Institution: Aberystwyth and Bangor Universities - Biosciences, Environment and Agriculture Alliance (BEAA)

Unit of Assessment: 6: Agriculture, Veterinary and Food Science

Title of case study: The conservation and protection of grassland fungi

1. Summary of the impact

Research conducted at BEAA has made a significant contribution to the conservation of grassland fungi (notably waxcap fungi) through changes to policy decisions as they related to fungal conservation, including the provision of specialist advice that has led to the notification of two SSSIs (sites of special scientific interest) and to changes in SSSI notification guidelines. BEAA research has also enhanced public understanding and awareness of fungal conservation through 'citizen science' activities, public lectures, radio programmes, film productions such as Disneynature's *Chimpanzee*, as well as articles in newspapers and widely-read magazines. These wider achievements are based on underpinning science to address survey methodologies, taxonomic issues and the elucidation of the basic biology of grassland fungi, all of which are essential for effective conservation strategies.

2. Underpinning research

Our understanding of the ecology of grassland fungi has been transformed over the past three decades. Studies in mainland Europe had highlighted the consequence of huge losses in lowland grassland habitats (estimated to be >95% since 1945) on the biodiversity of grassland macrofungi. This was most serious in the Netherlands where it is estimated that only 200 ha of 'waxcap grassland' habitat remain [3.1]. Work at BEAA since 2001, led by Gareth Wyn Griffith, has developed and enhanced this area of biology, making a major contribution to the understanding of the diversity and ecology of fungi in grassland ecosystems [3.1,3.2]. This includes the fungal inhabitants of herbivore digestive tracts (e.g. discovery of two new genera of anaerobic fungi) and plant roots (dark septate endophytes; discovery of the importance of these fungi in mesotrophic grasslands) but the greatest impact has emerged from our work on grassland macrofungi of conservation importance.

Underpinning these studies of fungal diversity in grassland systems has been the contribution of several past and present members of BEAA staff (G. W. Griffith, D. R. Davies [until 2010], B. Douglas, J. Edwards, J. Ironside) to landmark publications in fungal phylogenetics [3.3], which have led in turn to taxonomic revisions [3.4] and ultimately the establishment of an agreed fungal DNA barcode [3.5]. Such developments have been crucial to the development of a stable nomenclature for fungi and in development for genetic methods for the detection and identification of fungi.

This impact in protecting the more vulnerable populations of grassland macrofungi has been achieved from underpinning research at AU funded by diverse stakeholders (e.g. NERC [3.6], DEFRA, Plantlife, Grasslands' Trust and UK statutory conservation bodies, such as the Countryside Council for Wales (CCW) and equivalent bodies in Scotland, England and Northern Ireland. These have permitted the development of quantitative survey methodologies [3.1] that allow objective assessment of fungal diversity and, thus, identification of sites in need of protection. Investigation of the basic ecology of these fungi has led to the development of specific management recommendations (in particular appropriate grazing management and avoidance of eutrophication) based on robust experimental data [3.2]. These results are of direct relevance to conservation-orientated land managers (e.g. nature reserve wardens) and also to policymakers (e.g. in the design of agri-environment schemes or assessment of sites warranting statutory legal protection). This research has also raised the public profile of microbial conservation [3.7].

3. References to the research

3.1 **Griffith, G.W.,** Gamarra, J.G.P., Holden, E.M., Mitchel, D., Graham, A., Evans, D.A., Evans, S.E., Aron, C., Noordeloos, M.E., Kirk, P.M., Smith, S.L.N., Woods, R.G., Hale, A.D., Easton, G.L., Ratkowsky, D.A., Stevens, D.P. and Halbwachs, H. (2013). The international conservation importance of Welsh 'waxcap' grasslands. *Mycosphere,* **4(5)**, 969-984**.**1. doi 10.5943/mycosphere/4/5/10.

