**Having a LAFF with *Anthracoidea***

Stewart Taylor and Paul A. Smith

The Lost and Found Fungi (LAFF) project (<http://fungi.myspecies.info/content/lost-found-fungi-project>) has been enthusing people to go out and find fungi. Amongst its target species there are several smuts, and although we were both already looking for smuts (see Box), LAFF has provided an added incentive. One target has been examination of potential hosts in the Cyperaceae for ovary smuts in the genus *Anthracoidea*, whichmake reasonably obvious smutty balls which replace the utricles, mainly in *Carex* species, but also some related genera.

17 species of *Anthracoidea* have been recorded from Britain (FRDBI 10/9/16; excludes *A. liroi* which has been reported but not substantiated) and only one for Ireland (*A. subinclusa*). Most *Anthracoidea* species are specific to one or a small number of closely related host species. 18 species and 2 hybrids are therefore known as hosts of *Anthracoidea* from British records, though more species act as hosts for this range of *Anthracoidea* in the rest of Europe (Vanky 1994).

**Getting smutty**

Stewart Taylor

A long association with expert Mycologist Peter Orton (1983 – 2002) during visits to my previous place of employment, RSPB Abernethy Forest Reserve, introduced me to the world of fungi. Sadly, I was a finder not an identifier. However, a five-year study of populations of tooth fungi on the reserve (2007 – 2011) and a developing interest in fungi on land plants via links to the Highland Biological Recording Group (HBRG) prepared me for the world of *Anthracoidea*. My first find though came via another survey, the annual count of lesser butterfly and small white orchids in a nationally important UK meadow near to my home, and as I walked the transects in June 2013 I became aware of groups of unusual round black balls on the flower heads of *Carex caryophyllea* (Spring sedge). Intrigued, I took a couple of plants home and out of curiosity checked part of one of the black balls under the microscope to reveal masses of generally roundish dark brown spores, I then knew I was dealing with a fungus. Querying my find with local expert mycologist Liz Holden informed me that I was dealing with an *Anthracoidea* smut, but with the addition that little was known about this group. Martyn Ainsworth at Kew gave me the name *Anthracoidea caryophyllea*, and suggested I might carry out checks of other sedges in my local area to help with our knowledge of this probably under-recorded group. Thankfully, sedges are a group that I have had an interest in over the years, a big help with what was to follow. Re-visiting the orchid field the smut was found on *Carex panicea* (*Anthracoidea paniceae*) and during my last BTO survey that year I got quite excited as I found the fungus on *Carex echinata* (*Anthracoidea karii*). As other surveys came to an end in 2013 I targeted sedge rich areas locally and when *Anthracoidea inclusa* was found on *Carex rostrata* and *A. lasiocarpae* on *Carex lasiocarpa*, and Martyn informed me that both were new to Britain, I realised that I had stumbled into what would develop into my next long-term survey. Unbeknown to me at that time staff at Kew were developing, with funding assistance from the Esmée Fairbairn Foundation, The Lost & Found Fungi Project, which included two of the species covered in this article.

Paul Smith

I had been a botanist for many years when Arthur Chater introduced him to rust fungi. It took a bit of encouragement, but I eventually started collecting my own specimens, and then, with the help particularly of Nigel Stringer, to identify them. Most of my recording takes place in the Outer Hebrides (for which I am the botanical recorder), and it was a small step to add smuts, including *Anthracoidea* which are relatively obvious in moorland habitats with few plant species and which can enliven a recording trip. Rusts and smuts are being systematically recorded alongside the plants for an eventual new flora.

In this paper we give pen portraits based on our experiences of these species, both the relatively common ones and the more unusual ones that have been the subject of LAFF’s attentions (Table 1 summarises our finds). Then we look at the other British and Irish *Anthracoidea*, and at the end we briefly consider the species of *Anthracoidea* not yet found in Britain and Ireland, but whose hosts do occur here – maybe they are waiting to be discovered.

