# Final report on the Fungi of Great Windsor Park

# Study for Buglife – Back from the Brink  2020

Chris Knowles -  Where the wild stuff is…

*Saving the small things that run the planet*

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# Introduction

Windsor Great Park is home to many ancient trees, and due to its historical management as part of the once much larger royal hunting ground, it is one of only a few sites in the country to have had perpetual tree cover over the centuries. The Park has also benefitted from a continued supply of over-mature trees and dead wood habitat. The great diversity of wood rotting (saprophytic) species supported at Windsor critically relies on the continuity of the dead wood resource. Standing and fallen trees in various states of decay provide a wide range of habitats and niches for different species and the successive stages of their life cycles.

Ancient trees and the wildlife that relies on them are threatened by the increased prevalence of tree diseases, climate change and the age gap between the existing ancient trees and those that will eventually become the "ancients of the future".

# The scope of this project

This study was commissioned by Buglife, as part of their Ancients of the Future/Back from the Brink work. The work was required to take the form of a desk study investigating all known records of the non-lichenised fungi found in Great Windsor Park over the last 50 years.

These records were then used to identify and map geographical hotspots and key substrates/hosts. All species of conservation importance and those with legal protection were determined; and species whose ecology relies on mature trees and deadwood were classified then separated to be the main focus of this study. Management and monitoring recommendations were made in relation to these findings.

Figure 1. *Fistulina hepatica* (Beefsteak fungus), causing brown rot on Quercus (Oak).

# Methodology

## Data collection and selection

To access the data necessary for this desk study, national databases, local recording groups and individuals were approached to source any relevant records, all of which were then collated into a single list.

In the UK there are two national databases of fungi, the Fungal Records Database of Britain and Ireland (FRDBI) which is maintained by the British Mycological Society (BMS) and CATE2 which is maintained by the Fungus Conservation Trust (FCT).

All new records entered onto the FRDBI are already added to the NBN Atlas, however the FCT have an agreement with their network of recorders not to share their records in this way. It only became apparent after being granted access to CATE2 data, that it is a requirement of this project that all records included in this study will eventually be submitted to the NBN Atlas. Therefore, no data from CATE2 has been included.

Although this amounted to 3,500 potentially relevant, unusable records, only 3 of these were unique. These 3 records were of 2 different species, neither of which were of local or national importance, nor were they associated with mature trees or deadwood, so their exclusion from this study will not be detrimental to the results.

Contacting other local mycologists who may have had, or known of additional records that had not reached one of the national databases yielded hardly any additional data, but a further 1,000 relevant records were provided within datasets provided by the Crown Estate. Many of these proved to be unique, but had little information regarding habitat or substrate and there were many spelling mistakes in the scientific names given, so these needed to be edited manually to be included in the dataset.

A total of over 33,000 records were found to be potentially relevant to the project. It was not possible to simply filter the dataset by either grid reference, or place names including 'Windsor' as 10,000 records that needed to be included at this stage had no grid reference at all, and localised place names such as 'Cranbourne Chase', 'Cookes Hill' and 'Snow Hill' were often used, but not always with the same format or spelling.

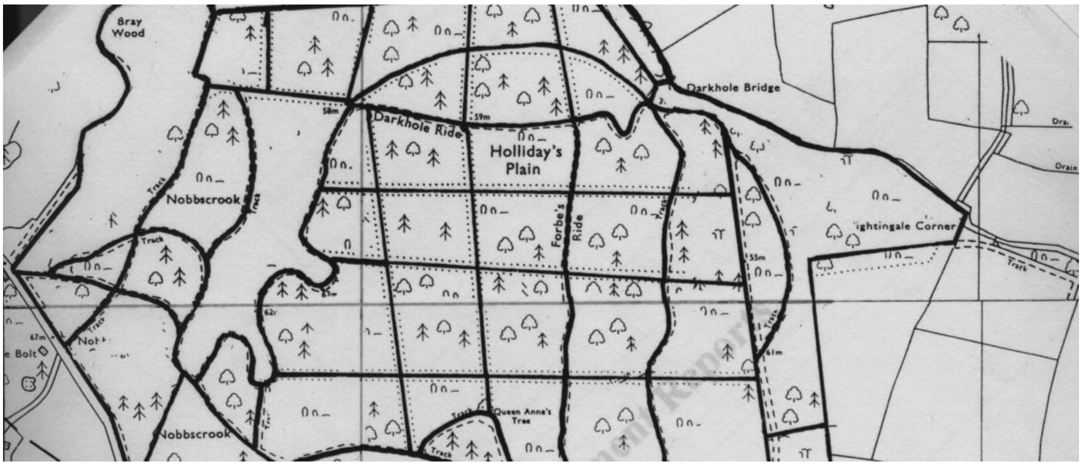



Figure 2. A partial map of Great Windsor Park labelled with some of the local place and feature names.

The locations of these records were checked manually by site name. A further 7,000 records had a wide, 6-digit grid reference, and also needed to be checked manually by location name for relevance.

This list was then checked for valid species, cleaned of duplicate entries and queried extensively to discover any over-looked or under-recorded groups. Recommendations for further monitoring that would be of benefit to this project were then suggested in the interim report for this project (Knowles, 2019).

After coarsely filtering the data in this way the dataset consisted of 6,180 records made up of 1,330 species in 582 genera. By comparison a similar study by Lewis (1999) described around 1,200 species having been found at Windsor Great Park by that time.

This processed dataset was then compared against these lists of threatened, protected and priority species:

- IUCN - Red list of threatened species
- UK Biodiversity Action Plan – Priority species and habitats
- Section 41 – Priority species
- Schedule 8 - Wildlife and Countryside Act 1981
- Red Data List of Threatened British Fungi (2006)
- Red List of Fungi for Great Britain (2016)
- Red List of Fungi for Great Britain: Boletaceae

The data was also used to carry out SSSI assessments using:

- JNCC - SSSI Guidelines Chapter 14 – Non-lichenised fungi (2018)

To ensure that no records were missed during this process, up to two recent synonyms were added to each species, and the comparison filter also checked these for inclusion.

The taxonomy of each record was also checked at this point. All taxonomy that already matched the current name given in the National History Museum's UK Species Index (UKSI) were left unchanged. However where records only had older names given, these were updated according to the preferred names and taxonomic opinions of Species Fungorum.

A secondary dataset was then created featuring only those species which corresponded with these priority species and red-lists.

After this, at every point that the dataset was filtered or adjusted by any factor, care was taken to identify any of these 'priority' species that would be omitted, and notes of these omissions were included with the results.

## Working Area

Windsor Great Park has been historically divided into 21 biological recording compartments, and this study used those compartments for all mapping and reporting.

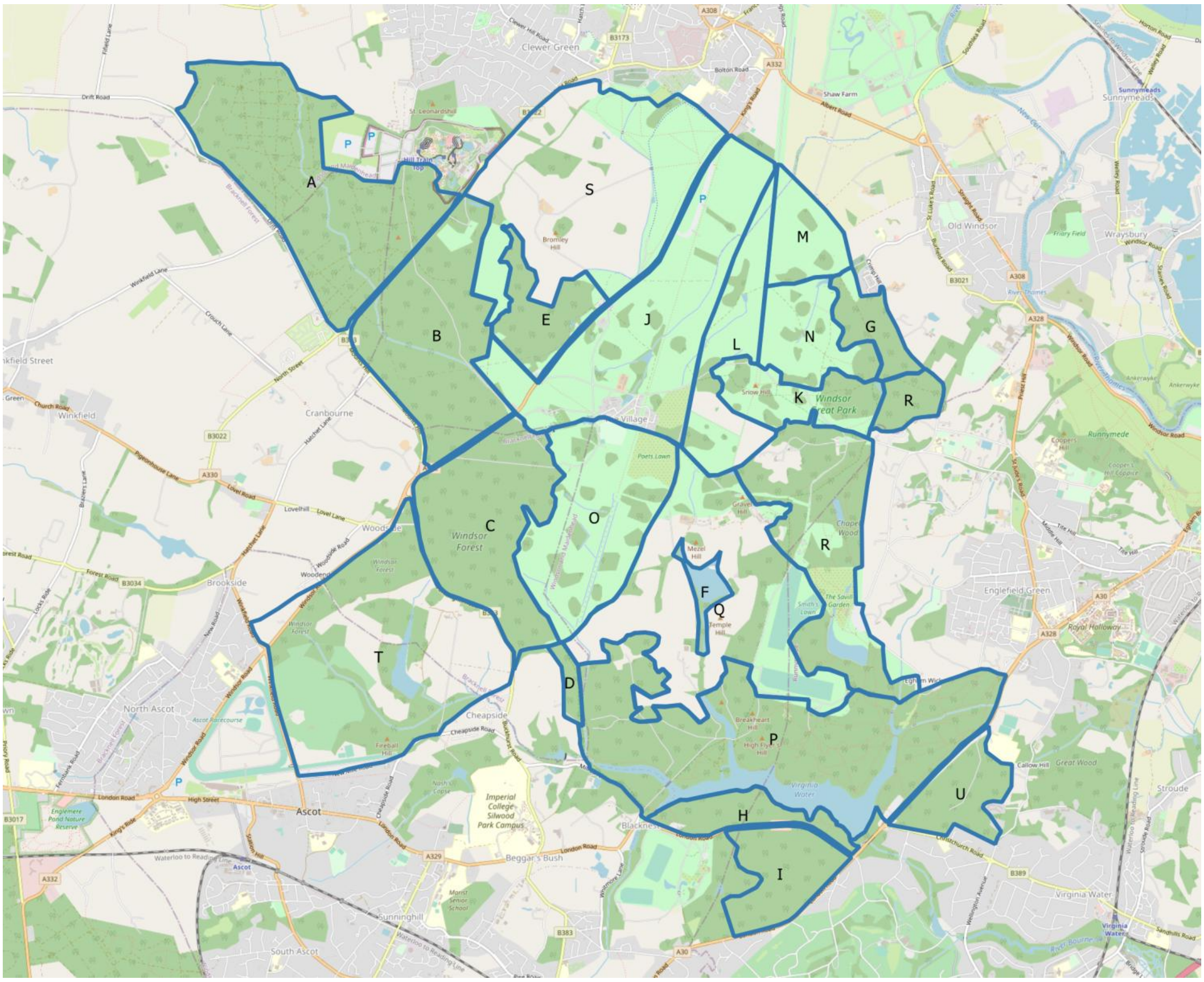



Figure 3. Map of Great Windsor Park with compartments marked.

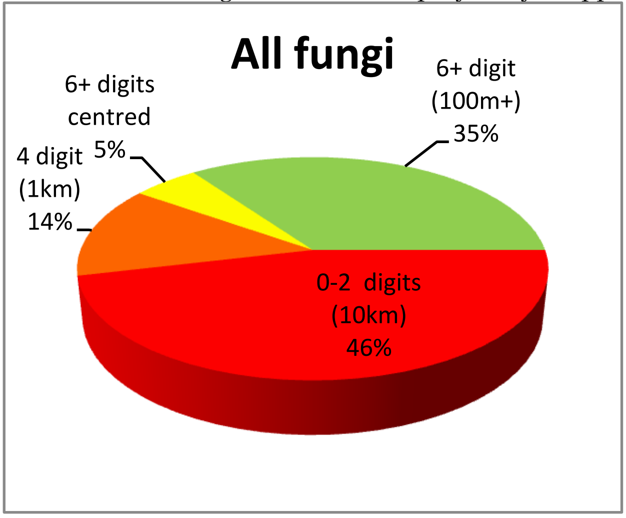
In the wider data set, 65% of all records had a poor grid reference, making it impossible to successfully map those records correctly.  This in turn made it difficult to match individual records to compartments and habitats.

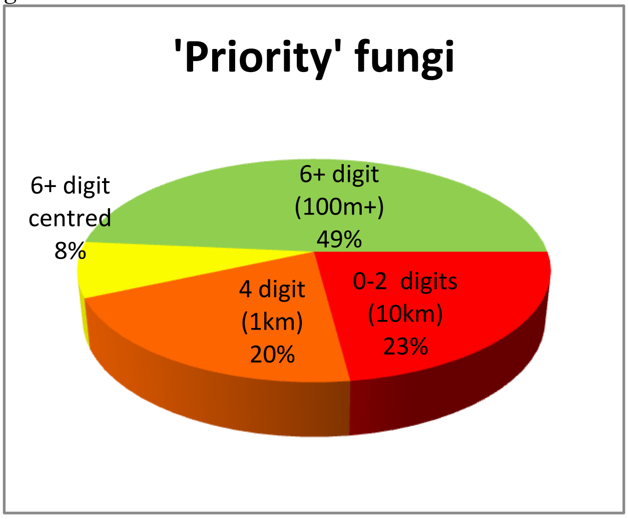
Chart 1 shows how 46% of all records had either no grid reference at all, or a 2 digit reference that only gives a resolution of a 10km square (encompassing ¾ of the entire site). A further 14% of all records only had a 4 digit grid reference, which has a resolution of a 1km square, and so is not particularly useful for mapping records.

