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Decision-making guidance for managing *Phytophthora* infections in *Vaccinium myrtillus* populations

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Contents

Executive Summary

Purpose of this document

This document is designed to be a resource to help site managers make decisions on whether and how to treat *Vaccinium myrtillus* on their land if infected with one of three *Phytophthora* species. It takes the form a framework containing lists of relevant issues that should be considered in the decision-making process. Current thinking around these issues and their relevance to *Phytophthora* management is summarised to contribute towards making the most effective decisions for the circumstances. This guidance has been produced using the best available evidence, but there are still gaps in knowledge that need addressing; these are summarised in section 6. It should also be noted that this guidance does not negate the requirement to comply with any Statutory Plant Health Notices (SPHNs) that are issued for any notifiable plant diseases.

Background

The oomycetes *Phytophthora ramorum, Phytophthora kernoviae* and *Phytophthora pseudosyringae* can all infect the native species *Vaccinium myrtillus* (bilberry), a frequently abundant ericaceous shrub in heathland and woodland habitats. The pathogens can cause lesion formation and leaf abscission in this species of *Vaccinium*, and can lead to death of the plant, though evidence suggests a degree of host resilience on infection in wild populations. Removal or reduction of *Vaccinium myrtillus* from UK habitats could have devastating implications for the retention of some habitat types such as degraded heathland; it could endanger populations of species dependent on *Vaccinium*; and it could have economic and social impacts on tourism and cultural activities such as the bilberry trade.

There are currently at least 30 known outbreaks of *P. ramorum* and *P. kernoviae* in wild *Vaccinium myrtillus* populations in Britain. These pathogenic species are non-native and outbreaks are recorded and monitored by the Animal and Plant Health Agency (APHA). After confirmation of an outbreak, APHA will issue a Statutory Plant Health Notice, outlining the minimum expected actions in response to the disease. Site managers must at least initiate biosecurity measures to contain the disease. Additional treatment of infected plants is only possible through destruction of infected plants, either using herbicides or through burning.

P. pseudosyringae is thought to be native to the UK and is not under statutory regulation. However, outbreaks of the disease in *Vaccinium myrtillus* can be just as damaging to the host as the two non-native species of *Phytophthora*. Observations of recent outbreaks have indicated that they are more damaging than those in the past, leading to suspicions that the pathogenicity of this species has increased in recent years.

Concerns surround all three of the species of *Phytophthora* should pathogenicity increase further in any of them, as death of host *Vaccinium myrtillus* populations would become more likely. Furthermore, *Phytophthora* can transfer to new host species if sporulation levels are high, as shown by numerous transfers already observed, such as *P. ramorum* into *Larix kaempferi* (Japanese Larch) in 2009. Laboratory studies have shown susceptibility of several other native ericaceous species to *Phytophthora*, so widespread *Vaccinium myrtillus* infection with high *Phytophthora* sporulation levels could endanger these species.

Deciding whether to treat *Phytophthora* outbreaks

In some circumstances, the destructive treatment methods are appropriate to preserve ecological, social or economic values dependent on *Vaccinium myrtillus*. However, in other sites, treatment can be more damaging than the disease itself, as it destroys the infected plant material, leaving the continuation of the *Vaccinium* population reliant on potentially highly disease-susceptible regrowth. Alternatively, certain site attributes will hinder treatment to such an extent that it is rendered ineffective, and not a cost-effective option. Treatment involves reasonable costs and resources and, to be effective, will require continued input over successive years to monitor the site and treat any recurrent infections.

A highly influential factor in deciding whether or not to treat a *Phytophthora* infection in *Vaccinium myrtillus* is the *Phytophthora* species involved. *P. kernoviae* outbreaks are currently limited in the UK, and targeted eradication of this disease at infected sites could lead to it being contained. This is highly desirable as this *Phytophthora* species appears to be more frequently lethal to *Vaccinium myrtillus* than the others. *P. ramorum* and *P. pseudosyringae* are already widespread in the UK, so it is less likely to be cost effective to attempt rigorous elimination of the diseases from a site, given the greater risk of reinfection. Some acceptance is needed that these pathogens are highly likely to persist in the environment and will cause some ecological changes. However, containment through biosecurity is highly desirable to reduce the anthropogenic spread of infection and the impacts it causes.

It is suggested that the following decision-making framework is applied to help specialists or land managers decide whether to treat a *Phytophthora* infection, or to solely implement biosecurity measures. In all circumstances, any control measures issued under statutory notice should be complied with.