Table 1 ST and PAS total records as of October 2016

|  |  |  |  |
| --- | --- | --- | --- |
| **Anthracoidea species** | **Sedge** | **ST nos** | **PAS nos** |
| Anthracoidea bigelowii | Carex bigelowii | 1 |  |
| Anthracoidea caricis | Carex pilulifera | 1 |  |
| Anthracoidea caryophylleae | Carex caryophyllea | 3 |  |
| Anthracoidea hostianae | Carex hostiana | 3 |  |
| Anthracoidea inclusa | Carex rostrata | 13 |  |
| Anthracoidea inclusa | Carex vesicaria | 1 |  |
| Anthracoidea inclusa | Carex x involuta | 1 |  |
| Anthracoidea karii | Carex echinata | 75 | 29 |
| Anthracoidea lasiocarpae | Carex lasiocarpa | 2 |  |
| Anthracoidea limosa | Carex limosa | 2 | 1 |
| Anthracoidea paniceae | Carex panicea | 56 | 22 |
| Anthracoidea pratensis | Carex flacca | 12 | 3 |
| Anthracoidea pseudirregularis | Carex pallescens | 2 |  |
| Anthracoidea pulicaris | Carex pulicaris | 5 |  |
| Anthracoidea scirpi | Trichophorum x foersteri | 5 | 9 |
| 13 smut species | 15 plant species | 182 | 64 |

**Introduction to *Anthracoidea***

*Anthracoidea* spp. infect the ovaries of members of the Cyperaceae, with the sorus forming around the ovary, which can be seen in the centre (see Fig. 2 below, and Scholler et al. (2003) Fig. 2A). At maturity the whole sorus falls to the ground where it overwinters (sometimes for more than one year (Ingvarsson & Ericson 2000)), and when conditions are right the teliospores germinate, forming short hyphae bearing basidia with (unusually for Ustilaginales) two basidiospores each. These spores infect the flowers of the next generation of the host plant. *Anthracoidea* are not systemic, and rely on reinfection from year to year.

Originally all the ovary smuts on *Carex* were lumped together under the name *Anthracoidea caricis*, but small morphological differences led to some species being separated, and later a narrower species concept led to separation of species more along host differentiation lines. This narrow view has been largely corroborated by DNA work (Hendrichs *et al*. 2005).

The life cycle of some *Anthracoidea* is entwined with that of the beetle *Phalacrus substriatus*, which feeds on the teliospores and basidiospores, as well as on pollen. In *A. heterospora,* *Phalacrus substriatus* appears to act as a vector for transmission between host plants (Ingvarsson & Ericson 1998). The beetle is widely scattered across Britain (Telfer 2013), and also recorded for Ireland, which might suggest that there are more *Anthracoidea* to be recorded there.

**Details of our recent finds**

***A. bigelowii***

First record, 07/08/19XX, near Braemar, South Aberdeen, followed by a single find on *Carex bigelowii* (Stiff sedge) July 2013 by ST below Central Gully Coire an t’Sneachda (NH99309 03044) in the Cairngorms, at 970m. These are the only two British records of *A. bigelowii*.

***A. caricis***

*A. caricis* is the type species for *Anthracoidea*, and originally acted as a general name for all ovary smuts in *Carex*. Different segregates have gradually been split off, and now only smuts on *Carex pilulifera* (and *C. montana*, though it has not (yet) been recorded on this host in Britain) are included here. In FRDBI this name has, in the past, acted as a ‘bucket category’, which needs tidying up by re-determining specimens in line with modern nomenclature. Until 2016 there was just a single record on *C. pilulifera,* from South Aberdeen (VC92) in August 1844. Whilst plant recording near Duthil, Carrbridge (VC95) on 19 July 2016 ST found the plant/smut combination on moorland close to the B9007 road (NH93201 27936) with the corresponding *Anthracoidea* spp. also present on *Carex pulicaris* and *C. panicea* close by.