The remaining 40% of records had 6 or more digits in their grid references, which provided a good enough resolution for contrasting them against compartments and habitats.

This issue was not as pronounced with 'priority' fungi records, presumably because recorders were more likely to make a special effort to get an accurate grid reference when finding those species.

Chart 1. Percentage of records displayed by mapping resolution




## Separation of general records

The kingdom of fungi is taxonomically very large, and is represented by species in a wide variety of forms, fulfilling a broad range of ecological niches. For the purpose of this study, the records were divided into 9 categories. These categories were devised along a blend of genealogical, ecological and morphological lines and therefore the lines between these them are blurred and vague, Although this meant that many species could easily be assigned to more than one category, to achieve the goal of focussing this project on those species associated with mature, ancient and dead trees a consistent method was applied to categorising each species.

The categories used were:

| Name of Category | Brief Description of Category | |
|---|---|---|
| Basidiomycete Saprophyte | A broad category including wood-rotting, mushroom-shaped (agaricoid) fungi, bracket fungi, jelly fungi and more. Some species are only parasitic on deadwood saprotrophs, but have been included here due to a shared reliance on the same underlying substrate. |  |

| | | |
|---|---|---|
| Resupinate Saprophyte | A wholly morphological distinction covering a wide range of crust-like fungi, including poroid species with this growing habit (on wood). |  |
| Ascomycete Saprophyte | Many wood-rotting acscomycetes are very small, but those included here are most likely to be found on larger deadwood. Some species are only parasitic on wood-rotting fungi, but have been included here due to a shared reliance on the same underlying substrate. |  |
| Ascomycete Other | This group includes all those ascomycetes more likely to be found on light, woody debris and litter or other substrates. Although they include wood-rotters, their substrate can be generated by very young trees and woody shrubs. |  |
| Basidiomycete Other | This category is dominated by ectomycorrhizal agaricoid fungi, but includes litter-rotting saprotrophs, truffles and many others.. |  |

| | | |
|---|---|---|
| Rusts | These fungi are associated with the soft growth parts of plants, like stems and leaves. |  |
| Smuts | The ecology of these fungi relies on the reproductive systems of plants, and is not restricted to the target trees at all. |  |
| Microfungi | This category includes several groups of mould-like fungi and similarly sized species. |  |
| Myxomycetes | Slime molds have long been recorded alongside fungi on mycological systems, but they are not of the fungi kingdom. |  |

Only the first 3 of these categories are relevant to this study, as none of the other species have the same reliance on deadwood or mature and ancient trees as a substrate. However, a mapping exercise has been carried out for all categories and all shapefiles and spreadsheets were provided along with this report.

# Distribution of fungi in Windsor Park

As previously mentioned, 46% of the records in this dataset were unmappable.  This issue was biased towards only a few genera, but was apparent across the whole set of data (apart from red-listed and priority species which tended to have more detailed grid references).   This meant that it was still possible to get a reasonable view of fungi hotspots by looking at geographical concentrations of records.

Unfortunately, as can be seen in Figure 4., when 4-digit grid references are used, large numbers of records cluster around the bottom left of grid squares, which is not a true representation of distribution – and makes it difficult to assign records to the correct compartments.

The problem is still apparent, though to a lesser degree with some 6 digit grid references.  To avoid the problem with 4-digit grid references appearing on the bottom left of 1km grid squares, some recorders centralise the reference in that grid square. (e.g.  SU9373  becomes SU935735). By removing these additional 330 records (5%) the hotspot map gives a representation of distribution not biased by grid squares. In Figure 2. The left hand map shows concentrations of fungi records including those with 4-digit grid references, the right hand map with concentrations of fungi referenced by 6-digits or more (with centralised  records removed).

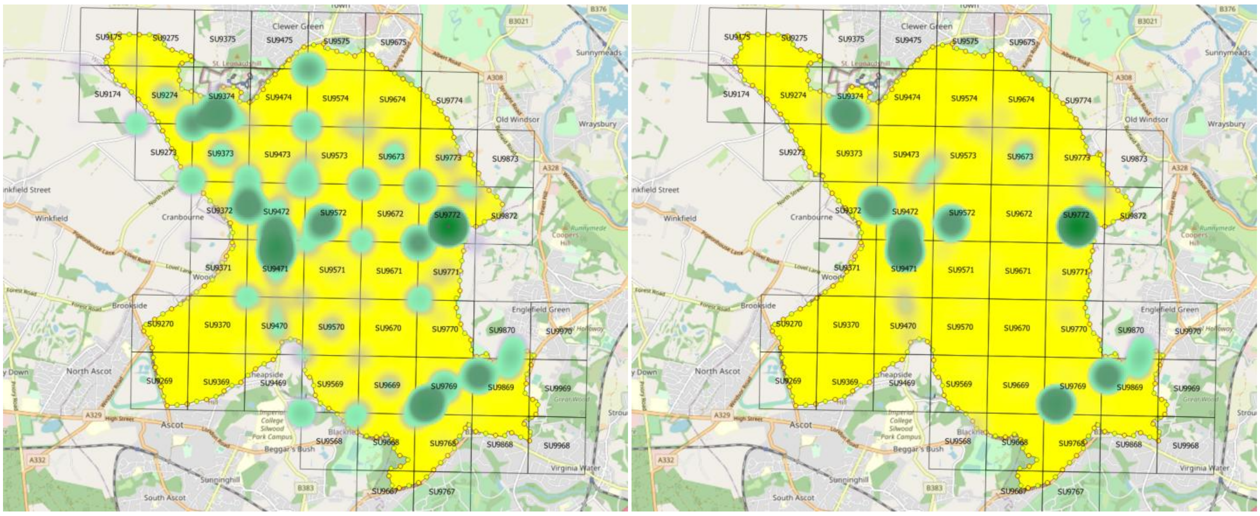


Figure 4. Heatmaps illustrating the problem with 4 digit and centralised 6-digit grid references (left) and with those removed (right)

Both of these maps have a use and value, The one on the right clearly illustrates where the highest proportion of records were generated, which infers that these are likely to be fungal hotspot. This is most useful when overlaid with a map of compartments or habitats for comparison (see Figure 3.). However the one on the left can be used to see a wider picture when compared to an overlay of OS grid squares as in Figure 2. Used in this way, it possible to ascertain distribution and (to some extent) density of fungal records within a given 1km grid square.

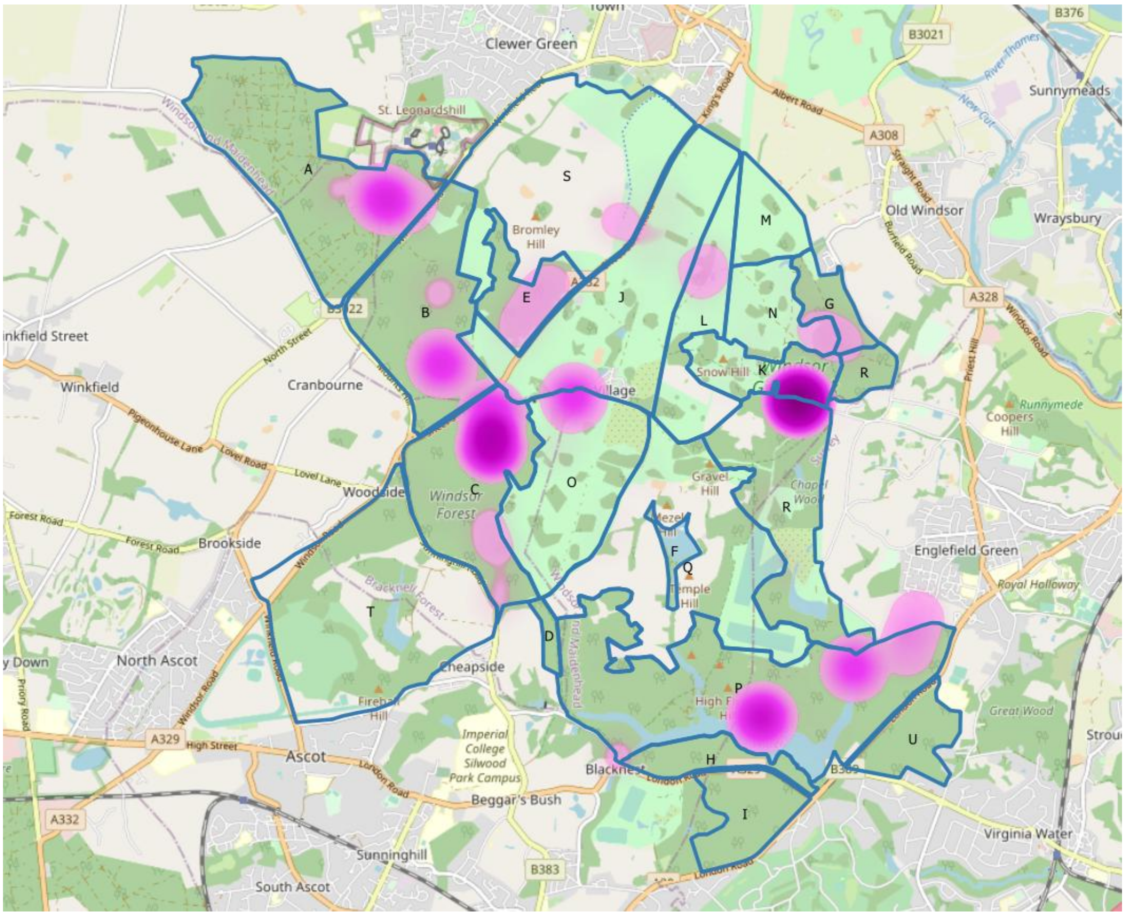
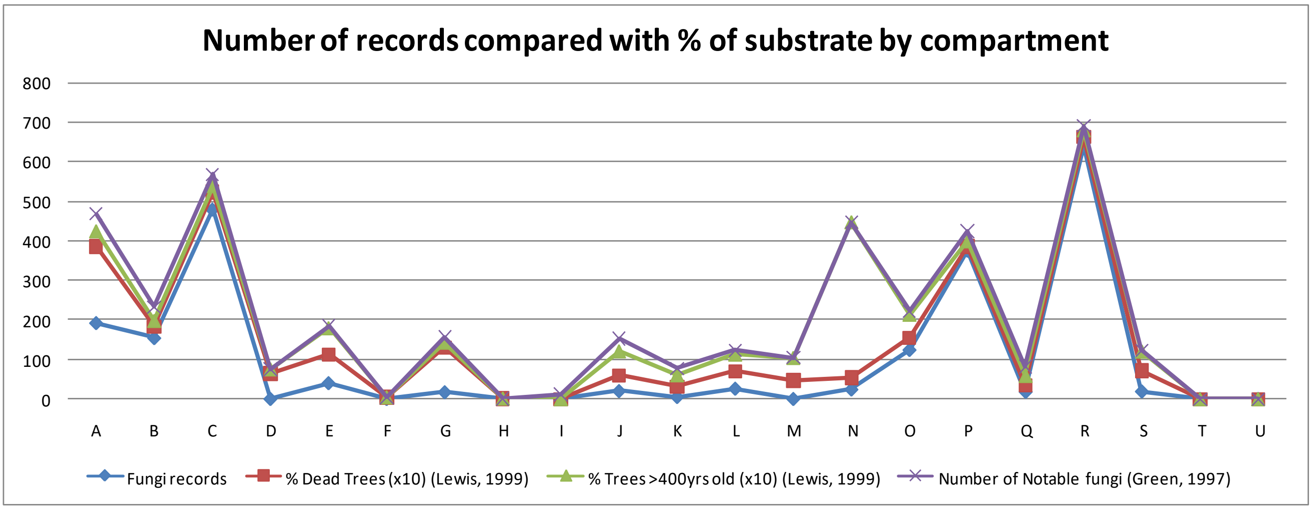


Figure 5. Distribution of all precisely mappable fungi records represented as a heatmap.