Decision framework for managing *Phytophthora* infections in *Vaccinium myrtillus* populations

The framework below sets out guidance to help in decision making on whether to manage *Phytophthora* infections in *Vaccinium myrtillus*. However, every site infected by *Phytophthora* will have different circumstances. Consequently, there may be exceptions where the most appropriate course of action varies from the framework recommendations. The framework should, at the very least, encourage consideration of all the criteria that should be taken into account before a course of action is chosen. Within this document, factors underlying the framework which should guide decision-making are discussed in detail.

<table>
<tr><td colspan="3">List 1
If the answer to any of the questions in list 1 is Yes with regard to a Phytophthora infection, consider treating the infection as soon as possible as opposed to solely implementing biosecurity measures. If the answer to all these questions is no, consider list 2.</td></tr>
<tr><th>Question</th><th colspan="2">Considerations</th></tr>
<tr><td>Is there an uninfected site of exceptionally high ecological or economic value within 10km (with habitat integrity or value dependent on a susceptible host)?</td><td rowspan="3">Eliminate disease outbreak when small scale to preserve an area with identified value</td><td rowspan="4">Preserving Value</td></tr>
<tr><td>Is the infected site highly connected to a site of high value (with integrity or value dependent on a susceptible host)? e.g. via footpaths, roads, water courses or animal movements</td></tr>
<tr><td>Is the site a SAC/NNR whose ecological integrity is dependent on Vaccinium?</td></tr>
<tr><td>Is the infected habitat in bad condition and/or declining? Would the loss of Vaccinium alter the habitat type?</td><td>Preserving a vulnerable area</td></tr>
</table>

Is the outbreak *Phytophthora kernoviae*?	More lethal to *Vaccinium* and less widespread than other *Phytophthora* species; higher chance of stopping extensive outbreaks through treatment	Controlling Disease spread
Is it impossible to restrict access to infected areas or the site? e.g. on open access land in Scotland	If biosecurity options are limited, target outbreaks early through treatment to prevent spread	Factors influencing treatment success
Is the infected area limited/localised within site or the wider landscape?	Higher chance of successful elimination of outbreak when at small scale	
Relative to the size of the site, are resources for effective disease surveillance and treatment sufficient or good, and are they certain to remain so into the future?	Treatment has a higher chance of success if adequate resources are available	

List 2

If the answer to 3 or more of the questions in list 2 is Yes with regard to a *Phytophthora* infection, consider treating the infection as soon as possible as opposed to solely implementing biosecurity measures. If the answer to fewer than 3 questions is yes, consider list 3.

Question	Considerations	
Is the site a SSSI/ASSI/Annex 1 habitat whose ecological integrity is dependent on *Vaccinium*?	Eliminate disease outbreak when small scale to preserve an area with identified value	Preserving Value
Is the site of exceptionally high value either economically, ecologically or socially? (with habitat integrity or value dependent on *Vaccinium*)		
Is the site an undesignated site in which *Vaccinium* is a dominant species on which many others depend?		
Are other susceptible hosts or species shown to be potential hosts present in high abundance in close proximity to the infection?	Many hosts means greater potential for *Phytophthora* spore build up, increasing the likelihood of host species transfer	
Is the infected area easily accessible (preferably to humans and machinery)?	An accessible site means treatment is actually possible	Difficulties implementing treatment
Are the soils reasonably resistant to erosion or compaction by heavy machinery or vegetation removal?	A resilient environment reduces the chance of adverse impacts of treatment	Environmental damage
Is there little or no scrub present, including bracken, to conceal *Vaccinium* and facilitate disease spread?	It is possible to treat all infected *Vaccinium* more effectively with less ground cover	Factors influencing treatment success
Is it possible to get a coordinated approach to treatment across all land owners of the infected area (including agreement over and funding for the long-term approach into the future)?	Treatment is more likely to be effective if there is a targeted and coordinated strategy	

<table>
<tr><td colspan="3">List 3
If the answer to 4 or more of the questions in list 3 is Yes with regard to a Phytophthora infection, consider treating the infection as soon as possible. Otherwise implement biosecurity measures to prevent the spread of the disease.</td></tr>
<tr><th>Question</th><th colspan="2">Considerations</th></tr>
<tr><td>Is the site a reasonable distance from a water course? (see section 5.6)</td><td>Treatment is unlikely to cause damaging environmental contamination</td><td>Environmental damage</td></tr>
<tr><td>Are visitor numbers to the infected area reasonably low? (see sections 5.4.1 and 5.4.2)</td><td rowspan="4">Higher chance of treatment success due to limited disease vectors</td><td rowspan="6">Factors influencing treatment success</td></tr>
<tr><td>Is there little evidence of wild animal presence/movements? (e.g. mammals, ground nesting birds) (see section 5.4.3)</td></tr>
<tr><td>Can livestock be excluded from the site if needed?</td></tr>
<tr><td>Can bilberry picking and shooting be excluded from infected areas?</td></tr>
<tr><td>Are visitors restricted to access routes around site with minimal access to the site elsewhere?</td><td>Spread is likely to be more limited and treatment can be more targeted</td></tr>
<tr><td>Is the climate dry? Or if the climate is wet, can the outbreak be treated rapidly?</td><td>Infection spread is fast when wet; it is desirable to stop disease spreading through treatment if it can be done before spread is likely to have occurred. Disease spread is slower in dry conditions; it is preferable to clear isolated sites whenever identified to prevent further spread.</td></tr>
</table>

