Baseline Fungal Survey For Findhorn Hinterland Trust

Bankera (Phellodon) fuligineoalba. L Holden

Report to Findhorn Hinterland Trust November 2020

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SUMMARY OF MAIN FINDINGS

- Areas of sheltered bare sand in the dune heath supports the rarely recorded, sand specialist *Sabuloglossum arenarium* alongside *Clavaria argillacea* (the latter a much commoner species thought to have an association with *S. arenarium*).

- The Scottish Biodiversity List (SBL) rust fungus, *Pucciniastrum goodyerae,* was found on creeping lady's tresses in the pine wood. The survey area is one of only a handful of sites, where this species occurs in the north east of Scotland.

- The interface of the pine plantation and the dune heath supported a number of pine associating species including SBL and UKBAP priority species *Bankera* (*Phellodon*) *fuligineoalba. Suillus flavidus* and five *Tricholoma* species, all considered to indicate old growth pine woodland, were limited in fruiting to this area.

- Three rarely recorded but data deficient species (*Agrocybe pusiola*, *Hygrophoropsis rufa* and *Leratiomyces ceres*) were found on site. Their appearance here is of interest but their true rarity in the UK is not known.

- Whilst none of the habitats surveyed passed JNCC thresholds as justification for consideration as SSSI status, there were some species present that suggest that the dune heath, the grassland and part of the pinewood could be managed to develop a future mycota of more interest.

INTRODUCTION

The habitats that make up the land managed by the Findhorn Hinterland Trust are underpinned by the sand and pebble deposits of longshore drift. The current vegetation includes extensive areas of gorse with some areas of open grassland in part grazed by ponies, lichen rich dune heath and an area of pine plantation with areas of natural tree regeneration following windthrowat part of the northernedge and also along the interface with the dune heath.

Most of the land is within an Area of Great Landscape Value (AGLV), a Coastal Protection Zone (CPZ) and a Site of Interest to Natural Science (SINS).

The Findhorn Hinterland Trust Management Plan (Piper 2019) outlines the complexity of recent ownership of the area known locally as the 'Hinterland'. The area surveyed in this document is solely that now belonging to and/or managed by the Findhorn Hinterland Trust (Appendix 1) with passing reference to the fungal interest in areas of pine regeneration on the dune heath owned by the Findhorn Dunes Trust.

Most of the habitats involved have been created relatively recently. It is understood that the area was extensively used in World War 2 and a number of aircraft were dismantled on site. Subsequently the area was used for dairy farming with grazing keeping the gorse in check. The pine woodland was planted in the 1950s and 60s. By 1997, when the Wilkie family sold this ground to Duneland Ltd., gorse was already extensively established. The least disturbed areas are those of the lichen rich dune heath.

LIMITATIONS

The difficulty of working with fungi is well documented and laid out in Bosanquet et al (2018) as follows:

- Fungi are primarily cryptic organisms living within substrates e.g. within soil, dead wood or living plants, and are only detectable by field mycologists/surveyors when they (often irregularly) produce fruitbodies and/or spores. Our knowledge of the distribution and status of many species is based on above-ground, macroscopic fruitbody appearance despite recent advances in molecular techniques, and many fungal species are therefore 'under recorded' and difficult to evaluate.
- For most species, the appearance of fruitbodies is erratic, unpredictable and usually of short duration. They are not necessarily produced every year and when they are, they may only remain for a few days.
- The abundance of fruitbodies and their frequency of production does not necessarily reflect the number of fungal individuals living within the substrate. Routine detection of different fungal individuals within a naturally occurring population is in its infancy. It is not currently possible to define the number of fungal individuals which constitute a viable population size for site selection, nor to provide a standard method of assessment in the field.
- Most fungi require microscopic examination to confirm their identification. This is increasingly being augmented by DNA-based checking as appropriate reference sequences become available.
- DNA studies are revealing 'cryptic taxa': the existence of a number of genetically distinct entities that look morphologically identical. To facilitate field recording and site evaluation, it is sometimes preferable to treat cryptic taxa as belonging to an aggregate of species.
- Although there has been an encouraging increase in the number of skilled field mycologists in recent years, there are still relatively few people who are able to identify fungi accurately, particularly in habitats other than grassland and some types of woodland. Moreover, skills in microscopy and laboratory analysis are as essential as field skills for the identification of many fungal groups and confirmation of records usually involves input from more than one mycologist.
- Data on the distribution of many species is inadequate, so it is sometimes difficult to determine what is rare and what is merely rarely recorded.

