



Lisvane and Llanishen reservoirs: Survey of grassland fungi 2017

Dwr Cymru Welsh Water

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1. Executive Summary

This report presents the findings of a survey and assessment of grassland fungi at Lisvane and Llanishen Reservoirs, Cardiff. The grassland embankments around both reservoirs are designated as a Site of Special Scientific Interest (SSSI) on account of these fungi.

Management at the site during 2017 has been affected by the current works programme to make Llanishen Reservoir safe and restore it to an operational condition. This has meant that the site has been closed to the public during 2017, and there has been changes in the grass cutting regime. Grass cutting was delayed through the spring but a hay cut was removed from most of the embankments during July. This is the first time grass cuttings have been removed for many years. Further cuts were carried out in late August and October. Cuttings were removed from the embankments after the August cut, but the ground was too wet to complete removal in October and this cut was undertaken by hand-mowers. The engineering work has also required an access track to be formed around the lower part of the SSSI at the foot of the bank, which affected at least one patch of grassland fungi.

The 2017 survey data confirmed that the fungal diversity still meets the SSSI selection criteria. The peak count, with 24 species of waxcaps recorded on a single survey visit, was on November 3rd. In addition, the Biodiversity Action Plan priority species *Microglossum olivaceum* was found again, and over a wider area than seen in previous years.

Several species of grassland indicator species were recorded that were not seen in the 2016 survey. These included the waxcap *Hygrocybe splendidissima*, which has not been recorded since 2006. A number of fairy club and earth-tongue fungi were also observed that have not been seen in recent years. The apparent increase in fungi diversity seen this year has almost certainly been helped by the shorter grass, the removal of the thatch of dead grass cuttings, and the absence of dogs (reducing trampling and nutrient input). However, a number of other factors are also likely to be involved, particularly the weather. The summer and autumn were relatively damp, and 2017 appeared to be a good year for grassland fungi at other sites too.

Two waxcaps seen in 2016 were not recorded in 2017. The uncommon *Hygrocybe calyptriformis* f. *nivea* was only recorded for the first time in 2016, so is clearly not a form that appears every year. In previous years *Hygrocybe laeta* was most regularly seen at the foot of the embankment south-west of Llanishen Reservoir. The main patch of this species has probably been lost under the access route around the SSSI perimeter. However, its absence from any other parts of the site may mean that this was a suboptimal year for this species.

The distribution of fungi was broadly similar to 2016. Lisvane Reservoir showed the highest diversity, especially in the north-eastern corner; and the east side of Llanishen Reservoir recorded very few fungi. However, there were two main differences. There were almost no fungi on the main dam south of Llanishen Reservoir, but relatively high numbers on the north-facing bank between Llanishen and Lisvane Reservoirs, where previously recorded fungi had been sparse. Removal of trees and dense scrub has re-exposed several areas where grassland had become overshadowed, and some grassland fungi species have re-appeared in the exposed patches.

The 2017 observations are encouraging, because they appear to show that the decline in grassland fungi has been halted, at least in some areas, and may even be reversed. To

ensure favourable condition status of the SSSI is maintained, recommendations are made to continue reducing the height of the grass cutting, removing grass cuttings and excluding dogs.

2. Introduction

Dwr Cymru Welsh Water (DCWW) is currently undertaking a programme of works at Llanishen and Lisvane Reservoirs, Cardiff (central grid reference approximately ST187818) to restore them for operational purposes. New provision for public recreation and access is also being considered at the site. The possible recreational facilities are still being discussed, but may include a new visitor centre and water-sports facility, landscaping, car-parking and improved access road, footpath access within the site, and a new slipway and pontoons for water-sports. DCWW has commissioned this survey of grassland fungi to help inform the ongoing management of the site, including the possible development options and long term management of the site.

The study of grassland fungi in 2017 follows a similar assessment undertaken during autumn 2016, and used the same survey method. The survey focussed on the Llanishen and Lisvane Reservoir Embankments SSSI, which is designated for its grassland fungi interest.

The fieldwork and assessment was undertaken by Dr Peter Sturgess CEnv MCIEEM, who also carried out the 2016 survey, and several previous studies. The survey was mainly completed solely by Peter, but for the survey on November 3rd Peter was accompanied by Dr Richard Cowie, formerly of Cardiff University and representing the Reservoirs Action Group; who also has a special interest in grassland fungi.

Several aspects of the site and its management have changed since the 2016 survey. Of particular relevance to fungi, the grass cutting regime has been modified, the public have been excluded, scrub clearance has been undertaken around much of the site perimeter, and several patches of trees and scrub have been removed from the western and southern embankments. The changes in grass cutting involved trialling several different approaches to reduce the cut-height and remove the cuttings (see below).

3. Survey method

The fieldwork involved a total of six survey visits spread out as evenly as possible through the main autumn fungi fruiting period of 2017. The study was commissioned on October 9th, and the first survey visit was carried out on October 11th. Subsequent visits were spread out through October and November, aiming to avoid periods of heavy frosts. The final survey was carried out on December 4th.

In addition to the six formal survey visits during the autumn, Dr Sturgess also made a number of incidental observations of grassland fungi that appeared early in the season, while carrying out Ecological Clerk of Works duties at the site. This meant that fungi fruiting during the early part of the season were recorded (they were not recorded in the 2016 study, which only commenced in late October).

The main target group for the survey was waxcap fungi (*Hygrocybe* species). However, fairy-clubs (*Clavariaceae*) and earth-tongues (*Geoglossaceae*) were recorded too, since they are good indicators of grassland habitat quality and had also been recorded during the previous studies. Other indicator species such as Pink-gills (*Entoloma* species) were also recorded, but it was not possible to identify many of these to species level. Most waxcaps were at least provisionally identified in the field, with specimens being collected for

confirmation by microscope where necessary. Most fairy-clubs and earth-tongues required confirmation by microscope.