***A. caryophylleae***

First record from a specimen on *Carex caryophyllea* (Spring sedge) collected by Dave Batty from Morrone, Braemar, Aberdeenshire (VC92) 31 July 1980 during SNH Grassland Survey and identified by Roy Watling. The next records were two finds made by ST at an orchid count site near Boat of Garten (NH94019 16223, VC96) 27 June 2013 and 22 June 2016, and near Lurg, Nethybridge (NJ04147 16706, VC95) 15 July 2015.

***A. hostianae***

First British record by ST during a plant survey near Tomintoul (NJ1711 2037, VC94) 28 July 2015. Targeted surveys of *Carex hostiana* (Tawny sedge) sites later that year found the smut near Grantown on Spey 11 August (VC95), and near Drumnadrochit (VC96) 2 September whilst searching (unsuccessfully) for the smuts on *Carex buxbaumii* (Club Sedge).

***A. inclusa***

First British record was found by ST on *Carex rostrata* (Bottle sedge) via targeted searching at RSPB Insh Marshes (VC96) whilst checking a *Carex chordorrhiza* (String Sedge) site on 4 August 2013. This is a species with multiple hosts, and not long after ST followed up with the first UK record from *Carex vesicaria* (Bladder sedge) from sedge-beds by the River Spey close to Kincraig VC96, on 4 September 2013, and then a further UK first from the hybrid *Carex* × *involuta* (*rostrata × vesicaria*, host det. Andy Amphlett) from a pool in RSPB Abernethy Forest near Nethybridge (VC96).

Several *Anthracoidea* species have been found to have their heaviest infections on hybrid sedges (Ericson *et al*. 1993 for *A. heterospora*, McIntire & Waterway 2002 for *A. limosa*), and in some cases are thought to persist because of the presence of hybrids. In species with multiple hosts, smut infections might even be worth considering as an indicator of hybridity. In *A. inclusa* however, the evidence so far is for most infections on *C. rostrata*, with ST making fourteen observations at nine locations between 4 August and 15 September 2013. The smut was found again at some of these locations in 2014 plus at one new site. Three new sites were found in 2015 when none of the previous locations were re-visited.

***A. karii***

*A. karii* infects a range of species, but we have found it only on *Carex echinata* (Star sedge), which it appears to infect quite commonly. This appears to be the commonest *Anthracoidea* amongst those we have recorded to date, with PAS having seen it in 29 tetrads (2 x 2 km sq) and ST in 35. At several of our sites many sedge heads have been seen covered with the smut.

***A. lasiocarpae***

*A. lasiocarpae* is apparently a rare species, and ST found it new for Britain in two locations on 4 & 15 September 2013 at Kincraig (VC96), in an area west of the River Spey outflow from Loch Insh, NH833054 and NH833560. It was still present at the first location 16 September 2016. Its host, *Carex lasiocarpa* (Slender sedge), is widespread, but often occurs in small quantity, and is also a shy-flowering species, so it is quite likely that the smut is overlooked. *Carex lasiocarpa* is actually host to two other species of *Anthracoidea*, *A. intercedens* which is not yet known from Britain and Ireland and *A. subinclusa* with two records on this host (one as *C*. ?*lasiocarpa*).

***A. limosa* LAFF species**

This species parasitises *Carex limosa* (Mud sedge), a species of the wettest parts of bogs and flushes. *A. limosa* is a LAFF top 100 species, and before the project began was known only from Rannoch Moor (VC88) and one site in West Sutherland (VC108). There are two locations linked to Rannoch Moor, one close to Rannoch Station where it was first found in 1920 and last reported in 2010, and the other near Loch Ba on the Glen Coe side of the moor and last recorded in 1943. ST made lots of efforts to find it from known *C. limosa* sites in his local area but without success, so on 2 August 2016 he made a visit to Rannoch Station where it was found in the same area where it was first recorded in 1920 (NN4202 5756). It is clearly persistent here. A second new location was also found about 500m from the original (NN4242 5744). At both sites many of the flowering spikes were infected. A later visit to

the Loch Ba area failed to find either sedge or smut, though the information on location was very vague, and there was a lot of suitable habitat to search. A check of several small populations of *C. limosa* 5km north of Loch Ba failed to find the smut. PAS meanwhile came across it just a few days later at Loch na Beiste Moire, a loch with floating mats of vegetation in an unexceptional part of the Lewis peatlands near Stornoway (NB3627 3462, VC110). Most flowering spikes of *Carex limosa* here were infected.



