showing the main areas of M3 habitat, at the foot of the Lower Cretaceous scarp.

Summary: *Cladopodiella fluitans* (Nees) H. Buch is closely associated with the deposition of iron oxides and iron pan formation on Dersingham Bog NNR. Under these circumstances the plant may adopt an atypical growth form.

Introduction

Dersingham Bog National Nature Reserve in north-west Norfolk, some 9 km NNE of King's Lynn, is underlain by Lower Cretaceous sands and sandstones (Table 1) which form a prominent scarp feature (Fig. 1) at the foot of which lies an area of mire. Much of the mire is probably underlain by Head deposits derived from the adjacent scarp. Details of the geology and geomorphology of the site are provided by Gallois (1994) and Stevenson & Giles (2013).

The vegetation

The main vegetation communities present on the mire are listed in Table 2 although of these the only one relevant is the M3 *Eriophorum angustifolium* bog pool community. As the name implies the most abundant vascular species present is *Eriophorum angustifolium* (Common Cottongrass), with other species such as *Molinia caerulea* (Purple Moor-grass) and *Erica tetralix* (Cross-leaved Heath) occurring at low frequency. However, the community, as present on Dersingham Bog, differs from that described in the relevant volume of the National Vegetation Classification (Rodwell 1991) in that although the vascular plants are broadly similar, the range of bryophytes present is much more limited: *Sphagnum cuspidatum, S. papillosum, S. recurvum, Polytrichum commune, Campylopus brevipilus, Odontoschisma sphagni and Gymnocolea inflata* are either absent or rare, whilst *Cladopodiella fluitans* and *Warnstorfia fluitans* are relatively abundant. (Nomenclature for bryophytes follows Hill *et al.*, 2008).

Although the *Eriophorum* can form quite dense stands in places it is distinctly patchy, and includes some very open sparse communities with much exposed iron pan (Fig. 2). Rising above the

Stratigraphic Units	**Formations**	**Age**
(Chalk)		**Upper Cretaceous**
(Red Chalk)		**Lower Cretaceous**
(Carstone)	Carstone Formation	**Lower Cretaceous**
	Unconformity	
(Snettisham Clay)	Dersingham Beds Formation	**Lower Cretaceous**
Dersingham Beds		
Leziate Sands	Sandringham Sands Formation	
(Mintlyn Beds)		
(Runcton Beds)		
(Roxham Beds)		
	Unconformity	
(Kimmeridge Clay)		**Jurassic**

△Table 1. The solid geology of the area. Those units enclosed in brackets are not exposed on the Dersingham Bog National Nature Reserve

general level of the community are small 'islands' of more varied vegetation, founded on 'islands' of peat. Around the base of these, and at the edge of open pools, there are frequent dark mats of the liverwort *Cladopodiella fluitans* (Fig. 3). Closer examination of these colonies shows that they are often quite thick, and that the lower parts are heavily impregnated and coated with iron oxide (Fig. 4). In places, where this material has dried out, it has formed hard resistant mounds of iron oxide in which 'fossilised' *Cladopodiella* can be seen (Fig. 5). This is very reminiscent of the textures associated with some calc-tufas, where deposition of calcium carbonate ($CaCO_3$) has occurred around bryophytes (e.g. Pentecost, 1985, 1996).

However, the *Cladopodiella* associated with these mounds is rather different (Fig. 6) in appearance from the normal form; in fact it was sufficiently different as to merit forwarding a specimen to the referee for the genus, Tim Blackstock, for a second opinion; he observed that: *There is no doubt that the 'good' material is Cladopodiella fluitans. It fits pretty well. I do think the other plant is probably the same, just a more flagelliferous form with reduced leaves. It has postical branching and underleaves, but there is always an element of doubt with such forms.* This form, with reduced leaves, occurs most frequently where the plant grows directly on an existing hard pan surface.

Whilst there is an extensive literature associated with carbonate deposition (Pentecost, 1985, 1996) comparatively little appears to have been written on the topic of iron deposition and the role played in it by bryophytes (as opposed to bacteria). However, some hepatics are known to tolerate Fe and other heavy minerals e.g. the metallophyte species, discussed by Porley & Hodgetts (2005). Vincent, Lawlor & Tipping

M2	*Sphagnum cuspidatum / recurvum* bog pool community
M3	*Eriophorum angustifolium* bog pool community
M21	*Narthecium ossifragum – Sphagnum papillosum* valley mire
M25	*Molinia caerulea – Potentilla erecta* mire

△Table 2. The major plant communities represented on Dersingham Bog NNR. Although present in places as 'pure' communities they are frequently present in complex mosaics which reflect the previous history and usage of the site - which included peat working

△Fig 2. View over M3 Bog pool community on Dersingham Bog. Note the many open patches.