Using only the records that allowed for the more precise mapping used in Figure 3. It was possible to show how host/substrate availability was a major factor in either species distribution or recording bias.   While the data used in Chart 2 was not directly comparable, the correlations between the number of notable fungi recorded by Green (1997), the percentage of trees over 400 years old (Lewis, 1999) and the percentage of dead trees (Lewis, 1999) with the number of records per compartment from this study was quite significant in most of the compartments.

Chart 2. Relationship between records found and available habitat.



# Designated, red-listed and protected species

Using the agreed lists of threatened, protected and priority species which are detailed in the methodology, the fungi of Great Windsor Park were checked and filtered to provide the following results:

Table 1. Priority species

| Fungi Category | Records | Species | Genera |
|---|---|---|---|
| Basidiomycete Saprotrophs | 403 | 20 | 15 |
| Resupinate Saprotrophs | 12 | 2 | 2 |
| Ascomycete Saprotrophs | 0 | 0 | 0 |
| Ascomycete - Other | 0 | 0 | 0 |
| Basidiomycete - Other | 510 | 36 | 20 |
| Rusts | 0 | 0 | 0 |
| Smuts | 0 | 0 | 0 |
| Microfungi | 2 | 1 | 1 |
| Myxomycetes | 0 | 0 | 0 |
| Total | 927 | 59 | 38 |

Of these species, those from the target categories are shown in Table 2 with the number of lists they appear on.  (The full table can be found in Appendix 1)

Table 2. Priority and Red-listed species on deadwood and mature/ancient trees.

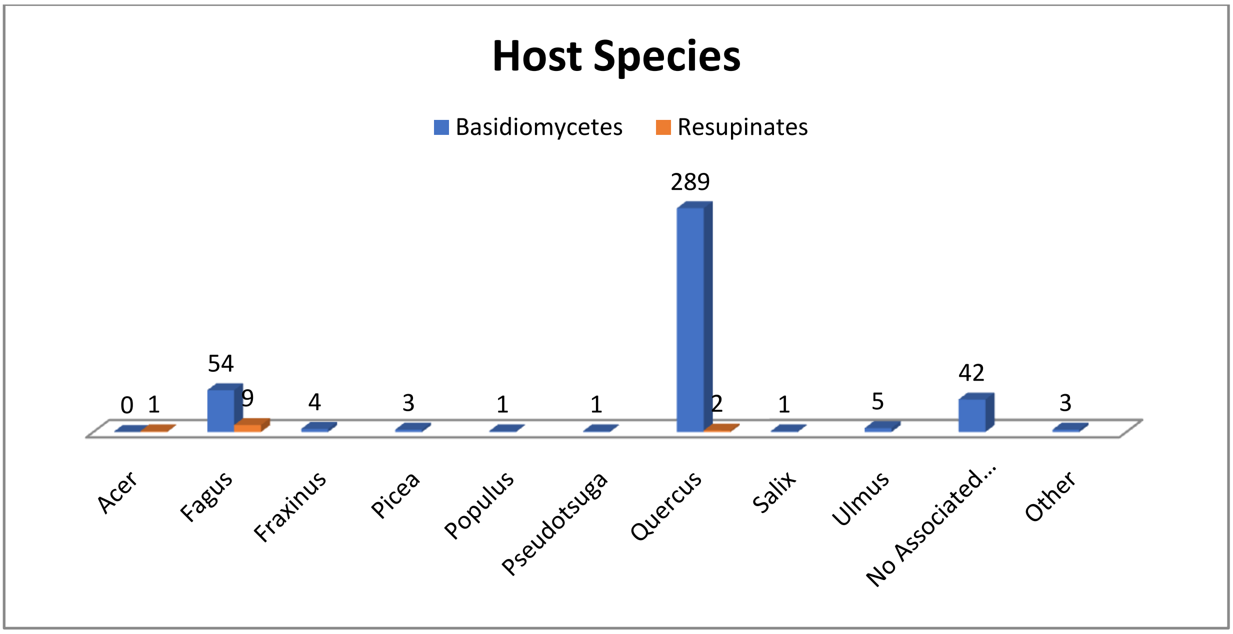
| Type | Current Name | Number of red lists etc. | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Basidio. Sapro. | Aurantiporus alborubescens | | | | | X | | |
| Basidio. Sapro. | Buchwaldoboletus lignicola | X | | | | | | X |
| Basidio. Sapro. | Buchwaldoboletus sphaerocephalus | | | | | X | | X |
| Basidio. Sapro. | Buglossoporus quercinus | | X | X | X | X | X | |
| Basidio. Sapro. | Fomitiporella cavicola | | | | | X | | |
| Basidio. Sapro. | Fomitiporia robusta | | | | | X | | |
| Basidio. Sapro. | Fuscoporia torulosa | | | | | X | | |
| Basidio. Sapro. | Gloeoporus dichrous | | | | | X | | |
| Basidio. Sapro. | Hericium cirrhatum | | | | | | X | |
| Basidio. Sapro. | Hericium coralloides | | X | X | | X | X | |
| Basidio. Sapro. | Hericium erinaceus | | X | X | X | X | X | |
| Basidio. Sapro. | Hohenbuehelia mastrucata | | | | | X | | |
| Basidio. Sapro. | Lentinellus ursinus | | | | | X | | |
| Basidio. Sapro. | Lentinellus vulpinus | | | | | X | | |
| Basidio. Sapro. | Phyllotopsis nidulans | | | | | X | | |
| Basidio. Sapro. | Podoscypha multizonata | | X | X | | X | | |
| Basidio. Sapro. | Rhodotus palmatus | X | | | | | | |
| Basidio. Sapro. | Schizophyllum amplum | | | | | X | | |
| Basidio. Sapro. | Tremella moriformis | | X | X | | X | | |
| Basidio. Sapro. | Tremella steidleri | | | | | X | | |
| Resup. Sapro. | Gloeohypochnicium analogum | | | | | X | | |
| Resup. Sapro. | Mycoacia nothofagi | | | | | X | | |

To assess which tree species support the greatest number of the target fungi species, a list of all substrates/associated organism was created. 50 species of woody plants and trees were identified from the full dataset, but only 37 of these were host to species on the priority/red-lists (See Appendix 2).

As can be seen in Chart 3, Fagus and Quercus stand out as being the most important ancient trees for Windsor Great Park's red-listed and priority species of wood-rotting fungi. Although a significant number of records had no details for host species/substrate (no associated organism), these records were distributed evenly throughout the data, and are therefore very unlikely to skew the results. A small number of records were not recorded as being in association with trees (other). In the case of Tremella species, this was because these jelly fungi were parasitising another species of fungi, which in turn were parasitising or rotting the host tree/deadwood (*Tremella steidleri* on *Stereum hirsutum* and *Tremella moriformis* on *Diatrypella sp*.). In the case of *Podoscypha multizonata*, the associated organism was wrongly recorded as grass (Poaceae), due to the way this fungus can appear to be growing independently of trees. It does in fact have an association with the roots of the host tree, which although likely to be Quercus or Fagus, was not recorded. There are many more records in the full dataset that have similar reasons for associated organisms that are not trees being recorded in the details, but all have been verified as having some reliance on these hosts and associations.

Some other groups of species like the stipitate hydnoids (Tooth fungi) also have some reliance on ancient woodland, however, the age of an individual tree is not the important factor for them, but the continuity of that habitat over great periods of time. They are therefore able to associate with younger trees, if they grow in close enough proximity to established specimens in 'old-growth' woods. Species with this kind of ecological need were consequently only included in the wider group of fungi (e.g. Basidiomycete – other).

Chart 3. Host species of priority and red-listed species of target fungi categories.



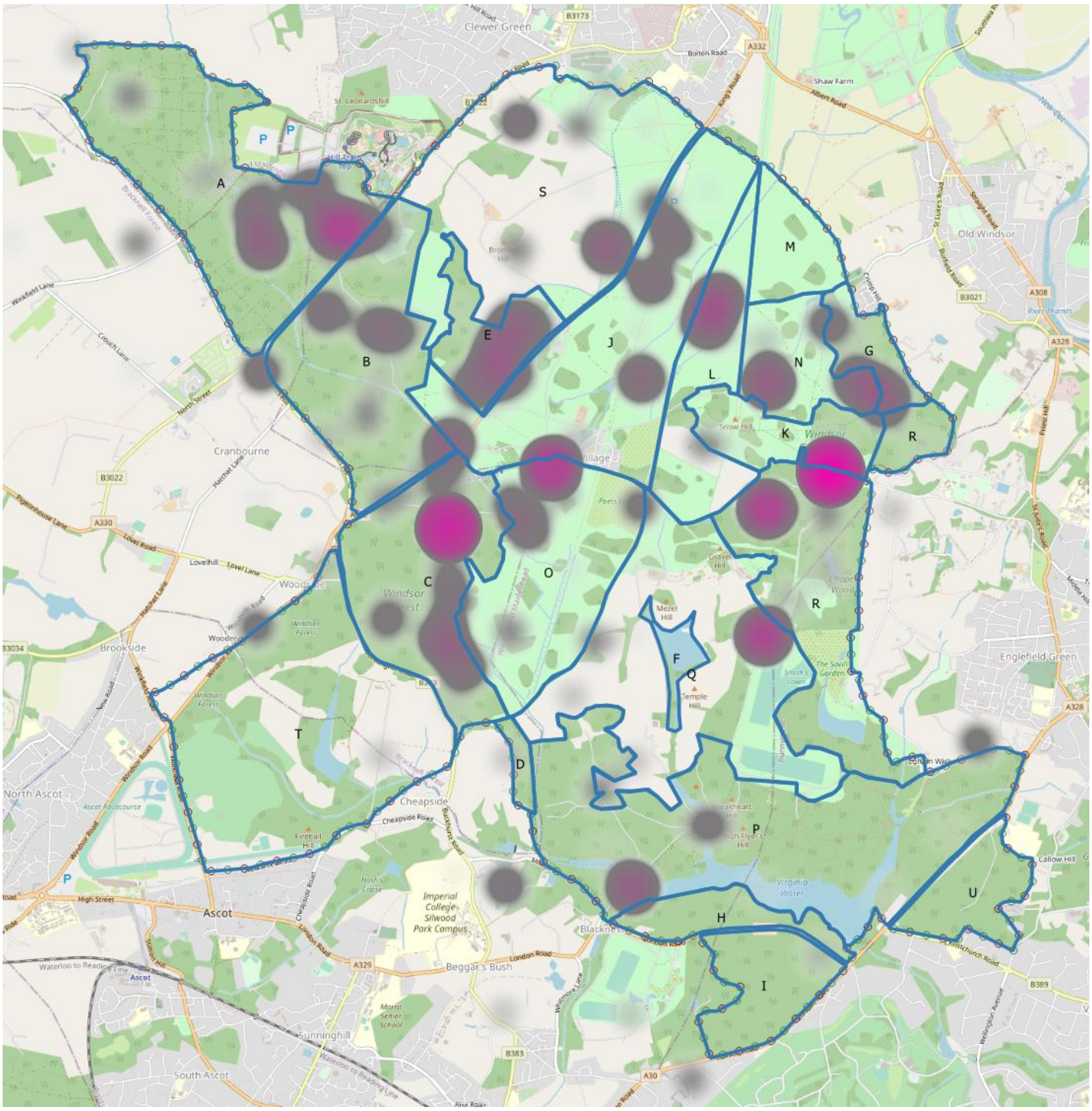



Figure 6. A Heatmap of priority species with a grid reference at 1km² accuracy or greater

Although the accuracy of grid references was generally better for priority species, it was still necessary to create a map including records with a 1km² resolution to include a good proportion of the priority species.

Of the 59 priority fungi species occurring at Windsor Great Park, 10 species either had no records with a grid reference, or only a 10km² grid ref. Only 11 species had any records with a grid ref. useful for relocating the fungi (10m² grid ref.) The full details of those priority species lacking quality geographical data are listed in Appendix 3.

However, with these limiting factors aside, and ignoring the bias given to the corners and centres of 1km grid squares there are clear hotspots in the distribution of the priority fungi that don't quite match the maps of the full fungi dataset and some areas that were rich in those records, but poorer in priority species (e.g. in SU9372 (Compartment B) and SU9869 (Compartment P).