Fig. 1: Habitat of *A. limosa* at Loch na Beiste Moire, Lewis, VC110. © Paul A. Smith

***A. paniceae***

*A. paniceae* infects *Carex panicea* (Carnation sedge) (and *C. vaginata*, though it has not yet been found on this host in Britain), the former being a very common sedge of moorland and wetland habitats. The smut is also relatively common with PAS making records from 22 tetrads in VC110 2007-2016. Although it is found regularly, PAS found it to be particularly frequent during fieldwork on Lewis in 2016, and it is possible that it has bumper years when conditions are just right for infection. Similarly, this is the second commonest species found by ST over many locations in the north of Scotland (Western Isles to Deeside) comprising 31 tetrads and 56 locations. At some sites many sedge heads were found to be infected.

***A. pratensis***

A parasite of *Carex flacca* (Glaucous sedge). Despite the commonness of its host, not so frequently reported as other *Anthracoidea* species. ST has found the smut in 10 tetrads

comprising 12 locations and PAS in three locations. At several sites many sedges were infected. At one site on Kinrara Estate near Aviemore (VC96) a beetle was seen in one of the fungal balls and identified by Richard Lyszkowski as *Phalacrus substriatus*. This species is known to frequent *Anthracoidea* spore masses, which it eats, but it is also an important vector for the spread of *Anthracoidea* infections (Ingvarsson & Ericson 1998, 2000).



Fig. 2: Section through utricle of *Carex flacca* infected by *Anthracoidea pratensis*. © Stewart Taylor

***A. pseudirregularis***

Several large populations of the sedge *Carex pallescens* (Pale sedge) were found during a plant recording visit to the Spey Dam area west of Laggan (NN5587 9236, VC96) by ST on 5 September 2015. The smut was found on two populations of the sedge providing just the second British record. The first record occurred on the Isle of Mull (VC103) in August 1966.

***A. pulicaris* LAFF species**

*A. pulicaris* is also a LAFF top 100 species. During an *Anthracoidea* search by ST of *Carex hostiana* locations near Dulnain Bridge on 3 August 2015 (NH99140 26257, VC95), several heads of *Carex pulicaris* (Flea sedge) were found infected by the smut. This was the third British location for the smut following the first find in East Norfolk (VC27) in July 1932, and on the Isle of Skye (VC104) in August 1932. ST found a further four sites in 2016.

***A. scirpi***

This is one of two European *Anthracoidea* species which has a host which is not a sedge – it parasitises a deergrass species (*Trichophorum*), and its distribution in Britain was reviewed by Smith (2010) following a year when it was abundant over a wide area of moorland in Lewis (Outer Hebrides, VC110). Despite extensive botanical fieldwork in moorland habitats in the Outer Hebrides each year since then, it did not turn up again until 2016, when it was again widespread (in a different area, though the original sites were not re-checked). This suggests that it may have occasional bumper years when conditions are just right and it produces heavy infections. There is some evidence that teliospores may persist for more than one year (Ingvarsson & Ericson 2000), which suggests a mechanism for persistence over years when no infections are apparent.

ST’s experience, in contrast, is that the smut is generally rare in VCs96 and 95, but that the same plants at one site are infected each year (this also accords with observations on other species, eg *A. heterospora*, where the correlation of infection incidence is high (Ingvarsson & Ericson 1998)). Perhaps this reflects a difference in conditions in the east and west of Scotland, or perhaps more observations are needed to suggest a pattern. During plant recording by ST in August 2016 large populations were found on moorland west of Carrbridge (VC95) and a single infected plant was found near Rannoch Station (VC88) in August 2016 but where the deergrass species wasn’t identified.