METHODOLOGY

Survey techniques: There are currently no tested and useable methodologies to assess the fungi from their mycelia using DNA techniques.

Much consideration has been given as how best to assess fungal diversity using fruitbodies. To quantitatively establish the fungal diversity and assess changes over time would require large, permanent, subdivided plots to be set up in each area of habitat with around six visits to each plot (Holden et al 2001). This approach was considered to be outwith the funding available for this survey.

Currently, the most frequently used approach to surveying fungi is based on a random survey effort using the surveyor's experience of habitats. The species recorded during the visit can be assessed as

species indicating sites likely to be rich in fungal biodiversityand worthy of SSSI status. In the case of Findhorn, pinewoods, grassland and dune systems have been assessed for species indicating high fungal diversity (Bosanquet et al 2018). In addition, species can be assessed against priority and red lists.

Red list species: The red listing of fungi is far from straightforward. Quite apart from the lack of agreement over use of available data by the recording bodies involved, only a small percentage of the fungal genera have been assessedand there remain taxonomic uncertainties. There are some species, even within those genera assessed, still not considered and it is also possible that some recent red listings reflect under-recording or rare fruiting rather than true rarity of the organism.

The situation is further complicated by the ecology of the fungi themselves, as outlined in 'Limitations' above. The presence of a fruiting structure does however, indicate the presence of the organism and there do appear to be distinct distribution patterns. As with many other organisms, the average temperatures and rainfall patterns and the underlying geology will impact on distribution, but fungi, because of their functional modes, are often also intimately linked to the presence of the host / partner organism or the presence of coarse and / or smaller items of woody debris.

A number of red list assessments have been independently published and although not endorsed by JNCC, they use IUCN criteria and are referred to here. Given the importance of the fungal kingdom to the health and wellbeing of all habitats, it is vital that we include them in conservation actions.

Site visits: Three visits to the site were made (Sept. 4th, Sept. 19th and Oct.15th 2020) and for each visit the author was accompanied by Alan Watson Featherstone (AWF). The first visit was for familiarisationand Timothy Finnegan of Findhorn Dunes Trust, an adjacent land manager, was also present. The third visit was accompanied by lichenologist Heather Paul and for part of the day by members of the Findhorn Hinterland Trust. A random survey approach was taken, guided by the site knowledge of AWF and the surveyor's experience. All macro fruitbodies seen were recorded and some fruitbodies were removed to enable identification with a microscope and keys. Microfungi (i.e. not visible to the naked eye) and corticioid species were not targeted.

In addition to the site visits, a number of collections were photographed, dried and sent to the author for identification by AWF. These records have been added to the collections made in the field and contribute to the species list known to date (Appendix 2).

RESULTS

A total of 196 records from Findhorn Hinterland were made comprising 142 species recorded during 3 site visits. A further 36 species have been recorded following examination of dried and photographed material sent by AWF to the author during the period from Oct 2018 toOct 2020. In total 178 species are known from this site, a figure that will undoubtedly increase as further recording takes place and also as habitats change. These figures include four species added to the list subsequent to the analysis below. They do not change the substance of the report.

Functional Mode

It is important to understand the way that fungi get their nutrition (unlike plants, they do not photosynthesise) to appreciate how the fungi are functioning on any site and how the habitats and their management will impact on fungal fruiting diversity.

It is thought that a little under half of the kingdom lives symbiotically with other living organisms. The word 'mycorrhizal' encompasses many of these symbiotic fungi and can take different forms. Ectomycorrhizal fungi in general, produce above ground fruiting structures and these are the mycorrhizal species referred to in this survey.

The other approximate half of the kingdom is comprised of species that recycle already dead plant and animal material; the saprotrophs. Fungi are the only organisms that can breakdown lignin and are thus major contributors to the carbon cycle.