# Deadwood Saprotrophs and related species

The target species of this project was those fungi whose ecology was reliant on mature trees, or the dead wood of mature trees. This meant that species saprotrophic on woody litter (twigs, small debris, cones, leaf litter etc.) were not included under this definition, but fungi found on fallen branches and bark were. The boundaries of these categories are indistinct and prone to overlap, but best efforts were made to remain consistent in the categorisation process, with the allowance of exemptions. Similarly, saprotrophs of fire sites were generally excluded, with the exemption of *Pholiota highlandensis* which has a preference for fire-blackened stumps over burnt ground (and is therefore associated with mature trees).

Figure 7. *Pholiota highlandensis* (The Bonfire Scalycap) is associated with burned stumps and can be found at the charred bases of trees after fires. © Henri Koskinen

Within this wide category of deadwood saprotrophs there is huge variation in the states and rates of wood rotting, fruitbody morphology and fruiting regularity. The next level of categorisation separated them into the following groups:

Table 3. Numbers of records and species categorised as deadwood saprotrophs

| Category | Records | Genera | Species | Records with 6+ grid ref. | Species with 6+ grid ref. | Priority records | Priority Species |
|---|---|---|---|---|---|---|---|
| Basidiomycete Saprotrophs | 1514 | 108 | 231 | 548 | 116 | 403 | 20 |
| Resupinate Saprotrophs | 241 | 65 | 121 | 20 | 12 | 12 | 2 |
| Ascomycete Saprotrophs | 148 | 70 | 94 | 15 | 8 | 0 | 0 |

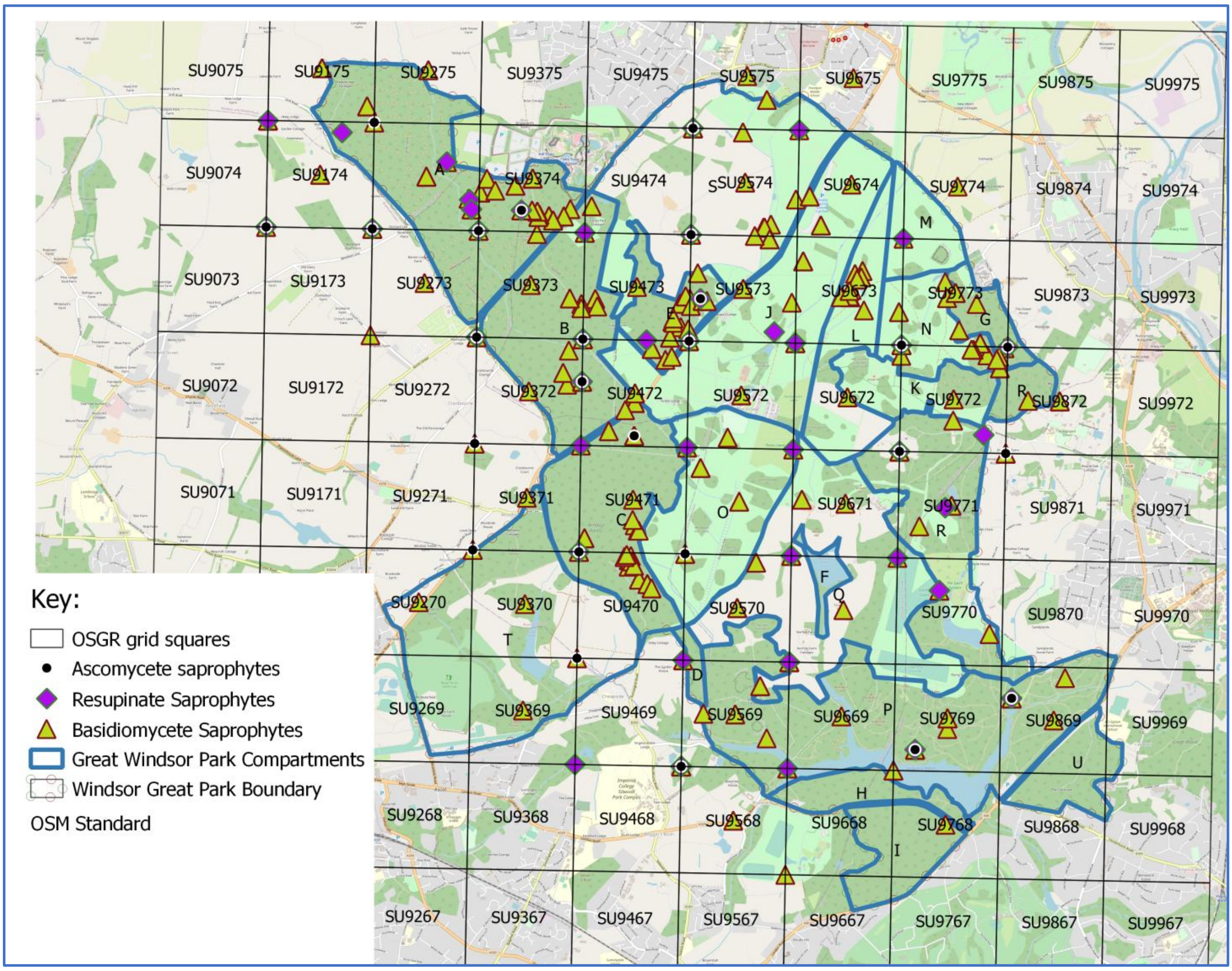
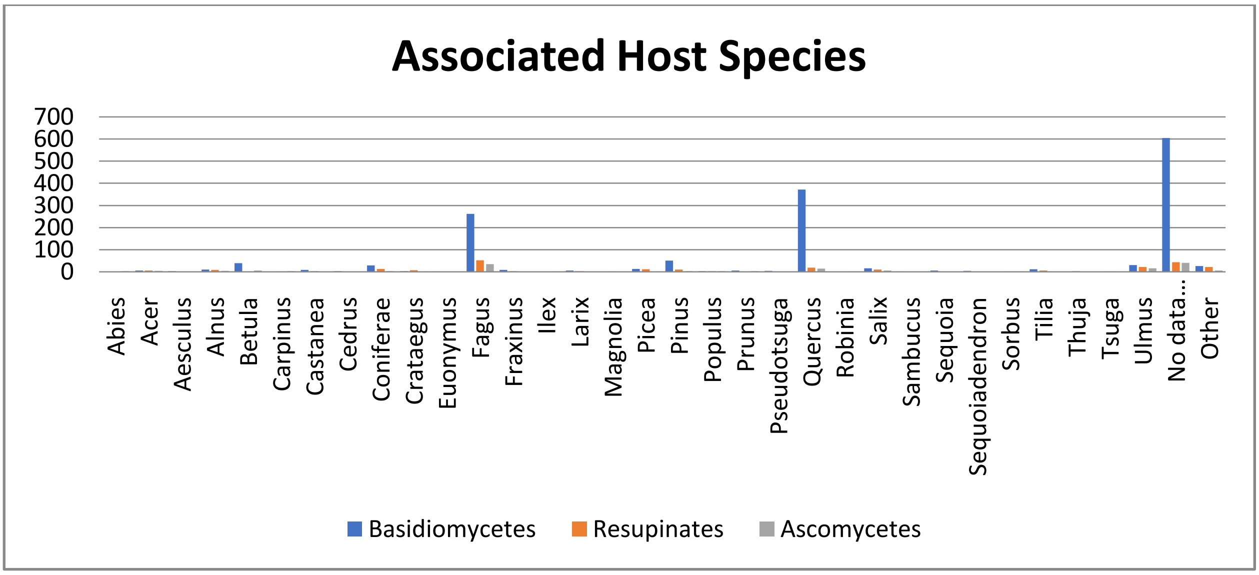



Figure 8. Distribution map of all target species with grid refs accurate to 6 or more digits.

As illustrated in Figure 4., the level of accuracy used in Figure 8. falsely appears to show the distribution of target species outwith the boundary of Great Windsor Park. To make this more evident the relevant grid squares are included in Figure 8. Further charts plotting the distribution of each category can be found in Appendices 10a -10c.

Chart 4. The number of target species associated with each host species.

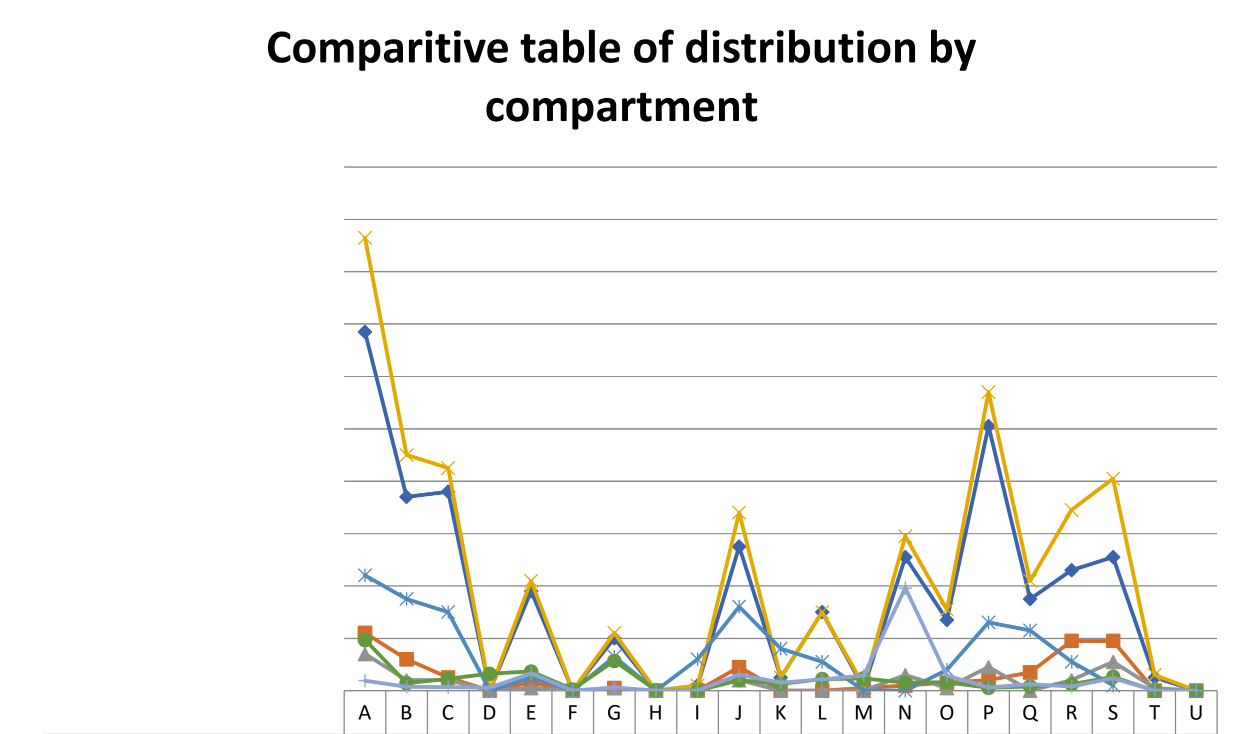


The target species records were sorted and filtered by the organism (tree host) associated with them (Chart 4). 36% of the records had no associated organism recorded; 21% were recorded associating with Quercus; 18% were associated with Fagus; 4% were associated with Ulmus; 3% were associated with Pinus; and 3% were recorded with associated organisms that were not tree species, (e.g. those species which were parasitically associated with fungi that were in turn associated with a tree species.)

# Distribution of fungi

Great Windsor Park has been divided into 21 compartments. In 1997, Green provided a breakdown of the percentages of veteran trees (over 400 years old) and deadwood in each compartment along with many other statistics. Chart 5 places that data in proportional relation to the target species of this project.