However, both of us find that *A. scirpi* occurs preferentially on the hybrid deergrass *Trichophorum* × *foersteri*, a situation apparently in contrast to the observations of Kukkonen in Finland (Smith 2010) who reports it exclusively from habitats typical for *T. cespitosum* s.s.. This association is interesting as *T.* × *foersteri* is a sterile hybrid; the sterility clearly does not hinder the smut in infecting the ovary – indeed the sorus in *Anthracoidea* is formed round it (see Fig. 2, and Scholler *et al*. 2003). This situation may be analogous to the hybrid infections described above for *A. limosa* and *A. heterospora* (see under *A. inclusa*), with the hybrid being more susceptible and potentially helping the parasite to persist (McIntire & Waterway 2001).

Because a relatively large number of records has been made since Smith (2010), an updated distribution map for *A. scirpi* is shown in Fig. 3. It seems likely that further records will continue to be added. On moorland in both our recording areas *Trichophorum* species are very common mostly *T. germanicum.*

Fig. 3: Known British distribution of *A. scirpi*. White circles = pre-1970, grey circles = 1970-99, black circles = 2000+. (Plotted using DMAP).

***Anthracoidea scirpi.emf***

**Other British species**

Other species of *Anthracoidea* that have been recorded in Britain are listed below. We haven’t found these in our searches, in most cases because we have not targeted the particular hosts.

***A. arenariae***

This parasite of *Carex arenaria* (and *Carex leporina* outside Britain) is relatively frequently recorded, with 22 distinct records (including some repeat collections in different years) on FRDBI.

***A. capillaris***

This species infects *Carex capillaris* (Hair sedge), and is known from a single record from South Aberdeen in 1844 with a specimen in K(M) (FRDBI). However, it is not a LAFF target species, and we haven’t searched specifically for it. But in view of the finds of other species made so far, it’s probably out there somewhere, and worth looking out for if you are near the host (which has a restricted, mainly northern, range in Britain).

***A. heterospora***

*A. heterospora* is a parasite of species in the *Carex nigra* group. FRDBI has two records, but both on unlikely hosts; however, one of the FRDBI records under *A. karii* is on *Carex recta*, originally identified as *A. hetersopora*, and this seems likely to be correct and therefore should be maintained on the British list, although confirmation would be nice. Clearly FRDBI records for some *Anthracoidea* spp. need more work!

***A. subinclusa***

The principal host of *A. subinclusa* is *Carex vesicara* (Vanky 1994), but it has a wide host range, and none of the British records are from this species. Instead they are from *Carex hirta*, *C. lasiocarpa*, *C. riparia* and *C. rostrata*. *A. subinclusa* differs in it spores, which are more spiny than *A. inclusa*, so it is important to check the spores on this range of hosts.

**Species waiting to be found?**

There are 16 species of *Anthracoidea* (*angulata*, *aspera*, *atratae*, *buxbaumii*, *caricis-pauciflorae*, *echinospora*, *fischeri*, *humilis*, *intercedens*, *irregularis*, *lindebergiae*, *misandrae*, *rupestris*, *tomentosae*, *turfosa*, *vankyi*) where the hosts are present in Britain and Ireland, but the smut itself has not yet been recorded. So maybe the female flowers are awaiting infections, or maybe these smuts are already present but have not yet been detected.

Rather than try to list all the associations, which are rather complicated as several hosts have multiple smuts and several smuts are polyphagous, we list the Cyperaceae (excluding hybrids unless already recorded as hosts in Britain) that it’s worth looking closely at (in fact almost the whole British list of *Carex*!), derived from Vanky (1994). The ones in bold already have British records for at least one *Anthracoidea*, and the ones marked \* are potential hosts for *Anthracoidea* not yet recorded for Britain (so it is worth checking any specimens on these hosts carefully):