Relatively few species are considered parasitic i.e. utilising living plant or animal material. This word has very negative connotations and should be used with great care. In some instances it is likely that the 'parasite' will confer an advantage to its host – that advantage may not be immediately apparent and a lot more work is required to validate this claim; in such cases, the use of the word 'parasite' might need revision. In the wild wood, aggressive colonisers that cause the death of trees and plants are a part of the natural order and generally such species only colonise a tree / plant when its own defences are compromised.

Table 1 shows the spread of species by functional mode on this site. When undertaking survey work in older woodland habitats, the author would expect there to be roughly equal numbers of ectomycorrhizal and saprotrophic species. At Findhorn there are far more saprotrophs (mostly litter recyclers) than ectomycorrhizal – 24% : 69%.

The reasons for this are connected to the nature of the habitats present with a relative lack of differently agedhost species. The abundance of humicolous saprotrophs is a reflection of the varied plant cover present whilst low numbers of lignicoloussaprotrophs reflects the paucity of dead wood on the site.Ectomycorrhizal species will only occur in dune heath and grassland if there are host species present and if woodland colonisation is not encouraged, such hosts will continue to be few.

Table 1: Fungal species by Functional Mode

Functional Mode	**Number of species**	**% of total**
Mycorrhizal – Ecto	41	24
Lignicolous saprotroph	32	18
Humicolous saprotroph	89	51
Parasite	12	7
Total	**174**	**100**

Assessment of Fungal Interest by Habitat

Pinewoodplantation: the main area of pinewood known as Wilkie's Wood was planted in the 1950s and 60s and comprises a mix of Scots, lodgepole and Corsican pine. Windthrow at the eastern endhas led to small areas of natural regeneration (including pine and birch) whilst at the western

end, the plantation borders onto the dune heath and again pine regeneration is taking place. The main area of the plantation did not contain any pinewood indicator species although the rust *Puccinastrum goodyerae* growing on *Goodyera repens* (creeping lady's tresses) was found here. Whilst the host plant is found throughout pinewoods in Scotland, this rust is known only from the north east of Scotland and care should be taken to maintain a suitable habitat for the host plant. One other species of interest is *Clitocybe diatreta*, a conifer litter decomposer, rarely recorded but possibly overlooked. *Inocybe subcarpta* was found in this location and is considered vulnerable in the red listing (Table 5); this species is almost certainly under-recorded.

Peripheral to the existing pinewood plantation along the northern edge, a windthrow event took place around 15 years ago. Since then, natural regeneration of birch and some pine has taken place. The birch adds to the fungal diversity both mycorrhizal and saprotrophic; the greater the native tree diversity that develops on the site, the greater the mycological diversity will be. *Hebeloma sordescens* was recorded here; this species is red listed but almost certainly under-recorded.

The interface with the dune heath on the northern edge of the pinewood, is of particular interest. Here the pines are regenerating in the nutrient poor sand and pebble substrate. In this area, growing in association with the pines, are a number of old growth pinewood indicator species, including the SBL and UKBAP Priority species *Bankera fuligineoalba* (recently moved into the genus *Phellodon*). This is one of a group of tooth fungi associated with bare mineral soils in well established pinewoods (see 'Discussion' below). Of interest to note is another SBL tooth fungus growing nearby (NJ05626430) on Findhorn Dunes Trust land, *Sarcodon squamosus*. These two species were fruiting alongside five members of the genus *Tricholoma* (Table 4) – all species associated with long established pinewoods.

Tricholoma equestre. L. Holden

Table 2 shows that the fungal species in the pinewood at Findhorn do not however, reach the threshold for consideration as an SSSI given by Bosenquet et al (2018).