Chart 5. A proportional representation of all data linked to compartments




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Basidio Saprophytes | 137 | 74 | 76 | 0 | 38 | 0 | 20 | 0 | 2 | 55 | 5 | 30 | 1 | 51 | 27 | 101 | 35 | 46 | 51 | 5 | 0 |
| Resupinate Saprophytes | 22 | 12 | 5 | 0 | 3 | 0 | 1 | 0 | 0 | 9 | 0 | 0 | 1 | 2 | 3 | 4 | 7 | 19 | 19 | 0 | 0 |
| Ascomycete Saprotrophs | 14 | 4 | 4 | 0 | 1 | 0 | 1 | 0 | 0 | 4 | 0 | 0 | 0 | 6 | 1 | 9 | 0 | 4 | 11 | 1 | 0 |
| Total target records | 173 | 90 | 85 | 0 | 42 | 0 | 22 | 0 | 2 | 68 | 5 | 30 | 2 | 59 | 31 | 114 | 42 | 69 | 81 | 6 | 0 |
| Fungi Sp. (Green) | 44 | 35 | 30 | 0 | 5 | 0 | 13 | 0 | 12 | 32 | 16 | 11 | 0 | 0 | 8 | 26 | 23 | 11 | 2 | | 0 |
| % Dead Trees | 19. | 2.8 | 4.4 | 6.4 | 7.2 | 0.4 | 11. | 0.1 | 0.0 | 4.0 | 2.5 | 4.4 | 4.6 | 3.0 | 3.1 | 1.1 | 1.6 | 2.4 | 5.3 | 0.0 | 0.0 |
| % Trees >400yrs old | 3.7 | 1.5 | 1.4 | 1.0 | 6.6 | 0.0 | 1.2 | 0.0 | 0.0 | 6.0 | 3.0 | 4.2 | 5.7 | 39. | 5.7 | 1.2 | 2.4 | 1.6 | 4.8 | 0.0 | 0.0 |

No clear correlation across compartments could be found when comparing the percentage of dead trees/veteran trees to the number of records of target species, however Table 4 compares the 10 compartments with the greatest number of records of target species with the 10 compartments with the greatest amount of dead trees and trees over 400 years old.

Compartments A, E, J and S all feature in each 'top ten', while compartments C, N and Q share compartments with the 'top ten' of a single substrate feature.

This implies that some correlation is apparent between the total number of target species records and substrate availability within a smaller range as 7 out of 10 of the compartments with the most records also have some of the highest levels of substrate availability as would be expected.

Table 4. Compartments with the highest numbers of records, dead trees and vintage trees, colour coded to display matching compartments. (White cells denote compartments that only occurred once).

| Cmpt. | Total target species | Cmpt. | % Dead Trees | Cmpt. | % Trees >400yrs old |
|---|---|---|---|---|---|
| A | 173 | A | 19.39 | N | 39.20 |
| P | 114 | G | 11.35 | E | 6.62 |
| B | 90 | E | 7.28 | J | 6.05 |
| C | 85 | D | 6.45 | O | 5.79 |
| S | 81 | S | 5.30 | M | 5.71 |
| R | 69 | M | 4.69 | S | 4.82 |
| J | 68 | C | 4.49 | L | 4.25 |
| N | 59 | L | 4.40 | A | 3.78 |
| E | 42 | J | 4.02 | K | 3.00 |
| Q | 42 | O | 3.12 | Q | 2.42 |

# SSSI assessment

The filtered and corrected dataset created for this project was used to assess the fungi of Windsor Great Park against the current Guidelines for the Selection of biological SSSIs –Chapter 14, Non-lichenised fungi (Bosanquet et al, 2018). It is important to note however, that these guidelines do not include all of the important fungal assemblages likely to be found in different habitat within the park, as there were no accepted scoring systems for those assemblages at the time of this project. Appendix 11 lists a number of assemblages that are acknowledged in the guidelines, but do not have scoring systems.

As an example of the potential importance of some of those assemblages to the park, a draft version of an assessment for thermophilous boletes was applied to the dataset with very positive results which are discussed as the end of this section.

Of the six assemblages with selection guidelines, four were relevant to the habitats found in the park. The guidelines for coastal sand dune fungi and Caledonian pinewood fungi assemblages were not looked at for this research, the comparisons to the remaining assemblages follow here:

## Tooth fungi associated with oak, beech or sweet chestnut

(Stipitate hydnoid fungi predominantly mycorrhizal with Quercus, Castanea and Fagus. Habitats include woodland, lowland heath and other habitats where the host trees occur)

7 species/species aggregates were used to assess sites for this assemblage. The threshold for SSSI selection in the south and south-east of England was 5 of these species/species aggregates.

Assessed as a single site, Great Windsor Park had 6 species/species aggregates present, surpassing the threshold for this assemblage to be considered for SSSI designation. (See Appendix 12 for species list).

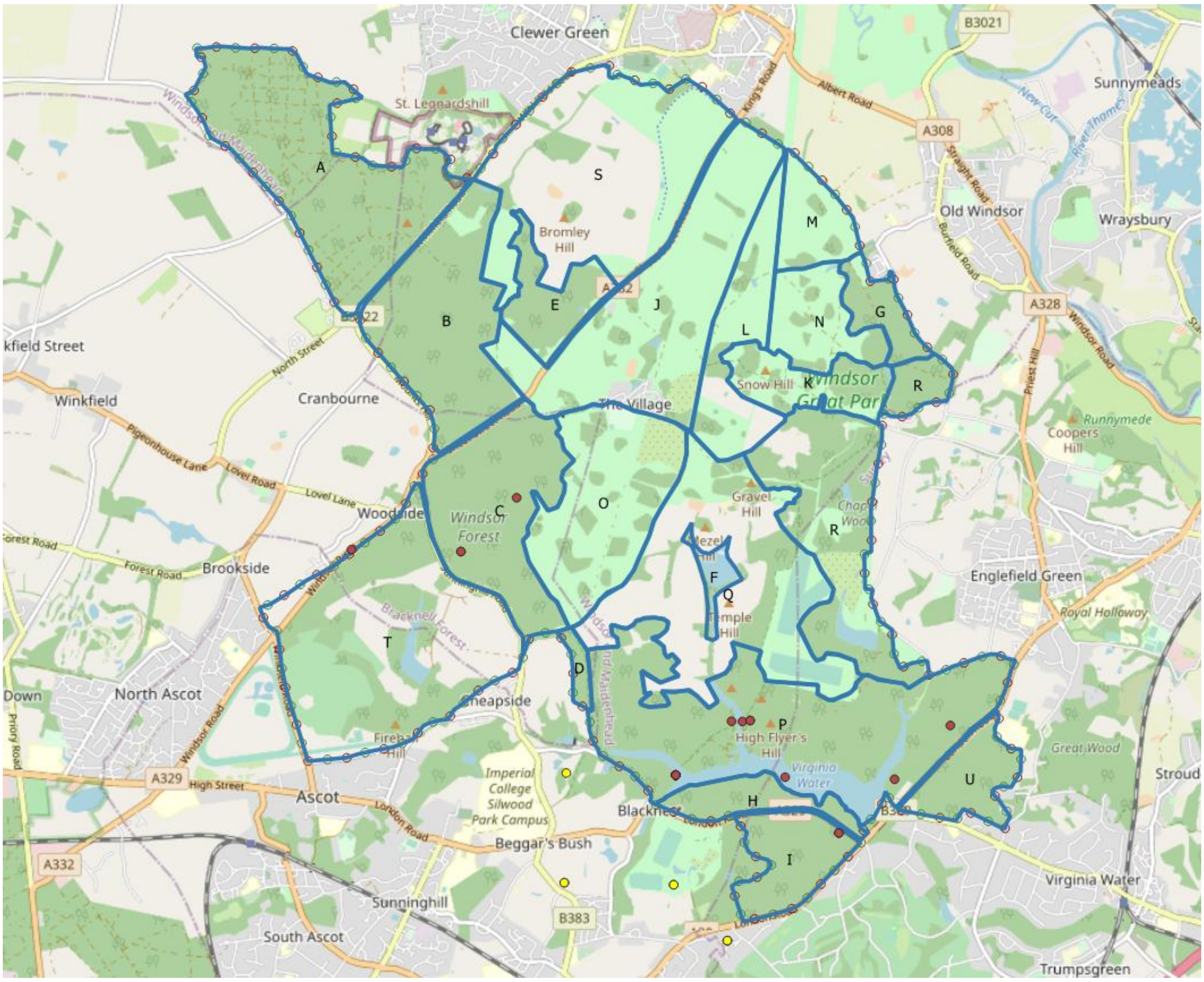



Figure 9. Distribution of tooth fungi in great Windsor Park

According to the available data, the distribution of these species was limited to 4 compartments (Figure 9). If no suitable habitat is available within the rest of the park, any proposed SSSI designation based on this assemblage could limit the SSSI boundary to the south of the park. However, if suitable habitat is present in the north of the park, designating the entire park for this assemblage would benefit the possible future expansion of this group of fungi.

## Beech deadwood

(Saprotrophs of beech in parkland, wood pasture, or woodland)

30 species were used to assess sites for this assemblage. The threshold for SSSI selection was 15 of these species.

Assessed as a single site, Great Windsor Park had 25 species present, surpassing the threshold for this assemblage to be considered for SSSI designation. (See Appendix 13 for species list).

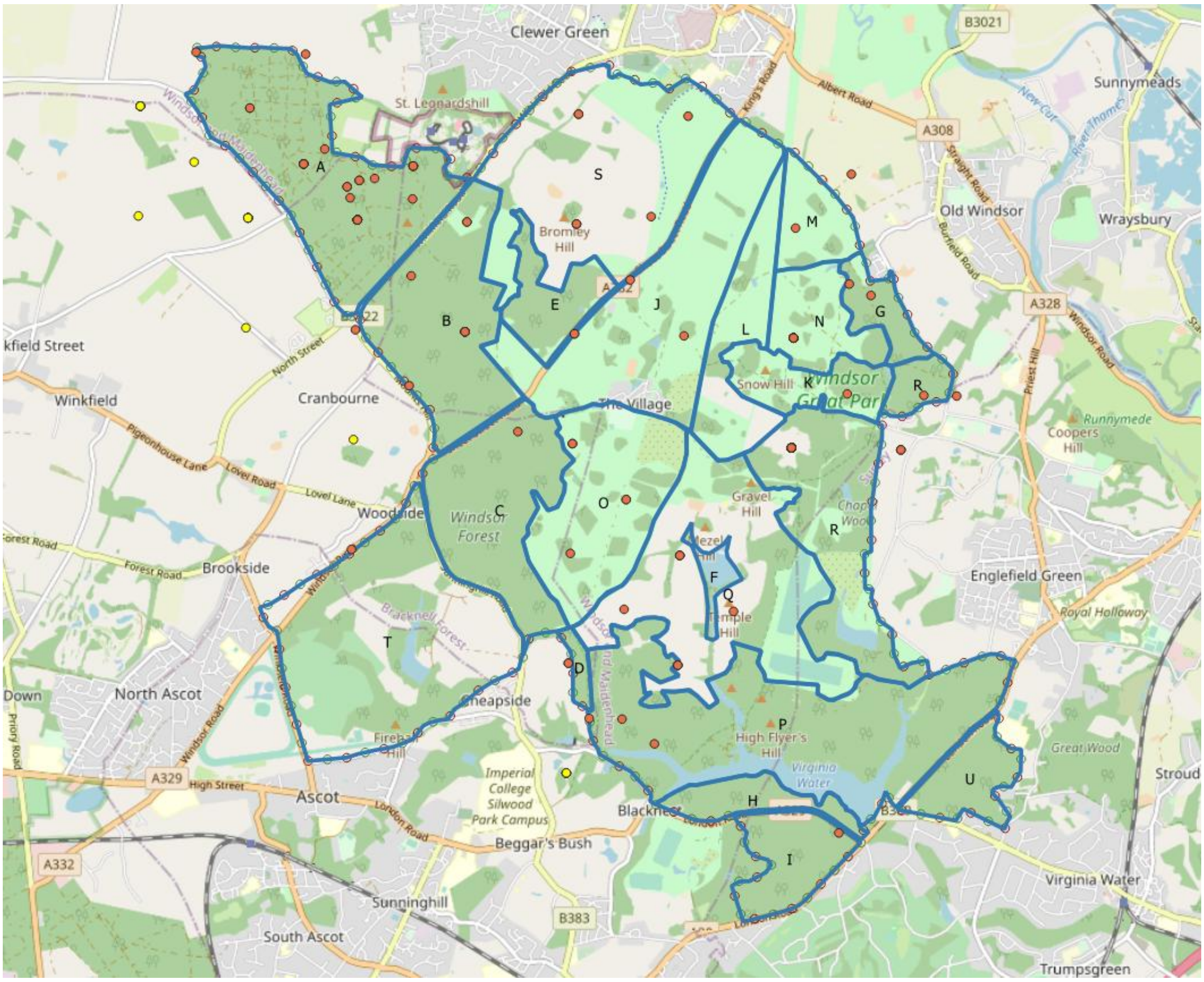



Figure 10. Distribution of Beech Deadwood assemblage

According to the available data, this assemblage was distributed across most of the compartments. Therefore, a SSSI designation based on this assemblage should include the entire park within its boundary.