*\*Carex acuta*

*Carex acutiformis*

*\*Carex appropinquata*

*Carex aquatilis*

***Carex arenaria***

*\*Carex atrata*

*\*Carex atrofusca*

***Carex bigelowii***

*\*Carex buxbaumii*

*\*Carex canescens*

***Carex capillaris***

***Carex caryophyllea***

*Carex cespitosa*

*\*Carex chordorrhiza*

*\*Carex diandra*

*\*Carex digitata*

*\*Carex dioica*

*\*Carex disticha*

*\*Carex divulsa*

***Carex echinata***

*\*Carex elata*

*Carex ericetorum*

***Carex flacca***

***\*Carex hirta***

***Carex hostiana***

*\*Carex humilis*

***Carex × involuta***

*Carex lachenalii*

***\*Carex lasiocarpa***

*Carex lepidocarpa*

***Carex limosa***

*Carex magellanica*

*Carex montana*

*\*Carex muricata*

*\*Carex nigra*

*\*Carex ornithopoda*

*Carex ovalis*

***Carex pallescens***

***Carex panicea***

*\*Carex pauciflora*

***Carex pilulifera***

*Carex pseudocyperus*

***Carex pulicaris***

*Carex rariflora*

***Carex riparia***

***Carex rostrata***

*\*Carex rupestris*

*Carex salina*

*Carex saxatilis*

*\*Carex spicata*

*\*Carex tomentosa*

*Carex vaginata*

***Carex vesicaria***

*\*Carex vulpina*

*\*Kobresia simpliciuscula*

*Trichophorum germanicum*

***Trichophorum x foersteri***

There are keys to *Anthracoidea* in Vanky (1994, 2012), but the earlier one is out of print, and the later one ridiculously expensive. The recent (and excellent) Klenke &Scholler (2015) is a more reasonable (though still expensive) id guide. Earlier works do not cover the splitting up of *A. caricis* s.l. into many segregates.

**Impostors**

Not all ovary parasites on Cyperaceous hosts belong to *Anthracoidea*. Another LAFF top 100 fungus infecting *Rhynchospora alba* (White Beak-sedge), *Ustanciosporium gigantosporum* has so far evaded recapture since its last British appearance in 1959. Several species of *Carex* are hosts to *Farysia* species, which generally form much messier (and generally paler) infections.

**Acknowledgements**

Huge thanks are due to Martyn Ainsworth whose help with identifying ST’s initial finds was invaluable and whose encouragement to look for more made this article possible. Thanks also to Andy Amphlett for help with identifying some sedge species that were collected late in the season and had lost key identification features and to Ian Green for recording his smut finds whilst undertaking plant surveys. Brian Douglas (Kew LAFF Project) has provided support and guidance, and suggested writing this article.

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| DSC_9379 Carex bigelowii & A. bigelowii.jpg | DSC_7267 Carex caryophyllea & A caryophylleae.jpg | DSC_9798 Anthracoidea hostianae on Carex hostiana fm.jpg | DSC_0247.jpg Carex rostrata & A inclusa.jpg |
| a) *A. bigelowii* | b) *A. caryophylleae* | c) *A. hostianae* | d) *A. inclusa* |
| DSC_9829 Carex echinata & A karii.jpg | DSC_3422 Carex lasiocarpa & A lasiocarpae.jpg | P1300148 Carex limosa and A limosa.jpg |  |
| e) *A. karii* | f) *A. lasiocarpae* | g) *A. limosa* on *Carex limosa* | h) *A. paniceae* on *Carex panicea*, nr Creagan Bheiceamair, Lewis, vc110 |
| Anthracoidea on Carex flacca ii.JPG | DSC_6471 Carex pallescens & A pseudirregularis.jpg | DSC_0149 Carex pulicaris & A pulicaris.jpg |  |
| i) *A. pratensis* on *Carex flacca*, Dail bho Deas, Lewis, vc110 | j) *A. pseudirregularis* | k) *A. pulicaris* | l) *A. scirpi* on *Trichophorum* ×*foersteri*, Tom Mor Eimasgro, Lewis, vc110 |

Fig. 4: Recent *Anthracoidea* finds in Scotland. a-g, j, k © Stewart Taylor, h, i, l © Paul A. Smith.