Table 2: JNCC Pinewood Assemblage Thresholds applied to Findhorn Hinterland Trust Ground

	Threshold 9 or more	**Additional species of interest**
Findhorn species recorded	4 Bankera (Phellodon) fuligineoalba Suillus flavidus Tricholoma equestre Tricholoma focale	3 Tricholoma albobrunneum Tricholoma pessundatum Tricholoma stans

Dune Heath:

Extensive areas of dune heath on the survey site with impoverished, mineral soils (a mix of sand and pebbles) are known to be important for their lichen assemblage. The JNCC criteria (Table 4) are intended for sand dune systems which only form a small part of the survey area and unsurprisingly the site did not reach the threshold for consideration as an SSSI. Nevertheless, three dune specialists were found (Table 3) and whilst *Hygrocybe conicoides* is regularly recorded in sandy situations, recording of the other two is much rarer. In addition there was a record of *Agrocybe pusiola* – a sand dune species that was only recognised as British in 2020 and is known from dune systems in Wales. It does not feature in the dune assessment speciesand only further investigation will show whether this species has been previously overlooked or whether it is a truly rare fruiter.

The fungal interest of the interface of this habitat with the pine wood is presented under 'Pinewood plantation' above and in 'Discussion' below.

Table 3: JNCC Dune Assemblage Thresholds applied to Findhorn Hinterland Trust Ground

	Threshold 10 or more
Findhorn species recorded	3 Hygrocybe conicoides Psathyrella flexispora Sabuloglossum arenarium

Sabuloglossum arenarium with *Clavaria argillacea* (A. Watson Featherstone)

Grassland: The community of fungi that have specialised in long established, low input, short sward grasslands (managed by either grazing or mowing) are recognised as being excellent indicators of the conservation value of this habitat (Spooner & Roberts 2005). This community of fungi includes members of the groups Clavariaceae (fairy clubs), *Hygrocybe* (waxcaps), *Entoloma* (pinkgills), Geoglossaceae (earth tongues), *Dermoloma* (crazed caps), *Porpoloma* (meadowcaps) and *Cuphophyllus* (fanvaults). For ease these are often collectively referred to as CHEG species and their supporting habitat as 'waxcap grassland'.

It is widely accepted that waxcap grasslands, as a habitat, are threatened across Northern Europe by a mixture of human activities. These include agricultural improvements (primarily ploughing, reseeding and fertilising), and management changes, including housing or other development schemes or reversion to a woodland situation, either by natural regeneration or planting schemes. Bosanquet et al (2018) in the JNCC guidelines for biological SSSIs, state the following:

"*Sites rich in grassland fungi are scarce and threatened on a world scale, and the extent of this habitat in northern Europe has declined dramatically (Veen et al., 2009). Relative to these losses, Britain retains a high number of species-rich waxcap grasslands (Newton et al., 2003; Evans, 2004; Griffith et al. 2013), for which we clearly have an international responsibility*."

There are small areas of semi-improved grassland at the eastern end of the site. Much of the grassland at Findhorn is currently ungrazed and the grass is rank. In general, it is well above the 3cm height that produced the best fruiting results in field mowing experiments conducted by Griffith et al (2011). Limited numbers of waxcap grassland species were recorded in mown verges and in the short grazed pony fields but Table 4 shows that none of the grassland surveyed reached any of the thresholds for consideration as an SSSI given by Bosenquet et al (2018).

Table 4: JNCC Grassland Assemblage Thresholds applied to Findhorn Hinterland Trust Ground

	Waxcap species Threshold 19 or more	**Clavarioid (clubs and corals) Threshold 7 or more**	**Geoglossoid (earthtongues) Threshold 5 or more**	**Entoloma (pinkgills) Threshold 15 or more**	**Other grassland spp Threshold 3 or more**
Findhorn species recorded	6 Hygrocybe cerecea Hygrocybe conica Hygrocybe insipida Hygrocybe (Gliophorus) laeta Hygrocybe miniata Hygrocybe (Gliophorus) pscittacina	2 Clavulinopsis helvola Clavulinopsis luteoalba	1 Geoglossum glutinosum	1 Entoloma sericeum	0

Gorse scrub: As grazing and the collection of gorse for firewood decreased across the site, the areas of gorse have expanded and now form robust stands across much of what would have been grassland. Some areas have been cut back with the brash left to decompose, this has provided an opportunity for large numbers of *Psathyrella cf noli-tangere* and *Tubaria furfuracea* to colonise this new decomposition opportunity. As with the colonisation of woodchips, some species of fungi are able to quickly take advantage of a new micro habitat before a more 'normal' balance of competition becomes established. These species will gradually reduce their fruiting as the substrate is exhausted of nutrients.