3.2 **Griffith, G.W.**, Roderick, K., Graham, A., Causton, D.R. (2012). Sward management influences fruiting of grassland basidiomycete fungi. *Biological Conservation*, **145,** 234–240. doi 10.1016/j.biocon.2011.11.010. **[REF2 submitted]**

3.3 James, T.Y., […33 authors...] **Griffith, G.W., Davies, D.R.,** [..34 authors..] (2006). Reconstructing the early evolution of the fungi using a six gene phylogeny. *Nature, London,* **443**, 818-822**.** doi:10.1038/nature05110. (771 citations in Google Scholar)

3.4 Hibbett, D.S., [….29 authors….] **Griffith, G.W., Ironside, J.E.,**[….36 authors….] (2007). A Higher-Level Phylogenetic Classification of the Fungi. *Mycological Research* **111,** 509-547. doi 10.1016/j.mycres.2007.03.004. (867 citations)

3.5 Schoch, C.L., [....70 authors....) **Griffith, G.W., Douglas, B., Edwards, J.,** [….70 authors….] (2012). The internal transcribed spacer as a universal DNA barcode marker for Fungi. *Proceedings of the National Academy of Sciences, USA,* **109(16),** 6241-6246. doi: 10.1073/pnas.1117018109. (248 citations)

3.6 **NERC.** Fine scale analysis of *Hygrocybe* spp. (waxcaps) in semi-natural grasslands and elucidation of their role in decomposition processes. Sep 2001-Dec 2002. NER/T/S/2001 /00143. (02/943; G.W. Griffith [PI] and Roland Bol, IGER).

3.7 **Griffith, G.W.** (2012). Do we need a Global Strategy for Microbial Conservation? *Trends in Evolution and Ecology*, **27(1),** 1-2. doi 10.1016/j.tree.2011.10.002.

4. Details of the impact

The impact of this research has been twofold: firstly it has influenced major planning decisions and also environmental policy decisions. Secondly, it has established that fungi, along with other microbes should be considered in conservation planning and conservation practice, a process that has involved the raising of public awareness that fungi deliver important ecosystem services and that they can be threatened by human activities.

As noted above, semi-natural grasslands are amongst the most threatened habitats in Europe. In the UK many such sites are legally protected following notification as SSSIs. It is only very recently that distinctive fungal populations have factored in the notification of any SSSIs and in this respect the UK leads the world in recognising that sites with distinctive fungal populations merit legal protection. For two of the four such SSSIs in the UK , there has been significant input from G. W. Griffith, as follows:

The notification of Eithinog (Bangor, Gwynedd) as an SSSI was based on an assessment of the fungal diversity by BEAA. Following plans by the site owner (Gwynedd Council) to undertake a building development at the site and resultant objections, G. W. Griffith was commissioned by CCW to undertake an assessment of the mycological value of the sites [5.1]. Based on his report, CCW decided to notify the site as SSSI in 2008 [5.2], with a press release from CCW stating "An in-depth assessment by Aberystwyth University commissioned by the Countryside Council for Wales, revealed the development would not affect the site's important fungi, provided appropriate measures were put in place to protect the new SSSI during the work". This notification was accompanied by several newspaper reports [5.3] and the site has since been sold to the North Wales Wildlife Trust and established as a nature reserve for the local community.

A similar proposed housing development of Llanishen Reservoir (Cardiff) also led to the

notification as an SSSI based on its diverse populations of grassland fungi (on the embankment areas). The notification was based on work by G. W. Griffith that discovered 28 species of waxcap on the site and his assessment that this site was of international importance for these fungi. This notification was upheld following judicial review at the Royal Courts of Justice and subsequent challenges to the notification by the site owners between 2009 and 2013. The fate of the reservoir and the legal challenges generated considerable press attention and were discussed in the House of Commons (Hansard, 25th Feb and 6th July 2010) [5.4]. The development plans were ultimately quashed by the Welsh Assembly Government (24th April 2013) [5.5]. This legal saga [3.1], is described in a recent legal textbook with specific reference to data generated by G. W. Griffith (Rodgers, 2013; [5.6]).

In light of these SSSI notifications, JNCC (Joint Nature Conservation Committee; statutory adviser to the UK Government on national and international nature conservation and part of DEFRA) undertook a review of guidelines relating to the selection of biological SSSI's and specifically grassland fungi [5.7]. These new guidelines relied heavily on BEAA research findings and informal advice from G. W. Griffith. These publications and other advice have also been widely used to inform prioritisation of sites important for conservation, for example in UK Local Biodiversity Action Plans [5.8].