1 Context

Phytophthora is a genus of oomycete which can cause disease in a wide range of plant species and habitats. In Britain, there are several species of *Phytophthora* which infect ericaceous plants, namely *P. ramorum*, *P. kernoviae* and *P. pseudosyringae*. The first two species are believed to be non-native, possibly introduced through trade from Asia, and the first infections in British plants were found in 2002 and 2003 respectively. They have now caused widespread infection across the west of Britain in plant species such as *Larix kaempferi* (Japanese larch) and *Rhododendron ponticum*. *P. ramorum* infections have also been identified in England and Scotland in the more sparsely growing *Larix decidua* (European larch). Legislation is in place to actively control and reduce the spread of these two plant diseases, which are quarantine organisms. Statutory action to eradicate and contain the diseases in forestry and the wider environment has been taken against *P. ramorum* since 2002 in all British countries, through Plant Health Orders specific to the species[1] and against *P. kernoviae* through the Plant Health (England) Order 2005, as amended.

P. pseudosyringae is believed to be native, and because there is little focus on the recording of native oomycetes, there have been fewer recorded cases of infection located in Britain. However, observations of *P. pseudosyringae* outbreaks indicate a recent increase in pathogenicity.

All three species are known to infect *Vaccinium myrtillus*[2] (bilberry/blaeberry, referred to in this report as *Vaccinium*), and the threat from *Phytophthora* infection in this British species is increasing (see figure 1). In terms of *Vaccinium* management, all three *Phytophthora* species need to be considered, not only those for which there is legislation.

[1] http://www.legislation.gov.uk/all?title=Phytophthora

[2] *Vaccinium x intermedium* (hybrid bilberry) can also be infected by *Phytophthora* species; for example a population at Cannock Chase in Staffordshire is infected by and under pressure from *Phytophthora pseudosyringae*. This *Vaccinium* hybrid has a much more limited distribution than *Vaccinium myrtillus*: it is found in scattered sites across northern England and northern Wales, and rarely in Scotland. This framework can also be applied to populations of this hybrid.

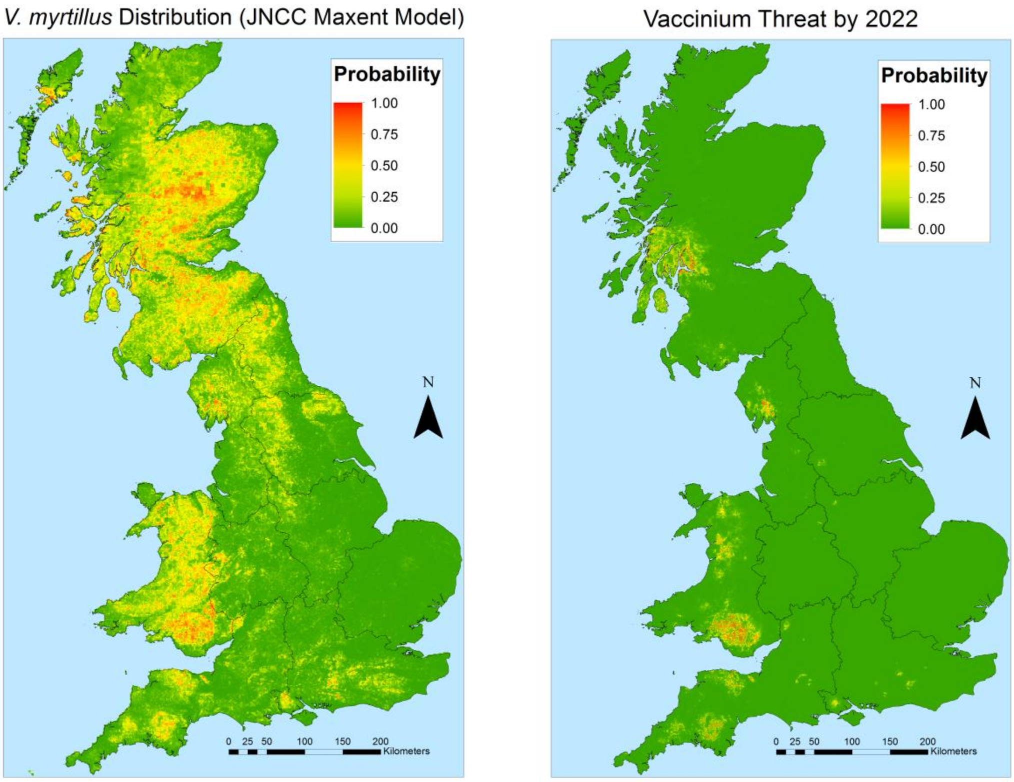

Figure 1: The distribution of *Vaccinium myrtillus* in Britain and the probability of its infection by *Phytophthora ramorum* by 2022 (Castle, 2014).