Gorse itself supports a number of species and whilst not an ectomycorrhizal species, a number of saprotrophic species were recorded in the survey area. The poroid species, *Polyporus tuberaster* was found on dead branches, as were the pinky-orange crusts of *Peniophora incarnata* and the bright yellow gelatinous fruiting bodies of *Tremella mesenterica*. The mycelium of the latter fungus is feeding off the mycelium of the former. *Byssomerulius corium* was also found on dead attached and fallen branches.

The presence of gorse does offer fungal diversity but, if the resources are available, some reduction in its overall area might enable an increase in grassland or woodland – both potentially more fungally diverse.

Woodland garden and bonfire sites:A number of interesting species were found in both of these micro-habitats. The extensive use of locally created woodchips (of mixed coniferous and broadleaf origin) has provided an opportunity for a number of wood decomposers to become established. The delightful coral fungus, *Ramaria stricta*, was fruiting in large numbers and is a regular coloniser of woodchips in humid situations. Of particular interest were the records of *Hygrophoropsis rufa* and *Leratiomyces ceres*, both of which seem to be linked to the use of woodchips and are gradually moving north having first been recorded in the south of England. *Parasola* (*Psathyrella*) *conopila* is common further south but has only been recorded from a further 10 sites in Scotland; on this

occasion it was also growing in association with the woodchips. It is a small but rather distinct species and unlikely to be overlooked.

Areas out with the garden used for the preparation and storage of wood might also be expected to support these fungi but they were not recorded during the 2020 visits.

Ramaria stricta on woodchips in the woodland garden area. L Holden

The succession of chemical and nutrient availability in fire sites also provides an opportunity for a suite of specialist fungi to colonise and function in this habitat. Fire is a natural part of woodland ecology and these fungi have obviously evolved to accommodate the erratic occurrence of naturally started fires (see 'Discussion' below).

The old fire sites beside the track on the northern edge of the pine plantation were colonised by five specialist species, *Tephrocybe*(*Lyophyllum*) *ambusta*, *T*. (*Lyophyllum*) *anthrocophila*, *Neotiella hetieri*, *Pholiota highlandensis* and *Psathyrella pennata*. The latter species is the rarest of these with only nine other Scottish sites recorded.

The fire pit at the shelter by the burial ground produced one species – *Clitocybe sinopica*. This is listed as vulnerable by Jordan et al (2016) and is often found early in the year in slightly base rich ground as well as on burn sites. It is widespread but rarely reported.

Assessment of fungal interest by Red and Priority Species Lists

As noted in 'Methodology' above, there are a number of limitations in relying on red lists to assess the importance of fungi as many of the species assessed are poorly understood and under-recorded. Table 5 below includes all species recorded on the survey site, considered 'vulnerable' (i.e. between 25 and 99 discrete fruiting patches recorded at the time of assessment) or rarer. The red listsdo however, pull out the *Tricholoma* species found along the interface of the plantation and the dune heath and also the *Pucciniastrum goodyerae*, which is a genuinely rare species. *Bankera*

fuligineoalba was assessed as near threatened so not included as a red list species but it is the only UKBAP priority species recorded on the survey site.

Table 5: Species of conservation status (VU = vulnerable)

**Smith et al (2016) is the same piece of work at Bailey et al (2015) listed in references.*

Name of Fungus	Associate / habitat	Evans et al 2006	Jordan et al 2016 (2)	Smith et al 2016 *	Jordan et al 2017 (4)	Jordan et al 2017 (3)	Jordan et al 2018 (5)	Scottish Biodiversity List spp	UKBAP priority spp	Comments
Bankera (Phellodon) fuligineoalba	Pinus							1	1	
Clitocybesinopica	Litter and often bonfire sites		VU D1							
Hebelomasordescens	Betula						VU D1			Probably under-recorded
Inocybesubcarpta	conifer				VU D1					Probably under-recorded
Leratiomycesceres	Woodchips					VU D1				Recently spreading. More common in south
Pluteuspouzarianus	Conifer wood		VU D1							Under-recorded – recent species split
Pucciniastrumgoodyerae	Goodyerarepens	V D 2						1		Local to NE Scotland only
Tricholomaalbobrunneum	Pinus					VU D1				Much confused and only recently accepted as British
Tricholomafocale	Pinus					VU D1				
Tricholomapessundatum	Pinus					VU D1				
Tricholomastans	Pinus			VU D2		VU D2		1		Much confused with T. albobrunneum