The fundamental research at BEAA has been accompanied by activities to raise public awareness of the conservation importance of fungi (and other microbes). These activities have involved the establishment and maintenance of the 'Waxcap Website' (http://www.aber.ac.uk/waxcap/; >100,000 hits and 'top hit' in Google search for 'waxcap') which provides a valuable online resource for both conservation specialists and the general public, offering unpublished survey data and other relevant publications for download. Articles written by G. W. Griffith about conservation of fungi and other microbes in magazines read by naturalists (*British Wildlife*; *Y Naturiaethwr* [In Welsh]), environmental consultants (IEEM's *In Practice*) and the broader scientific community (*New Scientist*) have led to invitations to appear on radio programmes, such as Radio 4's *Living World* [5.9] and Interviews which are available as online podcasts (*Naked Scientists*; 28th Oct 2012 [5.10]). Other radio broadcasts involving G. W. Griffith include '*Country Focus*' with Huw Jenkins about grassland fungi and '*Dan yr Wyneb*' with Dylan Iorwerth about microbial conservation (16th Jan 2012; 15 min Live interview in Welsh; BBC Radio Cymru). Several of these contributions have appeared online on the *New Scientist* website and the major US online magazine *The Slate* and generated significant response from readers [5.11].

Expertise in the ecology of grassland and other fungi at BEAA has also been called upon in various TV/film productions, through contacts with present and past members of the BBC Natural History Unit in Bristol, with G. W. Griffith providing specialist advice for a TV programme *Kingdom of Plants 3D (*broadcast on 26th May 2012 and written and presented by David Attenborough) [5.12] and the film *Chimpanzee* (US release 20/4/12; UK release 3/5/13; boxoffice income USD28,972,000 [boxofficemojo.com/]) [5.13] This advice took the form of provision of fungal cultures and samples and advice on how to induce these fungi to fruit under 'studio' conditions.

5. Sources to corroborate the impact

5.1 CCW Contract specification for assessment of fungi at the Eithinog site and associated invoice to AU (11th January 2008). The tender was won by G. W. Griffith and the report "Assessment of Grassland fungal populations at Eithinog with relation to the West Gwnyedd area of search" was submitted by G. W. Griffith to CCW on 18th Feb 2008.

5.2 SSSI notification for Eithinog site (2008)

5.3 Press attention in BBC News website (7th February 2008) entitled "School plan agreed for fungi site": http://news.bbc.co.uk/1/hi/wales/north_west/7228777.stm.

5.4 Discussion of the future of Llanishen Reservoir in the House of Commons as reported by Hansard http://www.parliament.uk/business/news/2010/07/llanishen-reservoir-debated-in-commons/ (25th February 2010 and 6th July 2010).

5.5. Final rejection of Western Power Distribution's application for planning permission at Llanishen Reservoir by Welsh Assembly Minister for Housing and Regeneration (24th April 2013).

5.6 Rodgers, C. (2013). *The Law of Nature Conservation*. OUP, Oxford. Screenshot of relevant with specific reference in footnote to data generated by GWG.

5.7 JNCC Guidelines for the selection of biological SSSI's Part 2: Detailed guidelines for habitats and species groups. Section 18: Grassland Fungi (jncc.defra.gov.uk/page-2303).

5.8 Conservation action plans relating to grassland fungi from Cheshire, Co. Durham and Cumbria (2008-2013).

5.9 BBC Radio4 "Living World" programme about Waxcap Fungi (13th Nov 2011; 25 mins) http://www.bbc.co.uk/programmes/b0171yqt (Radio 4 has 12.5% of UK radio audience share).

5.10 Interview on Microbial Conservation and answering of listeners' questions. 28/10/12. (popular science show broadcast/podcasted by BBC East and repeated on BBC Radio5; www.thenakedscientists.com/HTML/content/interviews/interview/1000004/).

5.11 Online comments from readers relating to an article in '*The Slate'* (US-based online magazine; 4th March 2012; "Let's stand up for the little guys"; [PDF available] and letter in 'New Scientist' (On Biodiversity; 19th May 2010.).

5.12 E-mail correspondence with Mark Linfield, director of *Chimpanzee* (2010) and Tim Shepherd, wildlife cameraman (2011) concerning *Kingdom of Plants 3D.*

5.13 Presspack for the Disneynature film *Chimpanzee* (2012) with credit to G. W. Griffith on page 5.