(2001) have also noted metal accumulations in *Scapania undulata* in British upland streams and Satake (2000) has noted iron accumulation in the cell walls of *Warnstorfia* (*Drepanocladus*) *fluitans.*

According to BRYOATT (Hill *et al.,* 2007) *Cladopodiella fluitans* is a boreal-montane, circumpolar, native plant found on peat or floating in water, or growing up through other bryophytes. It occurs as solitary creeping stems or as wefts and, as a dioicous species, produces sporophytes rarely. BRYOATT also includes the Ellenberg values for the species. (Heinz Ellenberg was a German botanist and ecologist who developed scales for rating plant preferences for various environmental conditions, such as light (**L**), soil moisture (**F**), pH (**R**), nutrients (**N**), salinity (**S**) and Heavy Metals (**HM**). These were partly based on actual measurements, but also included assessments based on expert ecological opinions). The Ellenberg values ascribed to *C. fluitans* in BRYOATT are: **L** - 8 [1 -9]; **F** - 9 [1 -9]; **R** - 1 [1 -9]; **N** - 1 [1 -9]; **S** - 0 [1 -9]; **HM** - 0 [1 -9]. The figures in brackets indicate the total range of the scale used.

This characterisation is supported by other accounts of the species, such as those by Paton (1999), Damsholt (2002), and Schuster (1974).

What is odd about this situation is that whilst *Cladopodiella fluitans* has an Ellenberg HM value of zero, *Gynnocolea inflata*, with an HM value of 3, is very rare on the site, resulting in a species allegedly *more* tolerant of heavy metals being less common than one which is supposed to be extremely intolerant. Elsewhere in West Norfolk, where very acid conditions exist, such as Bawsey (Stevenson, 2011), *Cladopodiella* is completely absent but *Gymnocolea* is not infrequent, which is what one might expect.

Formation of iron pan & bog iron ore

There is an extensive literature on iron deposition and the formation of iron pans and bog iron ores; Rydin & Jeglum (2006) concentrate on processes in peatlands whilst Ollier & Pain (1996) discuss the processes involved under a wider range of circumstances. Rydin & Jeglum (2006) note that it is often formed where groundwater is discharged at the surface, often at the foot of a slope, wetting the surface sufficiently to promote peat formation. Primary deposition may occur as bog iron (or iron ochre) within the peat, where reducing conditions occur, allowing Fe^{2+} to occur in solution. However, on reaching (or being exposed at) the surface the Fe^{2+} is oxidised to Fe^{3+} and then becomes insoluble - forming a hard iron pan, a point also stressed in Ellis & Mellor (1995) who also noted that the influence

△Figs 3 & 4. A mat of *Cladopodiella fluitans* growing over an iron-rich substrate. Knife is 19 cm long. A section through a portion of iron pan showing a surface mat of *C. fluitans*. Knife blade is 10 cm long.

of humans, in clearing vegetation, may also be an important factor in the process of exposing iron-rich horizons to hardening. Rydin & Jeglum (2006) also stress the important role played by bacteria in these processes, as is the case with the deposition of carbonates (Pentecost 1986; 1990).

According to Wirt *et al.* (2007) what they call ferricrete form 'down gradient from large exposures of acid generating rock types.... containing pyrite and other sulphide minerals' and form when 'reduced, acidic ground water discharges near the surface and becomes oxidised'. However, Cunningham *et al.* (2001) suggest that thin iron pans (in soil) may form under a wide variety of circumstances, irrespective of topographic position, the triggering mechanism being changes in Eh : pH and/or acid : base conditions.

However, deposited iron does not always form an impenetrable layer - this seems to depend on exposure to the atmosphere. On Dersingham Bog, where the iron pan is up to 5 cm. thick, iron deposition is taking place at the present day on surfaces which consist of hardened pan; twigs of *Calluna* and fragments of wood can be seen littering the surface, all coated with iron oxide, and colonies of the liverwort *Cladopodiella fluitans* may form mounds several centimetres deep, the lower portions of the plants being encased in an armour of iron oxide (Fig. 5).