Other species of conservation interest

Agrocybe pusiola: has only recently been confirmed in two Welsh dune systems and added to the British Checklist in 2020. It does not feature therefore in any assessment systems and only more active searching for it will reveal if it is truly rare in the UK.

Hygrophoropsis rufa: this was elevated from variety to species and added to the British Checklist in 2016. The 2016 checklist update suggests that it is known from Kent, Norfolk, Surrey and West Sussex but that it is likely to be widespread. It has now been recorded near Penicuik and is likely to be spreading northwards, quite probably taking advantage of woodchips.It does not feature in any assessment systems as knowledge of its distribution is data deficient and only more active searching for it will reveal if it is truly rare in the UK.

Hygrophoropsisrufa. L. Holden

Leratiomyces ceres: added to the British Checklist in 2008, most records are from England but two Scottish records are known, both on the west coast. This species appears to be linked to the spread of woodchips and was growing in that substrate at Findhorn. It does not feature in any assessment systems as knowledge of its distribution is data deficient and only more active searching for it will reveal if it is truly rare in the UK.

DISCUSSION

Pinewood and dune heath: One of the most significant fungi in the pine wood plantation, is the rust fungus *Pucciniastrum goodyerae*. This species colonises the more frequently found but still nationally scarce, higher plant, creeping lady's tresses (*Goodyera repens*), itself a pine associating species. *Goodyera repens*, the host plant, will need continuity of pine, enabling a damp bed of

needles with light to moderate shade. The rust is currently only known from 5 other sites in the north east of Scotland – as far north as Loch Fleet and as far south as Grantown on Spey.

The current lack of dead wood, both standing, fallen and of different sizes, will reduce the diversity of fungi present on the site. Some trees should be allowed to reach old age and their wood allowed to decay naturally. More humid parts of the woodland would be particularly suited to the colonisation of dead wood by fungi, as most fungi find dry, dead wood difficult to colonise. Enabling the survival of veteran trees will play an important part in the contribution of coarse woody debris.

Balancing the lack of natural processes by human management intervention to preserve perceived areas of natural importance will always present management dilemmas, a situation accepted in Reed (2020). Managing a site for one interest feature will almost certainly reduce the overall biodiversity. If that one interest feature has been assessed asrare, then there is some justification for micro managing a site i.e. effectively preventing 'natural' succession taking place.

The most interesting parts of the survey area within the dune and dune heath for macro fungi are the sandy areas that support the *Sabuloglossum arenarium* and the pine regeneration zone at the edge of the dune heath with its suite of 'old growth' pine wood fungi. The reasons for the presence of the 'old growth' pine fungi in the latter habitat, away from long established woodland, are not entirely clear. It is thought that these 'old growth' indicator species generally colonise seedling trees via established mycelia rather than from spores. The length of time that the spores of these species remain viable and the distance that they travel once airborne is not known. The nutrient status of a tree affects the ability of fungal mycelia to colonise its roots. This may be because the defence status of a plant can be positively related to its nutrient content, which means that the more nutrients a tree has (e.g. in a nursery situation where fertiliser including nitrogen will be applied) the more difficult it is for most fungi to colonise the roots. Even mycorrhizal species have to overcome the plant's defences in order to colonise the roots. It is possible that the extremely impoverished nature of the soil at Findhorn (and indeed at nearby Culbin Forest where species of tooth fungi are present) may assist with the colonisation of regenerating pine by 'old growth' species with no nearby well established woodland (A. Taylor pers. comm.).