Each survey used a simple walk-over/ transect-based method to search for grassland fungi, zigzagging through all of the various grassland types on the embankments, aiming to sample as much of the grassland area as possible within a survey day of approximately 5-6 hours. Survey effort was focussed on the areas of shortest grassland (where grass was not too heavily trampled), as these are the most likely to have value for grassland fungi. The locations of any waxcap fruiting bodies were marked onto a survey plan during the site visit. This was generally done by eye, but the locations of any especially uncommon species were also checked using a hand-held GPS device.

Notes were made on the condition of the site for fungi, such as approximate sward height and condition, and any other factors that might be affecting fungi. Digital photographs were taken to depict the habitats on site, and any particularly notable fungi species.

4. Survey findings

The species recorded during all six fungi survey visits in 2017 fungi are summarised in Table 1. An additional column shows those that appeared in September and were incidentally recorded.

The distribution of the waxcap fungi is shown in Figure 1 and non-waxcap target species in Figure 2, showing locations where the fruiting bodies were seen during all six survey visits, and during other site duties. Note that the scale used and degree of overlapping symbols does not permit the individual species to be seen clearly in the figure, and it is mainly intended to highlight the locations where the main groups of fruiting bodies were seen (a more detailed figure is available if required).

A series of photographs showing some of the more significant observations relating to grassland fungi during 2017 is provided in Appendix 1.

The 2017 survey confirmed the presence at the site of several species that were not seen during 2016. The most notable was *Hygrocybe splendidissima*, which has not been recorded at Llanishen since 2006. This appeared in several places on the Llanishen western embankment and also north of Lisvane Reservoir. The non-waxcap indicator species seen this year, but not in 2016, included *Clavaria fumosa*, *Clavulinopsis laeticolor*, *Entoloma incanum* and *Trichoglossum hirsutum*. The BAP species *Microglossum olivaceum* was found over a wider area north-east of Lisvane Reservoir this year than any previous year, and also in a location to the south-east of Llanishen Reservoir where it has never been recorded previously. In addition, *Clavaria fragilis* and *Geoglossum fallax* were recorded at the site for the first time this year.

Only two indicator species recorded in 2016 were not seen in 2017. These were *Hygrocybe laeta* and *Hygrocybe calyptriformis f.nivea*

Table 1 shows that the timing of the fungi fruiting period was very variable for different species. Most fungi appeared to peak in late-October and early November, but some peaked earlier, in particular, *Hygrocybe conica*, *H.citrinovirens*, *H.intermedia* and *H.quieta*. Species that were most frequent later in the season included *H.coccinea*, *H.russocoriacea*, *H.pratensis*, *H.punicea*, *H.splendidissima* and *H.virginea*.

Table 1 Summary of 2017 fungi survey observations

Survey date	(Sept)	11 Oct	23 Oct	3 Nov	10 Nov	21 Nov	4 Dec
Waxcaps							
<i>Hygrocybe aurantiosplendens</i>		X	X	X	X	X	
<i>Hygrocybe calcephila</i>			X	X			
<i>Hygrocybe calyptriformis</i>	X	X	X	X	X	X	X
<i>Hygrocybe cantharellus</i>	X	X	X	X	X		X
<i>Hygrocybe ceracea</i>	X		X	X	X		
<i>Hygrocybe chlorophana</i>		X	X	X	X	X	
<i>Hygrocybe citrinovirens</i>	X		X	X	X		
<i>Hygrocybe coccinea</i>		X	X	X	X	X	X
<i>Hygrocybe colemanniana</i>		X	X	X			
<i>Hygrocybe conica</i>	X	X	X	X	X	X	X
<i>Hygrocybe fornicata</i>			X	X			X
<i>Hygrocybe glutinipes</i>				X			
<i>Hygrocybe insipida</i>		X	X	X	X	X	
<i>Hygrocybe intermedia</i>	X		X	X			
<i>Hygrocybe irrigata</i>	X	X	X	X		X	
<i>Hygrocybe mucronella</i>			X	X	X		
<i>Hygrocybe pratensis</i>		X	X	X	X	X	X
<i>Hygrocybe psittacina</i>	X	X	X	X	X	X	X
<i>Hygrocybe punicea</i>			X	X	X	X	X
<i>Hygrocybe quieta</i>	X	X	X	X	X		
<i>Hygrocybe reidii</i>		X	X	X	X	X	X
<i>Hygrocybe russocoriacea</i>				X	X	X	X
<i>Hygrocybe splendidissima</i>				X	X	X	X
<i>Hygrocybe virginea</i>		X	X	X	X	X	X
Total waxcap species	(9)	14	20	24	18	14	12
Other indicator species							
<i>Clavaria fragilis</i>	X	X					
<i>Clavaria fumosa</i>	X	X	X				
<i>Clavulinopsis corniculata</i>		X	X	X	X	X	X
<i>Clavulinopsis helvola</i>			X	X			X
<i>Clavulinopsis laeticolor</i>	X	X	X				
<i>Clavulinopsis luteoalba</i>		X	X	X	X		
<i>Dermoloma cuneifolium</i>	X	X					
<i>Entoloma incanum</i>		X					
<i>Entoloma spp.</i>	X	X	X	X			
<i>Geoglossum fallax</i>				X	X		
<i>Geoglossum umbratile</i>				X			
<i>Geoglossum sp. (indeterminate)</i>						X	X
<i>Microglossum olivaceum</i>			X	X	X	X	X
<i>Trichoglossum hirsutum</i>			X	X	X		X



Figure 1 Summary plot showing distribution of waxcap fruiting bodies seen during 2017



Figure 2 Summary plot showing distribution of other indicator fungi seen during 2017

The distribution of fungi was broadly similar in 2017 to 2016, with the greatest density of waxcaps being recorded near the north-east corner of Lisvane Reservoir and the western embankment of Llanishen Reservoir. As in previous years, the majority of grassland fungi were found near the crest of the sloping embankments, and in the very narrow strip of grassland at the top of the reservoir stone pitching. The areas that tended to have few fungi in previous years generally also produced few in 2017. However, unlike previous years, there was a relatively high density of fungi on the north-facing embankment between Lisvane and Llanishen Reservoir. There was also a concentration of fungi fruiting in short-grassland protected by the palisade fence at the corner of Llanishen Reservoir near the Lewis site compound. This included a new location for *M. olivaceum*, and the first appearance of *C. fragilis* at the site. Surprisingly there were very few fungi on the main dam south of Llanishen Reservoir, which had produced good numbers of waxcaps in 2016.