The strata deemed likely to have the greatest influence on the water chemistry of the area are the Leziate Sands (which may contain pyrite nodules as well as glauconite), the Dersingham Beds, and the Carstone Formation (Table 1). All of these rocks contain iron minerals of various types (Gallois, 1994), and it is assumed that iron - in a variety of forms - has been leached downward through them to emerge at the foot of the scarp where it is deposited as a horizon within the peat of the mire. The pan has then impeded drainage sufficiently to allow the development of mire vegetation on the flat ground at the foot of the slope.

An unpublished report (Proctor, 1953) in the Natural England site office at Wolferton revealed that, over 60 years ago, Proctor had also been struck by the relationship between the iron pan and the *Eriophorum angustifolium* community. His report includes some preliminary work on the chemistry of the site which, unfortunately, was never written up formally. In it he refers to 'large sterile areas, with the water table at or near the surface, bearing only a sparse vegetation of *Eriophorum angustifolium*'; today, we suspect, the areas which can be so described are, although still prominent, probably smaller than in the early 50s, and the growth of *E. angustifolium* has

△Fig 5 (left). 'Fossil' *Cladopodiella* coated with iron oxide; photo taken from dried portion of Fig. 4, showing how even 'normal' *Cladopodiella* can tolerate iron deposition onto its leaves. △Fig 6 (right). The form of *Cladopodiella* most closely associated with iron-rich surfaces.

progressed considerably. Curiously, *Warnstorfia fluitans* is the only bryophyte he mentions.

To further Proctor's work we assessed surface water chemistry from close to *Cladopodiella* mats where iron pan formation was progressing. The results show that the *Cladopodiella* is growing in extreme acid conditions of pH 2.2 accompanied by a somewhat toxic soup consisting of high levels of iron (75mg/l), aluminium (14mg/l) and sulphate (240mg/l). Potassium concentrations were more moderate (4.2mg/l) in tune with levels elsewhere on the bog. The presence of these ions in solution was highlighted by conductivity (around 1500 microS/cm) indicating high ionic activity.

The eastern perimeter of the site is defined by an abandoned railway line, and historically fires (caused by sparks from steam trains) have had an influential role in controlling the development of the vegetation. Petch (1944) noted that '… the peat became so dry during a hot summer in the 'twenties that over big stretches it burnt down to the underlying sand. Recolonisation by *Eriophorum angustifolium* (cotton grass) has proceeded slowly…'. This seems as if it is the most likely trigger for the formation of the hard iron pan, though former peat extraction may also have been a contributory factor.

Discussion

The Ellenberg value of zero ascribed to *Cladopodiella fluitans* in Hill *et al.* (2007), whilst probably true for the bulk of populations, does not appear to be a 'universal' value, as the plant can, as here, clearly survive high levels of iron in the environment. In fact it appears to be sufficiently tolerant as to be able to grow up, and out of, a regime of active iron deposition. However, the typical growth form appears to be considerably modified in the process.

An ability to tolerate iron may give the plant a competitive edge but ultimately deposition on its surface may lead to its destruction, unless it is able to grow up faster than deposition occurs.

Given the disparity between the apparent intolerance of *C. fluitans* to heavy metals, as expressed by its existing Ellenberg value, and its presence in an iron rich environment on Dersingham Bog, Dr M.O. Hill (one of the authors of BRYOATT - Hill *et al.,* 2007) was approached. He replied that by heavy metals they had meant non-ferrous elements such as cadmium and tin, admitting that iron tolerance was 'a different matter' for which it would be interesting to have an indicator.

Any future refinement of the Ellenberg values for bryophytes would seem to require reporting of any apparent aberrations or deviations, the most appropriate place for which would seem to be the 'New and Interesting Records' pages in *Field Bryology*.

The reference by Petch (1944), coupled with the points raised by Ellis & Mellor (1995), suggest strongly that the present exposures of iron pan on Dersingham Bog date back to the 1920s, when during a very dry summer, sparks emitted by a steam train succeeded in setting part of the Bog alight. The loss of the peat cover then exposed the underlying soft iron deposits to drying and insolation, resulting in their hardening to form a hard plate-like surface pan.

At the present, nearly 100 years after the fires, the legacy of that event is still present both as an iron pan and as a degraded, albeit recovering plant community.

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