This immediately throws up a management issue as to how far this regeneration should be allowed to extend. Should the site be managed for the diversity of sand dune species (including the lichen interest not discussed in this survey) or allowed to develop as a *Pinus sylvestris* dominated woodland with 'old growth' fungal diversity? Clause 9.5.10 (Piper 2019) does suggest maintaining native trees to soften this boundary. Reed (2020) is more robust in his recommendation that regenerating trees be removed in this area. This area is, however, of interest for its fungal community with priority species present, something not previously taken into account. Reed (2020) notes that further information about the fungi is required. Non-native trees should be removed from the dune heath but the maintenance of a narrow belt of naturally regenerated *Pinus sylvestris* would enable the fungal interest to continue, including the SBL and UK priority species *Bankera fuligineoalba*and SBL species *Tricholoma stans*.

Where existing trees are to be harvested, the practice of continuous canopy forestry as suggested by Piper (2019) rather than clear felling will be of benefit to the below ground biodiversity including the fungi. Dead wood, both standing and fallen, should also be encouraged to develop the depauperate wood decomposing fungal community.

Grassland and gorse: the fungal interest of the grassland habitat would benefit from targeted grazing as suggested by Piper (2019) and Reed (2020). Keeping a wild flower interest in the grassland alongside developing the fungal interest should not be mutually exclusive as the shorter sward is more important during the fungal fruiting season – usually after the flowers have finished flowering and set seed. Grazing or cutting could be introduced in late August or September and grazing could continue through until the spring.

Whilst the gorse is a natural part of the dune system and does have its particular fungal associates contributing to the overall fungal diversity of the site, it would be good to have more of an open mosaic of gorse and grassland. This would contribute, as Reed (2020) points out, to more active wind scouring of the lichen rich dune heath.

The short term colonisation of the brash by large numbers of mostly two species of fungi, is not a reason to leave the brash in place if soil enrichment is considered an undesirable result of the decomposition of the brash.

JNCC assessments: Whilst none of the JNCC assessments suggest that the site should be considered for SSSI status, the presence of some indicator species of each of the three habitats formally assessed (pine wood, sand dune and grassland) suggests that conditions are suitable for further diversity to develop and that long term continuous management of the habitats would enable that to happen.

Bonfire sites: Old bonfire siteson the survey area produced interesting species and Callander (1985) points out that fire is considered to be a natural event in both boreal and taiga woodlands. A group of fungi have evolved to take advantage of the unique succession of mineral availability following a fire and the fungi recorded around the edge of bonfire sites may represent a snapshot of the fungi that would be associated with the aftermath of a naturally occurring fire. In naturally occurring fires the depth of penetration of the fire and its effects on the soil, may not be very great (Dix & Webster 1995). Temperatures in the centre of a bonfire may, however, be very high and there is often an accumulation of wood ash. The occasional bonfire might therefore benefit the overall fungal diversity of the site although these comments should not be seen as a reason to burn all dead wood. As Hodgetts (1996) points out, '*The worst of all possible dead wood management is to burn it. This in effect shortens the woodland nutrient cycle and leads to a depletion of material available for recycling by decomposition, thereby diminishing the fungal diversity of the woodland*'.

Bearing the above in mind, occasional bonfires will contribute to the fungal diversity of the site.

Woodchips: the use of woodchips is welcome in the garden area. In time more normal competitive checks and balances will become established in this relatively new 'micro-habitat' and the fungal composition will change to reflect this. Species that are currently considered rare fruiters now, may disappear again or become more common throughout.

RECOMMENDATIONS

- Maintain woodland within the survey site taking into account the needs of *Pucciniastrum goodyerae*, *Bankera fuligineoalba* and *Tricholoma stans*. Use continuous canopy methods where possible.
- Remove non-native trees and plants where possible, particularly on the dune heath and areas of open sand.
- Working with adjacent land managers to remove non-native tree seed sources will be important.
- Dead wood, both standing and fallen and both large and small girth, should be allowed to accumulate particularly in more humid areas. Veteran trees should be allowed to develop.
- The occasional use of bonfires to dispose of brash etc will contribute to fungal diversity but should play a very minor part in dead wood management.
- The use of local materials to provide woodchips in the garden area should be continued although the current fungal interest may decline.
- Targeted grazing and removal of gorse to improve the grassland for fungi and create more of a habitat mosaic is recommended.
- Existing open areas of sand should be maintained where possible