The fungi fruiting period appeared to start relatively early this year, probably due to wet summer weather. The first species seen this season were *H. calyptriformis*, *H. cantharellus*, *H. citrinovirens*, *H. conica*, *H. intermedia*, *H. irrigata*, *H. quieta*, *H. psittacina* and *C. fumosa*, which were all first recorded on 23rd August; and, unusually, a single specimen of *H. chlorophana* which was found in the plantation south of Llanishen Reservoir on 24th February 2017.

No attempt was made to quantify the numbers of fruiting bodies, but the numbers of locations for species plotted on the distribution figures gives an indication of relative abundance. Some species were represented by just a small number of fruiting bodies (e.g. just two for *H. calciphila* and three for *H. glutinipes*), while others produced hundreds. The most abundant species seen during 2017 appeared to be *H. calyptriformis*, *H. coccinea*, *H. conica*, *H. insipida* and *H. pratensis*. The period of greatest abundance generally coincided with the period of greatest diversity (see Table 1), although this was noticeably different for certain species. In particular, the greatest abundance of *H. calyptriformis* and *H. conica* was seen during September and early October, although both species were present through the whole survey period. Most fungi were generally very sparse during the last two surveys, which followed frosty weather.

5. Discussion

5.1 Grassland fungi observations in 2017

The survey shows that the site still easily exceeds the minimum 18 waxcap species (or 12 species seen in a single visit) as set out in the selection criteria for SSSIs¹, and should be considered important in a national context. In addition, it still supports the BAP priority species *M. olivaceum* and has the greatest diversity of grassland fungi in the county borough of Cardiff.

Owing to the wet summer, 2017 appears to have been a good year for grassland fungi in general. However, in this case the apparent slight increase in numbers of grassland fungi since 2016 is likely to be at least partially accounted for by the changes in the grass-cutting regime and exclusion of the public. During the autumn fruiting period the grass was slightly shorter than it was in 2016, and this would have favoured smaller and relatively low-growing species. The increase in fairy-clubs and earth-tongues is likely to be due to the shorter grass in certain areas, particularly inside the palisade fence where several parts did not appear to have been cut for at least several months prior to the 2016 survey.

The majority of *Geoglossum* and *Trichoglossum* observations were from the very edge of the SSSI grassland, immediately above the top stone of the reservoir stone pitching. This may be because it supported some of the shortest turf, free from trampling and coarse grasses, and typically amongst mosses. Similarly *H. calciphila* was also only found in short turf above the stonework. It is possible that there may have been some sampling bias here, because these very small species would have been easier to spot in this relatively exposed location than in the denser turf on the main embankments. However, it is more likely that they do not fruit well in taller swards.

Some grassland fungi have been linked to the presence of moss species², and the short grass swards at the edge of the SSSI above the stone pitching tend to support a higher proportion of mosses than the main swards. The grassland on the north-facing bank of Lisvane Reservoir has consistently supported a high proportion of mosses, which correlates with the highest density of fungi fruiting bodies observed there. The reduced cut-height and removal of grass thatch during the raking process may allow a more moss-rich sward to develop in the other parts of the embankments over the next few years which may be beneficial to the grassland fungi.

The apparent absence of fungi fruiting on the main south-facing Llanishen Reservoir embankment this year is difficult to explain as this was subject to similar management as the rest of the site and previously supported fungi in moderate numbers. Fruiting on this bank in previous surveys has been rather erratic, so it may simply be a reflection of this variability, perhaps related to weather. The south facing aspect might have meant it was affected more by drying out during the unusually hot sunny weather in late May. It is also possible that fungi may have been inhibited by the very tall, dense grass growth that developed when the

¹ Genney D. R., Hale A.D., R.G. Woods. & Wright M. (2009). Guidelines for selection of biological SSSIs: Rationale Operational approach and criteria. Detailed guidelines for habitats and species groups . Chapter 20 Grassland fungi. Joint Nature Conservation Committee.

² Griffiths, G., Easton, G.L. & Jones, A.W. (2002). Ecology and diversity of Waxcap (*Hygrocybe* spp.) fungi. *Botanical Journal of Scotland*, 54, 7-22

spring grass cut was delayed, particularly because the grass was tallest and thickest on this slope (it is still denser than the grass on the other banks).

The appearance of relatively high numbers of fungi on the north-facing bank between Llanishen and Lisvane reservoirs is a new observation. Several of the species seen have not been recorded on this bank before, and it has generally only produced small numbers of fruiting bodies in previous surveys. A key factor in the appearance of so many fungi this year may be a change in behaviour of the Canada geese that regularly roosted on the bank. During much of the summer the geese moved away from the bank and roosted on the drained down bed of Llanishen Reservoir instead, resulting in lower levels of grazing, trampling and enrichment by bird droppings. The bank produced many fruiting bodies through late August, September and October, but since the geese returned there in late-October, very few fungi have been seen. The fungi that have been found since have mostly been broken up and trampled by the grazing geese, consistent with the suggestion that such behaviour has been suppressing the fungi in previous years. It is however encouraging to note, that grassland fungi have survived almost unnoticed on this bank for many years, despite the effects of the bird droppings.