## Oak Deadwood

(Saprotrophs of oak in parkland, wood pasture, or woodland)

16 species were used to assess sites for this assemblage. The threshold for SSSI selection was 8 of these species.

Assessed as a single site, Great Windsor Park had 15 species present, surpassing the threshold for this assemblage to be considered for SSSI designation. (See Appendix 14 for species list).

Figure 11. *Grifola frondosa, one of the indicator species for the Oak deadwood assemblage.*

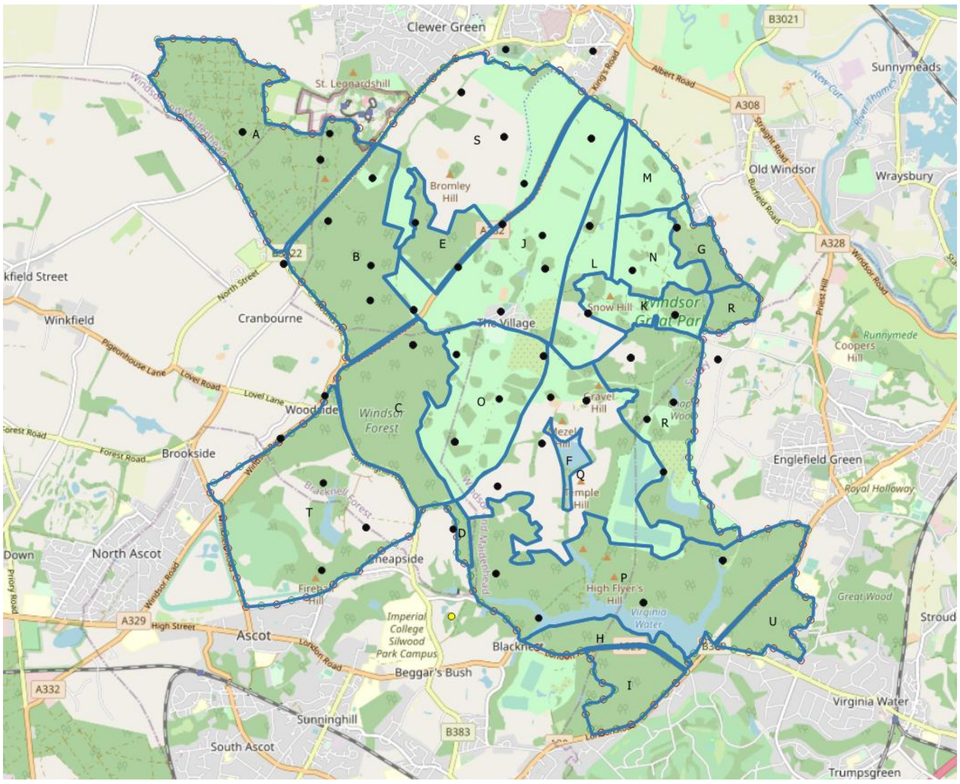



Figure 12. Distribution of the Oak Deadwood assemblage

According to the available data, this assemblage was distributed across most of the compartments. Therefore, a SSSI designation based on this assemblage should include the entire park within its boundary.

## Grassland fungi

(Nutrient-poor unimproved and semi-improved grasslands)

The grassland fungi assemblage was assessed against 5 groups of grassland species (divided by historic taxonomy) in the current guidelines for SSSI selection (Bosanquet et al, 2018).

Sites that meet or surpass the threshold for any one of these groups would warrant consideration for SSSI designation. The groups are:

Table 5. The genera and groups included in the grassland assemblage

| Common Group name | Group name | Included genera |
|---|---|---|
| Clubs, spindles and corals | Clavarioid fungi | Clavaria, Clavulinopsis, Ramariopsis |
| Waxcaps | Hygrocybe sensu lato | Cuphophyllus, Gliophorus, Gloioxanthomyces, Hygrocybe sensu stricto, Neohygrocybe, Porpolomopsis |
| Pinkgills | Entoloma sensu lato | Entoloma sensu lato |
| Earthtongues | Geoglossoid fungi | Geoglossum, Glutinoglossum, Microglossum, Sabuloglossum, Trichoglossum |
| Crazed caps, fanvaults and meadowcaps | Dermoloma etc. | Dermoloma, Porpoloma (Pseudotricholoma metapodium), Camarophyllopsis, Hodophilus |

### Clubs, spindles and corals

25 species/species aggregates were used to assess sites for this assemblage. The threshold for SSSI selection was 7 of these species/species aggregates.

Assessed as a single site, Great Windsor Park had 7 species present, meeting the threshold for this assemblage to be considered for SSSI designation. (See Appendix 15 for species list).

### Waxcaps

49 species were used to assess sites for this assemblage. The threshold for SSSI selection was 19 of these species.

Assessed as a single site, Great Windsor Park had 25 species present, surpassing the threshold for this assemblage to be considered for SSSI designation. (See Appendix 15 for species list).

### Pinkgills

There were over 200 species of Entoloma, (though not all are grassland fungi). The threshold for SSSI selection was 15 of these species.

Assessed as a single site, Great Windsor Park had 10 species present, although only 4 of these were relevant grassland species. Neither amount met the threshold for this assemblage to be considered for SSSI designation. (See Appendix 15 for species list).

However, with the large numbers of species present in other grassland fungi groups, it is most likely that this difficult genus is under-recorded in the park.

**Earthtongues**

18 species/species aggregates were used to assess sites for this assemblage. The threshold for SSSI selection was 5 of these species/species aggregations.

Assessed as a single site, Great Windsor Park had 2 species present, not meeting the threshold for this assemblage to be considered for SSSI designation. (See Appendix 15 for species list). However, any designation awarded to protect the other grassland fungi groups which met or surpassed their threshold would also protect the earthtongue group.

**Crazed caps, fanvaults and meadowcaps**

The threshold for SSSI selection was 3 of these species.

Assessed as a single site, Great Windsor Park had 2 species present, not meeting the threshold for this assemblage to be considered for SSSI designation. (See Appendix 15 for species list). However, any designation awarded to protect the other grassland fungi groups which met or surpassed their threshold would also protect the fungi in this group.

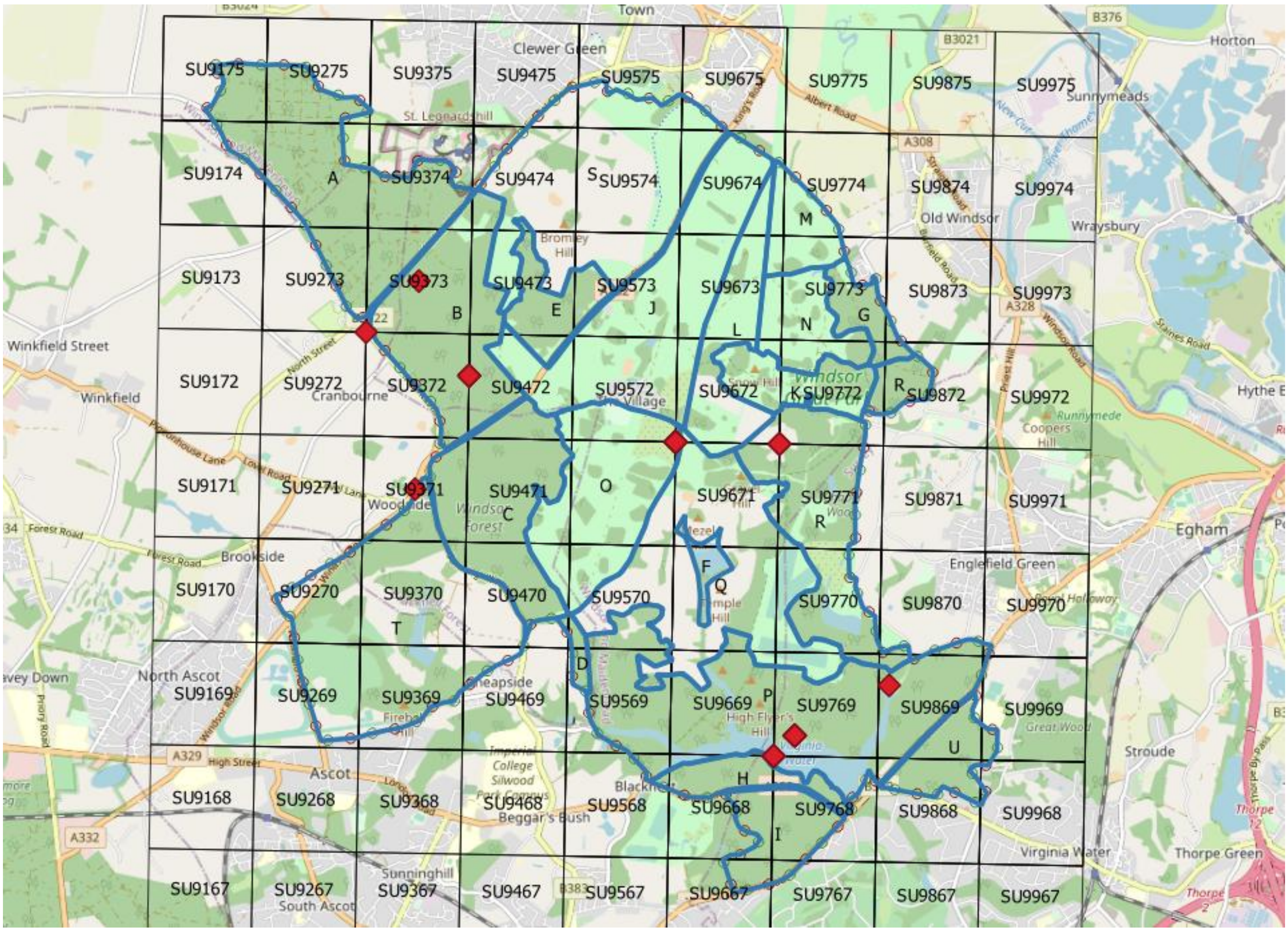


Figure 13. Mappable records of all grassland fungi in Great Windsor Park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Only 48 records of the combined grassland species had grid references that could be mapped in a useful way. These records shared only 9 coordinates across 7 1km grid squares, and only 5 gave more precise locations to within 100m. However, with the records widely distributed across the site, it would be most relevant to consider the entire park for designation for this group, as opposed to several more localised areas within the park.

### Boletes of wood pasture and parkland

(Thermophilous boletes: species of Boletaceae in warm, open sites with short ground cover; these tend to occur in open woodland or parkland)

An assessment for this group of fungi was not included in the current guidelines for the selection of biological SSSIs –Chapter 14, Non-lichenised fungi (Bosanquet et al, 2018) as "Very few species rich sites were known and all confined to southern England. The best sites were already designated SSSIs. It was therefore not considered a priority for further work", (Knowles, 2017).

However a draft version, for this group was included as Appendix 3 in the Draft SSSI Guidelines for Thermophilous Boletes in England (Smith, 2012).

In these guidelines, 25 species were used to assess sites for this assemblage. The threshold to be considered a 'High Priority Site' was 8 of these species.