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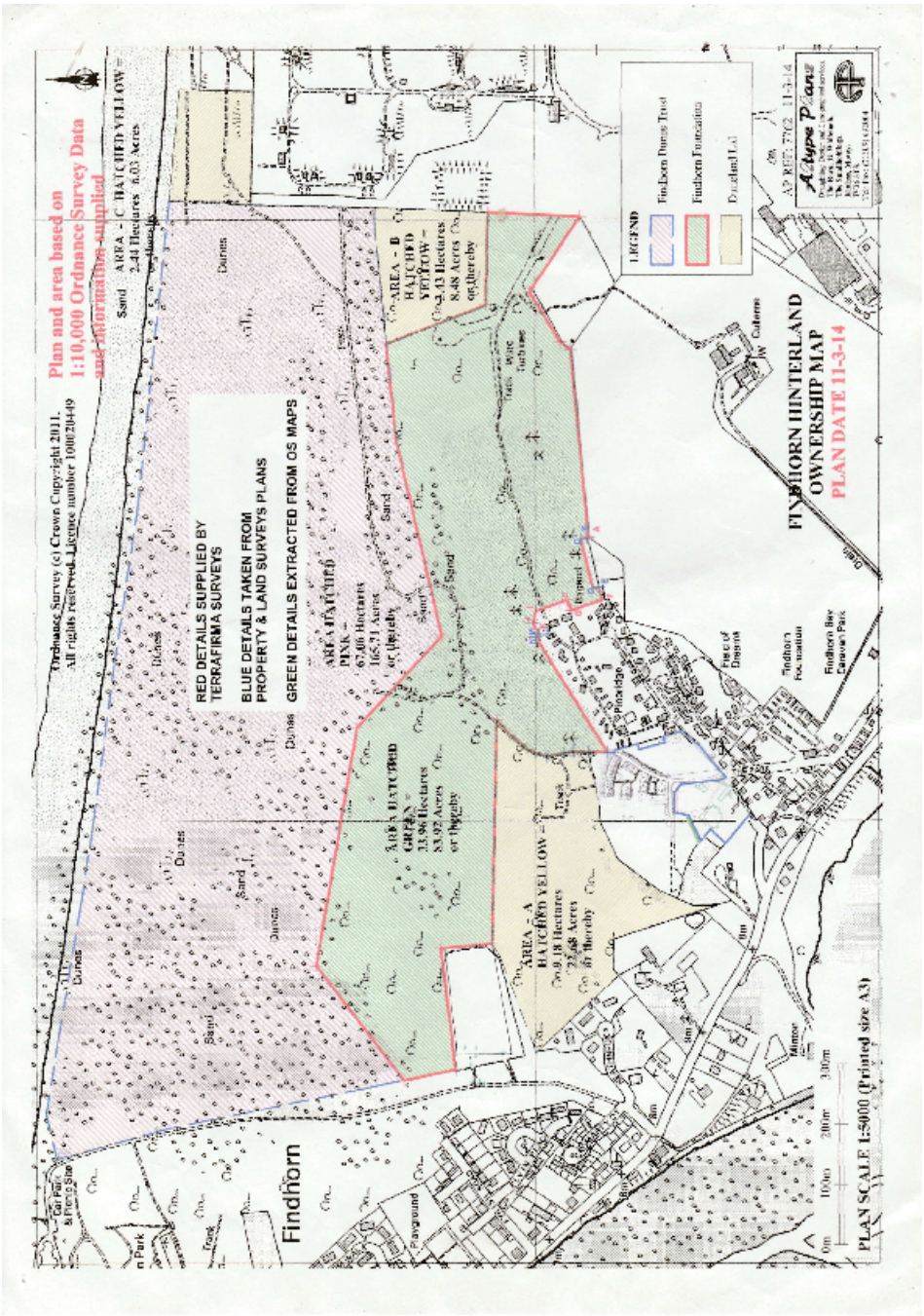

Appendix 1: Findhorn Hinterland Ownership Map

Appendix 2: Fungal Species Data: *spreadsheet of all fungi recorded during 2020 surveys. Presented as separate Excel document*