The re-appearance of *H. splendidissima* at the reservoirs for the first time since 2006 is also a good illustration of how fungi can remain undetected in the soil for many years.

M. olivaceum had a good year in 2017, and this is most likely to be due to the weather. Not only was it found over a wider area within the reservoir SSSI, but it was also present over a wider area at Cathay's Cemetery in Cardiff, and at a new site at Thornhill Cemetery. The increase at the reservoirs should be seen in this context, and so not attributed solely to the improvement in grassland management. Clearly the *Microglossum* mycelium must have been present for years before conditions were suitable for it to produce its fruiting bodies. The main locations where *Microglossum* grows at the reservoir were mostly cut by strimming and hand-mowing because they are in parts of the bank that are not easily accessible to the tractor-mounted flail. The locations at the two cemeteries have very similar conditions to these patches; being short grassland, free from recent ground disturbance and dogs, and managed by strimming.

Recent and ongoing research into *M. olivaceum* has shown it to be a 'species-complex'; consisting of several superficially similar, but genetically distinct species. Specimens have been sent for DNA analysis (at Aberystwyth University) to try to clarify exactly which species is present at the reservoir. Given that *M. olivaceum* is already considered to be uncommon, the individual species forming the species complex will undoubtedly have a higher rarity and nature conservation status if considered separately.

5.2 Observations relating to habitat management in 2017

The grass cutting on the main embankments was delayed during the early part of 2017, as DCWW investigated a suitable method for cutting and collecting the grass. With the exception of some trial hand-mowing adjacent to Llanishen Reservoir in late May the embankments remained mostly unmown until early July. The grass was eventually cut by a tractor-mounted flail, and the cuttings removed by mechanical raking, and collection at the foot of the bank. The delay meant that the grass was over 1 m tall when cut, and the coarse grasses had become very dominant for several months. However, the removal of the hay cut meant that a relatively large quantity of nutrients would have been taken away at that time, and the raking process also removed much of the thatch of dead grass that had accumulated over many previous years' cutting, and from the hand-mown areas that were

cut in late-May. In addition, the raking has removed litter (particularly plastic bags) from the embankment. Despite the initial delay, the 2017 grass cutting regime has almost certainly been more favourable for grassland fungi than the cutting in recent years due to the removal of the cuttings and lower cut height. The cutting also appears to have benefitted plant diversity, particularly by allowing a higher proportion of lower-growing species to survive and the exposure of small patches of bare ground during the raking. The benefits to grassland diversity should be more evident next year, as new plants begin to germinate; particularly if the cutting regime can be carried out more consistently through the year to reduce the dominance of coarse grasses.

The use of tractors on the embankments has made it possible to cut and collect the grass efficiently, and at a lower height than the hand-mowers had done previously. However, there are potential negative issues with soil compaction when using larger machines. The tractors used on the banks were therefore fitted with wide tyres to reduce the ground pressure, and there was generally no evidence of them causing soil compaction. However, the attempt to use tractors to cut the grass in September had to be abandoned because the vehicles were slipping on the damp soil, locally damaging the turf. Any future grass-cutting or raking using tractors should therefore not be carried out unless the soil is very dry, so as to avoid damage to the turf and soil (and also to avoid any risks to the operators).

The use of the tractor was generally an effective way of lowering the cut height and cutting into the tussock-forming grasses. The effectiveness of the cut was limited in some situations, particularly at the toe of the embankment, where the width of the cutting bar prevented it from cutting close to the ground. Strips of longer grass were also sometimes left when the tractor was used in damper conditions, because the tyres flattened the grass a few seconds before the flail passed over it, so the grass was not cut to a uniform height. This effect was much less pronounced in dry weather.

One unforeseen problem in removing the grass cuttings was that trailers were not able to access the slope north of Lisvane Reservoir. This meant that although the grass could be cut and raked into rows by the tractor, the cuttings had to be removed using smaller vehicles. The delay in sorting out arrangements for the grass removal meant that the row of grass cuttings lay on the ground for over a month in some cases, shading out and killing the strip of grass beneath it. The effect on any fungi in this strip is unknown, but it is unlikely to be beneficial, and no fruiting bodies were seen along it during 2017. In future the removal of cuttings from this bank should be planned more carefully to avoid a delay between cutting and collection.

The warm, wet summer and relatively long growing season made it very important to carry out a cut in October, to keep the grass reasonably short during the main fungi fruiting period. Relatively mild weather continued and extended the grass growing season through most of November. With the predicted effects of climate change this may become a regular occurrence, making a late cut very beneficial for grassland fungi.

The presence of the palisade fence meant that the grass around the top of the Llanishen Reservoir stone pitching was only cut by strimming twice during the year, and the arisings were not raked and removed from this strip. Even so, the cutting was still carried out better than it had been in 2016, and some of the grass was dispersed by the wind. The current proposals to remove the fence should make it easier to cut this strip in future.

The presence of structures in the grass, such as the concrete steps, and remains of old benches and posts, made cutting some parts of the banks difficult for the tractors and

mowers, often requiring multiple passes and sometimes skidding and damaging the nearby turf. Future planning should aim to minimise potential obstacles to mowing.