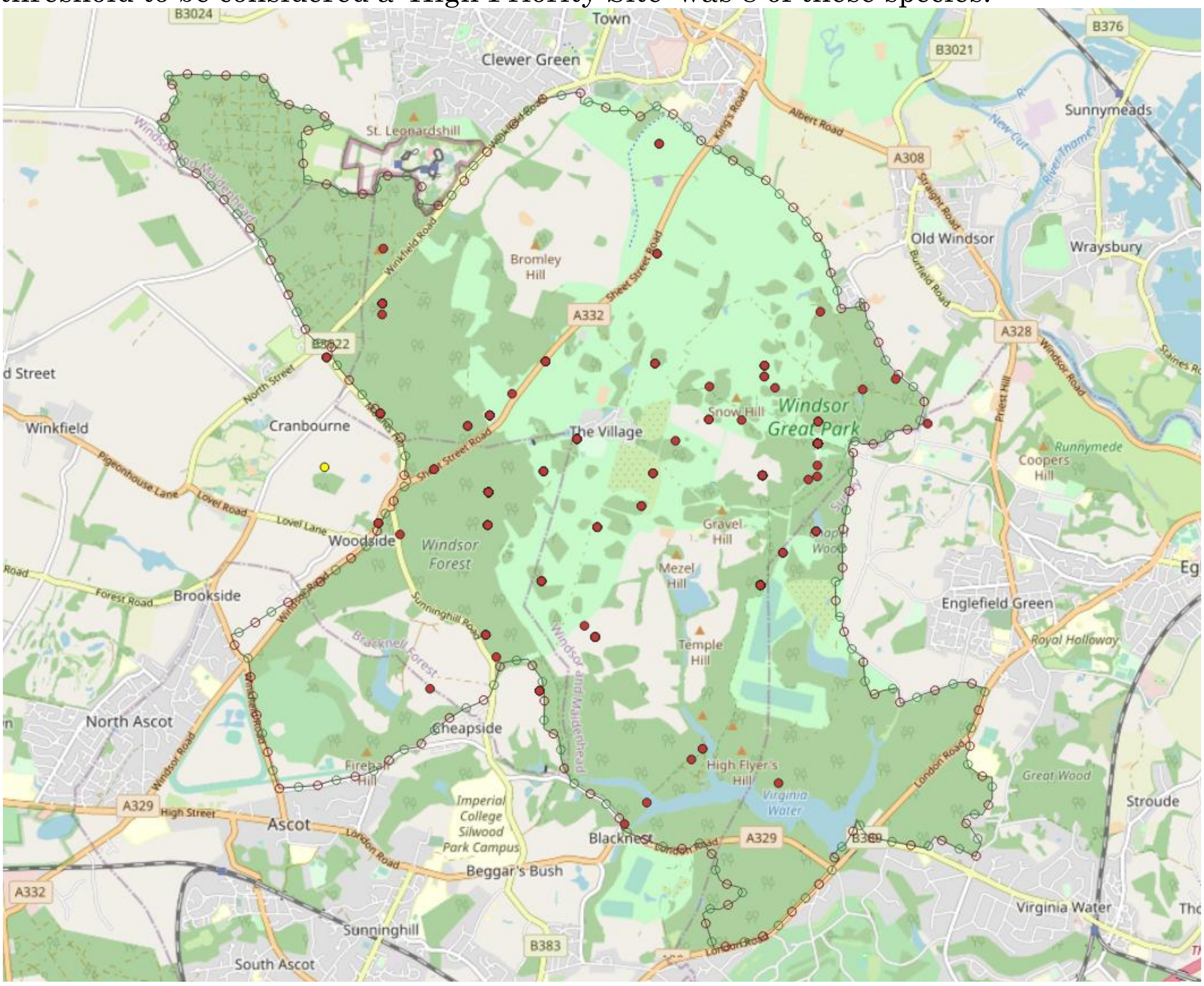


Figure 14. Distibution of Thermophilous Boletes in Great Windsor Park.

Assessed as a single site, Great Windsor Park had 22 species recorded as present since 1995, surpassing the threshold for this assemblage to be considered a 'High Priority site'. (See Appendix 16 for species list). Although only 6 species had been recorded in the last 10 years, which was a key factor in the guidelines.

In addition, all 4 of those designated as BAP/S41 species, (*Boletus regius, B. pseudoregius, B. immutatus, B. Rhodopurpureus/B. Torosus),* were recorded as present in the park historically, but only 2*, (B. immutatus, B. Rhodopurpureus/B. Torosus)* were recorded in the last 10 years. Unfortunately population sizes were not recorded with these finds, as this may have been another indicator for a 'High Priority Site'.

# Difficulties

The issues that hindered progress, or were beyond the scope of this project are listed here. They can be broken down into 4 types: Data quality, taxonomy, categorisation and mapping.

Data quality:

The quality of data in any given record was widely varied. Some were missing information from some or all important fields, others had all fields completed but with mistakes. Working through the dataset using filters could therefore only go so far, and much of the cleaning and correction had to be done manually, 1 record at a time.

Hundreds of erroneous and duplicated records were removed from the dataset provided with this project, however more could be done in a similar, manual way to find and remove more. 2 examples of this type of issue were:

- *Sphaerolea epilobii* – recorded on the same date, by the same collector, but with different grid reference resolutions, and subtly different information for 'medium' and 'notes'. In this instance, the latter two were deemed to be duplicates, and the record with the poorest grid reference was removed, (Table 6).

Table 6. A summary of potentially duplicate records of *Sphaerotheca epilobii*

| Current Name | Associated Organism | Medium | Ecosystem | Date | Grid Ref. | Locality | Notes |
|---|---|---|---|---|---|---|---|
| *Sphaerotheca epilobii* | *Epilobium montanum* | leaves | Waste-ground | 22/05/99 | | Windsor Great Park (Wick Lane) | Mostly conidial but a few cleistothecia present.*Pucciniastrum epilobii* also present on some of the leaves. |
| *Sphaerotheca epilobii* | *Epilobium montanum* | leaf, living | Waste-ground | 22/05/99 | SU986699 | Windsor Great Park (Wick Rd) | *Pucciniastrum epilobii* also present on the leaves. |
| *Sphaerotheca epilobii* | *Epilobium montanum* | leaves (living) | Waste-ground | 22/05/99 | SU9866 | Windsor Great Park (Wick Rd) | *Pucciniastrum epilobii* also present on the leaves. |

- *Lentinellus Ursinus* – recorded 4 times, 3 on the same day by the same collector, but one with a different person given as identifier. 2 different grid references/resolutions were given (2 records without grid refs.)... but both defined a location hundreds of miles away from the written description, which placed them near  to Virginia water at Windsor Great Park. The mistake could not be resolved which meant that although this red-data-listed species was included as present, it could not be mapped for the project.

- Some sources of records had so little detail, that it was not possible to rule them out as duplicates..

- It was apparent that some areas of the park have been a focus of more recording effort than others.  Although this may have been caused by accessibility issues, habitat preference, recorder bias etc., the outcome is still an incomplete picture of the fungi of Windsor Great Park.

- Another noticeable bias in the data was towards scarce, rare and designated species.  These fungi had been targeted for surveys in many years, which sometimes generated many more records for them than there were for the far more common species which would be expected to be recorded in greater numbers in those habitats.

Taxonomy:

Fungal taxonomy is in a state of upheaval as different groups and genera are examined more closely, and subjected to molecular studies.  While this project updated names to those currently in use, there were some instances where this became very difficult. Some typical examples of these types of issues were:

- *Boletus junquilleus* – there was more than 1 option for the new name of this species, which was split into other synonyms dependent on the reference literature (and therefore type description) by which it was identified.  As this information was lacking from the majority of records, it was beyond the scope of this project to unravel which species the original record then represented.  This might be done by contacting each recorder/confirmer, or checking voucher specimens when they were collected and kept.

- *Sarcodon scabrosus*  - historical records of this species from Great Windsor Park were re-identified as Sarcodon Sp.1 (with Fagaceae) and Sarcodon Sp.2 (Smith et al. 2016). However, associated organism data was not present for every record found, so the name *S.scabrosus* was left in the data for this project, with a comment in the notes column regarding current taxonomy.

- Lepiota echinatum – Some records were deleted as an incorrect name was given without enough information to correct them.  None of these were priority species.

Categorisation:

- The categories into which species were assigned for this study were not true categories based on fungal taxonomy and there were many instances where a single species could have fitted into more than one category. The ecological habit of *Mycena hiemalis* for example is dependent on the mossy trunks of mature broadleaf trees, although it is not directly dependent on rotting the wood of those trunks, it was categorised under 'Basidiomycete saprotrophs'.

- The process of categorisation was open to subjectivity. However, the same subjective divisions were made consistently throughout the dataset. For example, records were assigned to 'Resupinate Saprotrophs' according to the definition given in the Corticiaceae of Northern Europe (Hjortstam, 1987).

- Many species were recorded with misleading associated organisms or substrates which suggest the assigned category is incorrect. One example is *Podoscypha multizonata* which was recorded as 'in soil' and on grass, but was categorised as a 'Basidiomycete Saprotroph' in this study as this species is associated with the roots of 'Quercus or more rarely Fagus' (Overall & Mottram, 2006). No records were corrected to justify the category they were assigned to.

Mapping:

- As illustrated in Appendix 3, due to the poor resolution quality of many grid references, a large number of records (and the records of entire species) were lost when creating distribution maps. For the purpose of this study the use of 6 digit grid references was the best compromise between accuracy and exclusion of records.

- It will be possible to investigate the distributions of individual species using the data and shapefiles generated by this study, but the user should be aware of the acute loss of records in proportion to the accuracy of the location data.

- Some records were included as present, but not mapped. For example many records with the written location of 'Wick Road', which bisects Great Windsor Park, only had the 4-digit grid reference of SU9866. This incorrect grid reference refers to a location far from the park. In some instances the original recorder was traced for a correction, but when this was not possible the written location detail was not assigned a corrected coordinate, and so not mapped.

# Conclusion

At the time of this study, Windsor Great Park was host to a wide diversity of fungi, and featured many important, priority and protected species, some of which were restricted to only a very few locations.  The large number of records of these species was in part due to the historical continuity of relevant habitats, but also due to the concerted recording effort made by many mycologists over many years.

Although Windsor Great Park had a comparably high quantity of fungal records, many of these were of poor quality, giving little of the additional information that would be needed to assess or map them in greater detail.

Figure 15. Deadwood hosts in Great Windsor Park. © Solomiia Kratsylo

This desk-study found 1,330 species of fungi from 582 genera were recorded in the park over the last 50 years. Of these, 59 were priority and red-listed species (Appendix 1), and 446 species were the target, wood-rotting fungi.

Compartment A had by far the highest number of records of target species within it, although this figure was skewed by the high number of records relating to surveys of priority species.  Compartments P, B, C and N had the next highest number of records of target species in descending order (Table 4).

Fagus and Quercus were identified as the host tree species with the greatest amount of associated target deadwood records (Chart 4).

This study reconfirmed the importance of Great Windsor Park for fungi.  The desk-study stage of assessments for SSSI consideration passed the thresholds for broadleaf tooth fungi, beech deadwood, oak deadwood, and grassland fungi.  The park had a designation for its Fungi Assemblage, but it would be advisable to compare the current management policies with those that would benefit the specific needs and habitat requirements of the four assemblages listed here.

# Further monitoring

The records for fungi in Windsor Great Park betray a number of biases, and a lack of detail common to many fungi records across the UK.

It is only possibly to create useful distribution maps with a minimum of 6 digit grid references (100m$^2$), yet only 40% of records found in this study had grid references to this resolution. To adequately monitor scarce and priority species grid references of 8 digits (10m$^2$) or 10 digits (1m$^2$) are required to locate/relocate potentially lone specimens.

Almost as important, but often absent details are 'associated organism' and 'substrate', although there are others. Having information about the associated organism, (tree species for the purpose of this project) can be vital to correcting a misidentification, or resolving taxonomic changes (see Difficuties:Taxonomy, above).

The following list should be used as baseline for future recording surveys, and is to be encouraged in local amateur recorders to give their often hard-won records more value:

- A 6 digit grid reference minimum for all recorded finds
- An 8 or 10 digit grid reference minimum for species targeted for monitoring.
- The associated organism should be recorded for all finds

The following groups would benefit from targeted, or ongoing surveys as this study indicates they are either under-recorded, or not recently recorded in Great Windsor Park:

- Grassland fungi, (targeting Entoloma and Geoglussum which appear at different times of year)
- Thermophilous boletes (Boletes of Parkland and wood-pasture)
- Saprophytic ascomycetes (Pyrenomycetes and Discomycetes)
- Resupinate saprotrophs (Corticioid fungi)

Ideally, all red-listed and priority species should be resurveyed to get up-to-date and exact grid references, this will make future monitoring of those species more practical.

Appendix 11 lists specialised habitats for fungi that are considered to be important, but which do not yet have scoring systems for SSSI consideration. Any of these habitats that are present in Great Windsor Park should be surveyed for fungi. As with most fungal monitoring, a single autumnal survey should be considered a minimum, with repeat surveys at different times of year, over several years being the only way to get a true picture of the wider fungal community at any given site..

Compartments with no (mapped) records of fungi should be prioritised for surveys, before also surveying compartments with less than 10 and less than 50 records (Table 7).