The removal of trees and scrub from several parts of the SSSI is likely to be beneficial for a number of reasons. It has halted the gradual expansion of the scrub and associated loss of grassland habitat, and returned the affected patches to a state where the soil microflora favours waxcaps rather than woodland fungi. It has been encouraging to see several grassland fungi appearing in areas cleared of scrub within the first year after clearance, most notably *H. pratensis* and *C. fumosa* north of Lisvane Reservoir, and *H. coccinea* and *H. citrinovirens* from the area previously shaded by the large conifer north-west of Llanishen Reservoir. The observation of fruiting bodies of *H. chlorophana* and *H. psittacina* in the young plantation woodland south of Llanishen Reservoir (possibly 30 years old) shows that some waxcaps are able to persist for many years in a woodland habitat. This plantation is dominated by a canopy of ash, which has less mycorrhizal associations than many other tree species, so perhaps this favours the co-existence of grassland fungi species within the woodland habitat (G.Griffith, pers.comm.).

The areas subject to the heaviest trampling by the public during recent years did not produce any grassland fungi, despite the site being closed throughout 2017. However, several species appeared at the foot of the palisade fence, where the trampling was less intense. This included the south-eastern corner of Llanishen Reservoir near the Lewis compound, where most of the grass was previously very heavily trampled because it was close to the site entrance. No fungi appeared on the path itself, but a relatively high diversity of species was observed directly beside the fence (and in the strip beyond it). Fungi were also noted in the centre of old stone paths on the crest north-west of Llanishen Reservoir, including *H. conica*, *H. virginea*, *H. colemanniana* and several specimens of *E. incanum*, which has not been recorded at the site since 2006. The presence of the locked gate at the top of the bank meant that most dog-walkers avoided this section and used the foot of the bank instead, so trampling pressure was less intense here. The stone used for the old path surface probably provided a suitable habitat for *E. incanum*, which is often found in limestone areas.

The access track around the SSSI perimeter is likely to have damaged the grassland fungi in the areas where it was routed. In general it was routed across the lower grassland areas where there were relatively few waxcap records. However, it did pass through the patch of slightly acidic grassland to the south-west of Lisvane Reservoir where *H. laeta* was regularly recorded in previous surveys. The absence of this species from the 2017 survey may be due to the presence of the track. However, the absence of this species from any other parts of the site during 2017 may just mean that it was a poor year for this species.

Observations north of Lisvane Reservoir this year indicated that the damage to fungi caused by construction access in 2016 may not extend very far. The track used by Lewis contractors to repair a chamber north of Lisvane Reservoir in winter 2016 resulted in deep rutting along the northern crest of the reservoir between the car-park and the chamber. This was subsequently repaired during spring 2017. The current autumn survey confirmed that although there were no fungi on the damaged part of the crest, several species of waxcaps, fairy clubs and earth-tongues were present within 50 cm of the previously rutted ground. This shows that the mycelium of these species can be reasonably resilient to disturbance nearby.

It is possible that the *H. laeta* on the low-lying ground south-west of Llanishen Reservoir might also have been affected by badgers. Foraging badgers disturbed several patches of grassland around the perimeter of the SSSI, and along the reservoir crest during 2017. The foraging mostly appeared to follow the routes previously trampled by dog-walkers, where the

vegetation is characterised by a flora of perennial rye-grass and greater plantain. It appears that the badgers associated these routes with some form of food (possibly crane fly larvae; but no excavation was carried out to investigate this further). Extensive foraging was also seen south-west of the reservoir in patches of acid grassland, where the badgers appeared to be rooting up pignut tubers, locally turning over substantial patches of turf. These patches also included locations where *H. laeta* had been found in previous surveys. The loss of botanical diversity in the wider grassland area could potentially mean that these remaining patches with pignut will become subject to increasing disturbance by foraging.

6. Recommendations

The works carried out during 2017 have made good progress in restoring the SSSI grassland habitat to a more favourable condition for fungi, and have followed the approach recommended during the 2016 survey. The most beneficial, positive measures have been the reduction in cut-height when grass mowing, the collection of cuttings, exclusion of dogs, and removal of encroaching scrub. The efforts that have been made to minimise construction impacts during the engineering works have also been very important in safeguarding the fungi in the long term. It is recommended that all of these measures should be continued, but modified in some cases to take into account the observations made in 2017.

6.1 Grass management

The grass cutting in 2017 did not take place exactly as planned for a variety of reasons, but worked out reasonably well in the end. The teething problems encountered this year have highlighted several practical issues that should be taken into account in planning future management.

The use of tractors for cutting and collecting grass has proven to be an effective way to manage the site, provided that the ground pressure is minimised by using extra wide tyres, and that the ground is dry. Tractors should not be used when the soil is wet due to the potential for slipping on the embankments and causing soil compaction. On the steeper slopes and some of the less accessible parts of the embankments it will still be necessary to use strimmers or hand-mowers to complete the mowing.

The lowering of the grass cutting height that was started in 2017 should be continued. Ideally the cut height should be no more than 5 cm (preferably even lower, perhaps aiming for 2-3 cm where possible), in order to cut into the dense tussock-forming grasses. The flail cutter and the hand-mowers both produced a much better cut in dry conditions, so care should be taken to carry out the cutting during good weather.

Removing a hay crop in summer is a well-recognised approach to maintaining grassland diversity, and is likely to benefit the flora as well as the fungi. However, it may be necessary to limit the collection of grass cuttings to the summer cuts in dry weather, to minimise the potential for disturbing the ground during damper spring and autumn conditions. The observations made during 2017 showed that the raking and removal of cuttings was most effective when the grass was longest, so after the initial spring cut it may be beneficial to leave the grass uncut until July. This would allow a high proportion of nutrients to be removed, and would also allow a greater number of spring plants time to flower. Now that the cutting has started, the volume of cuttings to be removed each time is likely to get progressively lower as the coarse grasses become less dominant.

Future planning should aim for four cuts per year. Taking the lessons learned this year into account, the following approach may be appropriate, using tractors during the summer, but carrying out spring and autumn cuts using lighter hand-mowers when the ground is wet.

- Cut 1: Early April, using hand-mowers, and leaving the cuttings *in situ*.
- Cut 2: July. Cut and remove using tractor/ flail in dry conditions.

- Cut 3: Mid to late August. Cut and remove, using tractor/ flail in dry conditions.
- Cut 4: Late-September/ October, using hand-mowers, and leaving the cuttings *in situ*.

In the longer term, the raking and removal of cuttings could potentially be limited to just once per year (probably the July cut), to prevent the long term accumulation of nutrients in the soil and the formation of a thatch of dead grass.

It is recommended that any structures within the embankment that have become redundant, such as old steps or posts, should be removed, to reduce the number of obstacles for the mowers. In addition, when planning any recreational facilities, thought should be given to access for grass cutting and new structures such as benches, life-belts or signage should not be installed in the grassland. Any structures that need to be installed in or removed from the SSSI grassland must be approved by NRW.

6.2 Tree management

There has been good progress in recovering the area of waxcap grassland habitat that had been lost to shading by trees, but there is still more to be completed. It is recommended that the hedges adjacent to Lisvane Reservoir and along the eastern side of Llanishen Reservoir should be cut back to the site perimeter. Special care should be taken when working beside the north-east side of Lisvane Reservoir because some of the best waxcap grassland extends right up to the hedge. All cuttings should be removed from the grassland.

It is recommended that the grassland around the reservoir stonework at Lisvane Reservoir should be cleared of trees and other tall vegetation. This may allow the low-growing fungi that formerly grew in the shallow soil and moss to recover. Removing the non-native Mexican fleabane from the walls around Lisvane Reservoir would also help fungi and native flora to return, and slow its potential spread into the Llanishen Reservoir stone pitching. Tree management on the stone pitching is likely to require the use of herbicides. In this case it is important that the herbicide application is carried out extremely carefully because the grassland immediately adjoining the top of the stonework supports some of the most diverse fungi.

6.3 Palisade fencing

The palisade fence around the Llanishen Reservoir perimeter should be removed, so that the grass at the top of the stonework can be mown properly. This would also remove the sheltering effect; creating harsher conditions that would limit the dominance of coarse grasses, and help to disperse grass cuttings from the top of the banks. However, measures should be put in place to ensure that the edge of the grassland beside the stone pitching does not become heavily trampled.

6.4 Other construction works

There is an ongoing need for awareness of the vulnerability of the SSSI grassland to all staff working on the site. This should be included in all site inductions and toolbox talks, and special measures to safeguard the grassland strictly followed in the planning and implementation of works.

6.5 Recreational use

The plans for reopening the site for recreational purposes in the long term must take the requirements of the SSSI into account. Any proposals would need to be agreed by NRW. Activities such as water sports and fishing are unlikely to cause damage to the grassland habitat because they would be focussed on the water. Walking around the site would also not be problematic provided that suitable management is in place to avoid excessive trampling.

The construction of approximately 4,500 new houses to the north-east of the reservoirs proposed in the Cardiff Local Development Plan will inevitably mean a large increase in pressure on the remaining areas of green space, so a form of visitor management is strongly recommended. The mostly unrestricted and unmanaged access between 2005 and 2016 resulted in the site becoming used by high numbers of dog-walkers, and was associated with a decline in the site's most significant flora and fauna; including grassland fungi (although the decline in fungi was also related to neglect of habitat management). Measures should therefore be put in place to prevent this from being repeated.

It is recommended that the following measures should be considered to minimise the effects of recreational use on the grassland fungi:

- Restrict public access around Lisvane Reservoir. This area has been less used by dog-walkers in recent years and has retained much of its former fungi interest.
- Limit the opening hours and consider introducing a fee for visiting, to keep visitor numbers within manageable levels.
- Provide free-draining paths in areas that are not of high value for fungi, so that visitors do not trample their own paths through the grassland.
- Reinstate the former ban on dog-walking. This would significantly reduce the number of visitors, as well as the associated problems with nutrient input to the grassland, trampling of fungi fruiting bodies, and plastic bags of dog-faeces.
- If dog-walking is to be permitted, it should only be allowed within certain areas that are of least value for their grassland fungi, such as the east side of Llanishen Reservoir. Dogs should not be allowed off their leads, to minimise nutrient inputs from dog-faeces, and to limit trampling of the grass (which makes cutting difficult) and knocking over fungi fruiting bodies. Bins should be provided for the disposal of dog faeces, and resources allowed for emptying them regularly.
- If dogs are allowed access to the site it may be necessary to increase the frequency of grass cutting and collection to take account of the additional nutrient inputs, trampling and dog-related litter, to safeguard the fungi. However, increasing the number of cuts would be more expensive and probably detrimental to the grassland flora.
- A warden service should be provided. A permanent site presence helping to educate visitors about the value of the site, its fungi and other wildlife, and to enforce restrictions on dogs and access, and undertake conservation management work.

6.6 Educational use

The site could be a good resource for local school groups or university students. However, numbers of waxcaps are still relatively low compared to a few years ago, so to avoid disappointment it is probably best not to promote it as a demonstration site for fungi until the recovery has progressed further.