Table 7. Number of fungi records per compartment. Red = 0, Orange = <10, Yellow = <50 records.

| Compt.ID | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. of records | 173 | 90 | 85 | 0 | 42 | 0 | 22 | 0 | 2 | 68 | 5 | 30 | 2 | 59 | 31 | 114 | 42 | 69 | 81 | 6 | 0 |

Traditionally, surveys for fungi were carried out by trained mycologists who will have spent many years building up their identification skills both in the field and the lab. The fruiting bodies of the fungi are sought at the times of year they are expected to be produced by the fungi which is usually present in the substrate year-round.

This method can be hindered by many factors, but some key ones are: The skill-level of the field-worker, the cryptic nature of fungi, and the irregular fruiting of some species.

In recent years, a growing number of surveys have been completed by carrying out molecular work using environmentally sourced DNA samples (eDNA).

This method has had some proven success on grassland fungi surveys, where the eDNA studies revealed more species of notable fungi than traditional field studies had. (Griffiths et al, 2019).

There can be considerable appeal of a survey method that involves collecting a sample of the woody substrate of any target tree, then sending this 'to a lab where the eDNA can be separated, sequenced and identified before producing a list of all recognised species (even those which do not appear to fruit regularly/at all). However, there are some issues too:

- Many species of fungi (particularly microfungi) have no/no reliable sequences on record for comparison (Yahr et al, 2016).
- With an increase of eDNA surveys, the sequences of new, unnamed species are continually being discovered (Hibbert et al, 2011) It is possible that find fruitbodies may not be found to match these species.

Both of these situations are likely to improve, or be countered over time making eDNA surveys increasingly viable. In the meantime, Frøslev et al, (2019) found that when comparing surveys of soil fungi communities, "The fruitbody survey was slightly better in finding red-listed species", and that although

"more species (OTUs) were detected by eDNA-metabarcoding than by the classic fruitbody survey. This could mainly be attributed to the detection of groups, which always go undetected in a fruitbody survey, e.g. diverse groups of moulds and yeasts".

This suggested that for the purpose of carrying out the surveys that will inform woodland management and gauge site condition; traditional fruitbody searches for rare and priority species will continue to be more valuable than eDNA surveys.

However, eDNA surveys of signature trees and deadwood in Great Windsor Park will reveal more species and cryptic species that may eventually prove to be priority species of the future, so these surveys should be taken opportunistically. In the meantime, the general management of vintage tree specimens and deadwood in the park will continue to protect these as yet unknown species.

All surveys proposed here should be repeated for monitoring purposes every 5 years for priority species, and every 10 years for other fungi, (except when habitat has become damaged or destroyed, at which point monitoring should be carried out at that time).

# Management recommendations

The species of wood-rotting fungi that are noted and/or protected rely on the wood of large, dead boughs and trunks of standing and fallen trees, as well as the heartwood of standing, living trees. The most important trees for these fungi are usually the largest, and therefore the oldest specimens, although the next generation of these trees is also vital to the continuity of this fungal assemblage.

Maintaining veteran trees in wood and parkland should rely on low levels of practical management. However a baseline survey of the quantity and distribution of veteran trees (alive and dead) as well as fallen veteran trees and large pieces of deadwood should be conducted.

Maintaining a supply of deadwood may be vital to these populations of saprophytic fungi, but the felling of veteran trees should be avoided at all costs. Naturally occurring damage and death will provide enough resources and habitat, so long as the site is not allowed to shrink in size and that trees of a range of ages are always available to become recruited as the new veteran specimens.

Existing veteran trees should therefore be allowed to age and deteriorate naturally, including the dropping of limbs and hollowing of the trunk, all of which will extend the life of the tree and provide resources for the priority fungi.

Where possible, paths should be rerouted away from these trees so that they do not need to be felled for health and safety reasons. When this is not possible, the canopy should be reduced and/or offending limbs should be removed with all debris left in situ, or moved to a suitable location on site.

In areas of dense closed canopy (often typical of historical plantation, with trees of the same age), individual trees should be selected as 'future-veterans', and a ring of the surrounding trees should be removed to allow the chosen specimen to spread as it grows to fill the cleared space. All large debris should be left in situ or moved to a suitable location on site.

Where necessary and relevant, new trees should be planted in the park. While Quercus and Fagus should be prioritised, Appendix 10a and 10b should be used as a reference to identify other important tree species for saprophytic fungi.

Some ectomycorrhizal species of priority fungi also rely on ancient woodland habitats. To avoid the risk of damage or destruction of these fungal communities, care should be taken when working in these areas with heavy machinery (e.g. when removing non-native species). Where possible mats should be used to spread the weight of plant machinery which will avoid compaction of the ground, and the fungi within it. When it is necessary to uproot entire plants in these areas, soil should only be disturbed at each necessary location, (as oppose to scraping the surface away while working between several nearby locations).

# Bibliography


Ainsworth, A.M. (2004). English Nature Research Reports Number 600 BAP fungi handbook, English Nature

Ainsworth, A.M., Smith, J.H., Boddy, L., Dentinger, B.T.M., Jordan, M., Parfitt, D., Rogers, H.J., & Skeates, S.J., 2013. *Red List of Fungi for Great Britain: Boletaceae; A pilot conservation assessment based on national database records, fruit body morphology and DNA barcoding* Species Status 14. Joint Nature Conservation Committee, Peterborough.

Bailey, D., Bailey, J., Davies, K., Davies, V., Hayward, L., Jordan, M., & Nichol, P., 2015. *Red List of Fungi for Great Britain: Geastrum, Myriostoma, Sphaerobolus, Bankera, Boletopsis, Hydnellum, Phellodon, Sarcodon, Cantharellus, Craterellus, Pseudocraterellus, Dentipellis, Hericium, Laxitextum, Battarrea, Bovista, Lycoperdon, Piptoporus, Tulostoma.*

Beker, Henry & Eberhardt, Ursula & Schütz, Nicole. (2017). *Hebeloma in the United Kingdom.* Field Mycology. 18. 119-132. 10.1016/j.fldmyc.2017.10.005.

Bosanquet, S.D.S., Ainsworth, A.M., Cooch, S.P., Genney, D.R, & Wilkins, T.C. 2018. *Guidelines for the Selection of Biological SSSIs. Part 2: Detailed Guidelines for Habitats and Species Groups. Chapter 14 Nonlichenised Fungi*. Joint Nature Conservation Committee, Peterborough.

https://www.buglife.org.uk/projects/ancients-of-the-future-project/ [Accessed 20/02/20]

Conservation Designations for UK Taxa 2020,. jncc.defra.gov.uk. Joint Nature Conservation Committee. Accessed 03/02/20

Crawley MJ (2005), The Flora of Berkshire. Brambleby Books, Harpenden.

Davies, V., Jordan, M., & Nichol, P., 2016. Red List (2) of Fungi for Great Britain

Davies, V., Jordan, M., & Nichol, P., 2017. Red List (3) of Fungi for Great Britain

Davies, V., Jordan, M., & Nichol, P., 2017. Red List (4) of Fungi for Great Britain

ELLIS, M. B., & ELLIS, J. P. (1997). *Microfungi on land plants: an identification handbook*. Slough, England, Richmond Pub.

Evans, S.E, Henrici, A., Ing, B., 2006. *Preliminary Assessment: The Red Data List of Threatened British Fungi*. https://www.britmycolsoc.org.uk/application/files/2013/3537/5755/RDL_of_Threatened_British_Fungi.pdf. [Accessed 04/02/20]

Friebes, G., & Wendelin, I., (2015). Wer suchet, der findet: Seltene und interessante Ascomycota vom Jägerberg (Steiermark, Österreich) [Seek and you shall find: rare and interesting Ascomycota found on Jägerberg (Styria, Austria)]. Joannea Botanik. 12. 5–38.

Frøslev T.G., Kjøller R, Bruun HH, Ejrnæs R, Hansen AJ, Læssøe T, et al. (2019). *Man against machine: Do fungal fruitbodies and eDNA give similar biodiversity assessments across broad environmental gradients?* Biol Conserv. 2019;233:201–12.

Green, E., (1997): A Biological Record of Windsor Great Park and its Environs. English Nature, Newbury

Griffiths, G.W., Cavalli, O. & Detheridge, A.P. 2019. *An assessment of the fungal conservation value of Hardcastle Crags (Hebden Bridge, West Yorkshire) using NextGen DNA sequencing of soil samples*. Natural England Commissioned Reports, Number 258

Hibbett, D.S., Ohman, A., Glotzer, D., Nuhn, M., Kirk, P., Nilsson, R.H. (2011)*Progress in molecular and morphological taxon discovery in Fungi and options for formal classification of environmental sequences*. Fungal Biol. Rev. **25**, 38–47.

Hjortstam, K., Larsson, K-H., and Ryvarden, L. (1987), *The Corticiaceae of North Europe: Volume 1 Introduction and keys.* P.7. Fungiflora

Hugill, P., Lucas, A. (2017), *The Resupinates of Hampshire*, Pixart Printing

https://www.iucnredlist.org/search [Accessed 04/02/20]

Ing, B., 1992. *A Provisional Red Data List of British Fungi*. The Mycologist 6: 124–128.

Jaklitsch, W., Fournier, J., Dai, D., Hyde, K. & Voglmayr, H., (2015). Valsaria and the Valsariales. Fungal Diversity. 73. 10.1007/s13225-015-0330-0.

Jaklitsch, W. & Voglmayr, H. (2016). *Hidden diversity in Thyridaria and a new circumscription of the Thyridariaceae*. Studies in Mycology. 85. 10.1016/j.simyco.2016.09.002.

Knowles, C. and Wilkins, T.C. (2017). *Development of SSSI Selection Guidelines for Macrofungi – report of workshop proceedings*. Natural England, York. Unpublished

Knowles, C., *Final report on the Fungi of Great Windsor Park, Study for Buglife – Back from the Brink*, (2020). Unpublished

Larsson K-H, Svantesson S, Miscevic D, Kõljalg U, Larsson E (2019) *Reassessment of the generic limits for Hydnellum and Sarcodon (Thelephorales, Basidiomycota*). MycoKeys 54: 31-47.

Lewis, J., *Windsor Forest and Great Park, Nature Conservation Priority Areas - A Focus for Future Management*, English Nature (1999).

Nature Back from the Brink (2019). (https://naturebftb.co.uk/the-projects/ancients-of-the-future/) Accessed 04/10/2019

Ordnance Survey. (2019). *Windsor Great Park (tile SU, 1:50 000).* Retrieved from https://osmaps.ordnancesurvey.co.uk/51.44081,-0.61745,14, 09/09/2019

Overall, A., Mottram, K., (2006) *Podoscypha multizonata* – Zoned rosette. Field Mycology 7(3)

Rinaldi, A.C., Comandini, O. And Kuyper, T.W. (2008). *Ectomycorrhizal fungal diversity: separating the wheat from the chaff*. Fungal Diversity 33: 1-45.

Schedule 8, Wildlife and Countryside Act 1981. http://www.legislation.gov.uk/ukpga/1981/69/schedule/8 [Accessed 03/02/20]

Section 41 Species - Priority Actions Needed (B2020008). http://publications.naturalengland.org.uk/. Natural England. October 2013. [Accessed 03/02/20]

Smith, J.H. 2012. Identifying Key Fungal Sites in England with Potential for SSSI Notification. Unpublished draft report for Natural England.

Smith, J., & Suz, L., & Ainsworth, A.M. (2016). *Red List of Fungi for Great Britain: Bankeraceae, Cantharellaceae, Geastraceae, Hericiaceae and selected genera of Agaricaceae ( Battarrea, Bovista, Lycoperdon & Tulostoma) and Fomitopsidaceae (Piptoporus). Conservation assessments based on national database records, fruit body morphology and DNA barcoding with comments on the 2015 assessments of Bailey et al.*

Species Fungorum, http://www.speciesfungorum.org/ [Accessed 14/01/20]

UK BAP priority species and habitats. https://jncc.gov.uk/our-work/uk-bap-priority-species/. Joint Nature Conservation Committee. Accessed [03/02/20]

UKSI (Natural History Museum) https://www.nhm.ac.uk/our-science/data/uk-species.html [Accessed 14/01/20]

Yahr R, Schoch CL, Dentinger BTM. (2016). *Scaling up discovery of hidden 775 diversity in fungi: impacts of barcoding approaches*. Philos Trans R Soc 776 London B Biol Sci 371: 1–11.

Zhang, Y., Fournier, J., Pointing S.B and Hyde, K.D. (2008). *Are Melanomma pulvis-pyrius and Trematosphaeria pertusa congeneric?* Fungal Diversity 33: 47-60.