6.7 Further survey and monitoring

Continued surveys will be an important element in maintaining the SSSI in a favourable condition for grassland fungi, and particularly to study the response of the fungi to the modified grassland management and future recreational access. The following measures are recommended:

- A repeat of the grassland fungi surveys during autumn 2018, while the site is still closed to the public. If all goes well this should provide further observations on the recovery of the grassland fungi, or highlight any problems. Changes in fungi are always best monitored over several years, due to the natural variations in their appearance.
- In the longer term, surveys should be carried out every few years (perhaps every 3-4 years) to monitor the continued presence of fungi during the autumn. Ideally the monitoring would cover the whole fruiting period, rather than just the peak season in late-October/ early November.
- A study of fungi DNA in soils is recommended, particularly to check whether the waxcaps really have been lost from certain parts of the SSSI where they used to be present, or whether the mycelium is still in the soil without fruiting recently. A study of the western embankment of Llanishen Reservoir would be particularly helpful, because the decline in waxcap numbers has been most evident there. DNA investigations might also confirm whether rare but infrequently appearing species such as *H. ingrata* are still present. If the study suggests that the fungi have disappeared from some parts of the site it would still be a useful result; partly to demonstrate the fragility of these species, and partly so that resources can be prioritised to areas where the fungi are still present. A soil DNA study could also be a useful check of any areas where potentially damaging recreational activities or access structures are proposed in the SSSI grassland, such as paths or steps on the embankments.
- If dogs are to be permitted within the site it is recommended that a survey of soil properties is carried out, particularly to compare levels of soil nutrients and compaction areas of high waxcap diversity with other parts of the SSSI. It would also establish a baseline that can be compared with future years to clarify whether the removal of grass cuttings is being effective in limiting the levels of nitrogen and phosphorus. This could potentially be carried out as a university project.

Appendix 1: Photographs




1		<p>Grassland at north-east corner of Lisvane Reservoir. This bank produced the greatest diversity of grassland fungi during the 2017 survey. It also has some of the least dense grass, and most moss-rich turf.</p>
2		<p>Grassland south of Llanishen Reservoir. This had supported good numbers of fungi in 2016 but very few in 2017. The grass on this bank became very tall and dense during spring 2017, which may possibly have had an effect on the fungi.</p>
3		<p>Using a hand mower for the first grass cut in late May 2017. The grass was too long to be cut effectively by May, so in future the cutting should probably start much earlier in the year.</p>


4		<p>An attempt was made to cut part of the southern embankment using hand-mowers, but these were unable to cut the required height in such tall, dense grass (30 May 2017).</p>
5		<p>Grass-removal using a leaf-blower was one of several methods tried but soon abandoned (30 May 2017).</p>
6		<p>The tractor mounted flail cutter that was eventually used to cut the embankments was fitted with double wheels to minimise ground pressure (4 July 2017)</p>

7		<p>The tractor used a mechanical rake attachment to sweep the grass cuttings down the bank and into rows (5 July 2017)</p>
8		<p>The cut grass was then picked up and removed by trailer (5 July 2017)</p>
9		<p>Rows of grass cuttings were left uncollected on several occasions during the year. Future years must be planned more carefully to prevent this happening again (September 2017).</p>




10		North-east of Lisvane Reservoir, showing strip affected after uncollected grass cuttings were eventually removed (September 2017).
11		The grass closest to the palisade fence was cut by strimming. This is very labour intensive and was only carried out twice during the year. (7 September 2017).
12		Posts and structures on the embankments proved difficult for the mowers to move around. It is recommended that any redundant structures are removed if possible.




13		<p>Damage to the bank where the tractor slipped when trying to cut the grass in late September. The cut was abandoned to avoid further incidents and completed by the lighter hand mowers. In future it is recommended that the tractors should only be used during dry conditions in summer.</p>
14		<p>Removal of large willow from western embankment (April 2017)</p>
15		<p>Removal of large conifer from western embankment (April 2017).</p>




16		<p>Embankment north of Lisvane Reservoir following removal of encroaching scrub.</p>
17		<p>Encroaching boundary hedge east of Lisvane Reservoir, recommended for clearing back to the boundary in 2018.</p>
18		<p><i>Hygrocybe calyptriformis</i> at base of hedge north of Llanishen Reservoir (October 2017). Species in this situation are very vulnerable to becoming shaded out by scrub encroachment.</p>

19		<p><i>Clavaria fumosa</i> growing in an area cleared of dense scrub north of Lisvane Reservoir (note the ground flora dominated by ivy rather than grass). This shows that some grassland fungi species are able to survive several years under wooded conditions. (October 2017)</p>
20		<p><i>Hygrocybe chlorophana</i> found in broadleaved plantation south of Llanishen Reservoir (February 2017). This has persisted for approximately 30 years since the area supported grassland.</p>
21		<p>The construction access around the edge of the SSSI has mostly avoided areas of value for fungi, but has probably caused local disruption to species south west of Llanishen Reservoir (October 2017).</p>

22		<p>The grassland south-west of Llanishen Reservoir was also disturbed by badger foraging during the spring (April 2017). This may have affected some of the fungi, although the activity was mostly limited to the top layer of turf.</p>
23		<p>Badger foraging activity in the rest of the site was mostly focussed along former dog-walkers paths. It is unlikely to have affected any important fungi in these heavily trampled and nutrient enriched areas (November 2017).</p>
24		<p>Numbers of Moles appear to have increased during 2017. They are unlikely to have any significant impact on grassland fungi in their present numbers, but may soon be controlled as part of the Reservoirs Act safety inspections.</p>

25		<p>The embankment south of Lisvane Reservoir was temporarily abandoned by Canada geese during the summer of 2017, and subsequently produced more fungi fruiting bodies in this area than have been seen in previous surveys. The geese returned in late-October and virtually no fungi have been seen since.</p>
26		<p>Goose droppings and trampling of grass on the north side of Lisvane Reservoir in late-October 2017. Possibly indicating another change of roosting site following removal of scrub from the adjacent boundary, and ongoing works in Llanishen Reservoir. This area produced moderate numbers of fungi earlier in the season but very few have been seen since the arrival of the geese.</p>
27		<p>A new location for <i>Microglossum olivaceum</i> was found in short grass near to the Lewis site compound south-east of Llanishen Reservoir. For the last few years this strip of grassland has been protected from trampling and dog-fouling by the palisade fence. (October 2017).</p>

28		<p>Since work started on clearing the reservoir base, the grass inside the palisade fence has become more trampled, and no more fungi have been found along this strip. This is probably just a temporary effect, provided that the trampling does not become any heavier (November 2017).</p>
29		<p>Herbicide damage by spray drift into SSSI grassland west of Llanishen Reservoir (November 2017). This strip beside the stone pitching is known to support moderate numbers of fungi. Glyphosate is known to be harmful to waxcaps, but the extent of any impact here (and at several other locations around the stone pitching) is not known yet.</p>
30		<p>The route initially proposed for construction access to repair a valve at the east side of Lisvane Reservoir would have resulted in the loss of the most diverse assemblage of fungi in the SSSI. An alternative route was subsequently gained via the adjacent footpath which minimised loss of grassland and avoided the disruption to any known waxcap locations.</p>

31		<p><i>Hygrocybe calyptriformis</i> was found during every fungi survey visit in 2017.</p>
32		<p>Observations in August and September confirmed several new locations for early-fruiting species such as this <i>Hygrocybe citrinovirens</i>.</p>
33		<p><i>Hygrocybe splendidissima</i> was found in several patches on the western embankment. This is its first recorded appearance at the site since 2006.</p>

34		<p><i>Microglossum olivaceum</i> was observed in a wider area than seen in previous surveys. It was also found in two other sites in Cardiff so conditions during 2017 appear to have been good for this species.</p>
35		<p>The most frequent species of fairy club seen during 2017 was <i>Clavaria laeticolor</i>.</p>
36		<p>In the absence of trampling pressure, <i>Entoloma incanum</i> was found growing amongst mosses in old stone track surfaces north-west of Llanishen Reservoir. This species has not been recorded here since 2006.</p>

Appendix 2 Late season records addendum

1. Introduction

The 2017 survey of grassland fungi at Llanishen and Lisvane Reservoirs Embankments SSSI involved a total of six survey visits spread out through the main autumn fungi fruiting period. The study was commissioned on October 9th, and the survey visits carried out between October 11th and December 4th. In addition to the main survey visits, *ad hoc* observations of fungi were also made during the late summer, during the course of other ecological duties on the site. These have been included in the main report, which was drafted in December 2017.

Since the 2017 report was produced several species of grassland fungi continued to appear through December and into early 2018. The additional observations are not the result of such detailed study as the main survey, and consisted of occasional checks at the key fungi hotspots, plus any additional sightings made incidentally during other visits. This appendix summarises these late-season records to provide a more complete picture of the whole fungi fruiting period.

2. Observations

The late-season fungi sightings are summarised in Table 2.

Table 2 Summary of late-season fungi observations

Survey date	12 Dec	21 Dec	10 Jan	22 Jan	29 Jan	7 Feb
Waxcaps						
<i>Hygrocybe insipida</i>	X					
<i>Hygrocybe pratensis</i>	X	X	X	X		
<i>Hygrocybe psittacina</i>	X					
<i>Hygrocybe punicea</i>	X	X	X	X		
<i>Hygrocybe russocoriacea</i>	X					
<i>Hygrocybe splendidissima</i>	X	X				
<i>Hygrocybe virginea</i>						
Total waxcap species	6	3	2	2	0	0
Other indicator species						
<i>Clavulinopsis corniculata</i>	X		X	X		
<i>Microglossum olivaceum</i>	X		X	X	X	(X)

The distribution of these fungi was mainly confined to the same locations where the species had been recorded earlier in the season, with the majority seen along the northern-eastern side of Lisvane Reservoir and the west side of Llanishen Reservoir. One notable sighting was the appearance of *Hygrocybe punicea* on part of the western embankment of Llanishen Reservoir where it was not seen earlier in the year, although it had been observed there in 2016.

The numbers of fungi were much smaller than seen earlier in the season, typically only found singly or in pairs. The main exception was *Microglossum olivaceum* which continued to produce fruiting bodies into early February, with up to 10 fruiting bodies counted on most of the late season visits. The locations of the specimens seen on February 7th were marked with sticks. Some were still visible on February 12th, but had been badly damaged by frost and there had been no growth of new fruiting bodies so these observations are not included in Table 1.

3. Discussion

The observations between December 2017 and February 2018 provide useful supplementary data on the fruiting period for grassland fungi. They confirm that the main 2017 survey was undertaken during the optimal season, but also show that the season continued longer than might have been expected. This may be because not many fungi surveys are carried out during December and January, or because of the relatively mild and wet weather conditions, or it might indicate that 2017 was a particularly good year for certain fungi species.

Many of the fungi specimens that were observed in December and January had clearly been affected by frost, causing their tissues to soften and discolour. It is possible that some species are more frost-tolerant than others. For example, *Hygrocybe pratensis* is a relatively robust waxcap that appears to be able to withstand mild frosts, while many smaller waxcaps disintegrate immediately upon thawing. This might perhaps be related to the arrangement of the hyphae making up the tissues of the different species (long interwoven hyphae in *H.pratensis*, but often sub-regular short cells in many smaller species). However, in most cases once a fruiting body of any of the grassland fungi has been affected by a hard frost it does not recover. This was confirmed by marking the positions of several individual specimens with sticks on the January 10th visit, and they had all disappeared when checked on January 22nd. The specimens that were seen then all appeared to be new fruiting bodies that had developed in the intervening period.

The late observations of *Microglossum olivaceum* are interesting, as this rare species has typically been recorded relatively late in the season in previous surveys. However, it also appeared earlier than before during the current years' study, showing that it can have a very long fruiting season. The fruiting bodies appeared to be reasonably frost resistant, although in some cases this may have been due to microclimatic effects. The tips of some specimens had succumbed to frost damage, while their lower parts were protected within the mossy turf. The insulating effect of a thick moss layer might be one factor in the prolonged fruiting season in the north-east of Lisvane Reservoir. Most other parts of the site have little or no moss layer due to the grass being too tall and dense until the resumption of favourable grass cutting in 2017.