Vaccinium myrtillus grows commonly in heathlands and in woodland understories: the total area of the species in Britain has been estimated at 1.85 million hectares (Ball, In publication). *Phytophthora* symptoms in *Vaccinium* include brown lesion formation on stems, followed by leaf necrosis and abscission (FERA, 2012). All three species of *Phytophthora* can kill *Vaccinium* depending on the environment and disease pressure. However, observations suggest *P. kernoviae* is the most aggressive of the three species and infections are more likely to lead to *Vaccinium* mortality than *P. ramorum* and *P. pseudosyringae* (Judith Turner, personal communication, 2014). For certainty in this matter, longer-term observations of infections would be needed; repeated infections of any *Phytophthora* species may ultimately lead to death of a ramet or population of *Vaccinium.* Observations also suggest that unknown factors are contributing to widespread dieback in *Vaccinium*. A workshop hosted by JNCC in July 2014 comprised of experts in plant health highlighted the need to establish a national decision framework for managing *Phytophthora* outbreaks in *Vaccinium* populations.

2 Surveillance and Monitoring to date

In response to discovery of the first British *Phytophthora ramorum* and *Phytophthora kernoviae* outbreaks, a policy of disease containment and eradication was implemented in England and Wales. In 2009, FERA implemented a five year *Phytophthora* Disease Management Programme (PDMP) for *P. kernoviae* and *P. ramorum*, the aim of which was "to reduce pathogen inoculums to epidemiologically insignificant levels". The three main work streams of the programme were research and development; education and raising awareness; and disease control through clearance of host plants in high risk areas and outbreak sites, to reduce inoculums levels (FERA, 2013). The last work stream has included large scale Japanese larch felling and aerial surveillance since the first outbreak of *Phytophthora* was reported in Japanese larch in the UK in 2009. Recommendations from the programme relating to *Vaccinium* are incorporated into this framework.

Over the course of the five year PDMP, country-wide *Phytophthora* surveillance has been undertaken twice across all wider environment settings in England and Wales by the Animal and Plant Health Agency (APHA), including specifically in *Vaccinium* populations. This *Vaccinium* surveillance is likely to continue as an extension to the PDMP. If any reports about symptomatic *Vaccinium* are made by land managers, agencies or the public to the APHA, a follow-up site visit will occur. Monitoring of known infected *Vaccinium* sites occurs annually or twice-yearly, depending on site risk. Since first findings in *Vaccinium* there have been over 30 sites in Great Britain where *Vaccinium* has been found infected with *P. ramorum* or *P. kernoviae,* in a range of wider environment settings (Barbrook, 2014). There are no collated data sources recording total outbreaks of *Phytophthora pseudosyringae*, so infection extent is uncertain; as it is not a Statutory Quarantine pest this information is not kept by APHA. In Scotland, SNH area staff survey for *Phytophthora* infections in *Vaccinium* populations as part of Site Condition Monitoring or other surveys. As yet, there has been just one confirmed outbreak each of *Phytophthora ramorum* and *kernoviae* in *Vaccinium* in Scotland.

3 Control Strategy

Currently, there are no fungicidal treatments available that are effective against *Phytophthora*. This leaves two broad options that have been identified for managing *Phytophthora* infections in *Vaccinium*. Firstly, the infected plants can be destroyed, typically using herbicides, cutting and removal, or burning. Secondly, the infected areas can be left untreated, allowing the infection to run its course, alongside implementing biosecurity practices to contain the spread.

3.1 Treatment methods for *Vaccinium*

If treatment is deemed to be the most appropriate course of action for infected *Vaccinium* (see section 4), recommendations for treatment methods are shown in table 1 (FERA, 2012). The distinction between limited and widespread outbreaks is not specifically defined by APHA, but is usually related to the feasibility of spot treatment, extent of infection and whether the infection is the first found at a site. If one or more outbreaks cover an area extensive enough that spot treatment would be infeasible, or the 10m buffer zone treatment areas join up to encompass most of the site, it is treated as a widespread infection.

Outbreak Type	Outbreak Extent	Disease management options
Infected woodland	Limited	Spot treatment with Timbrel or glyphosate, including a 10m buffer zone around infected plant
		Spot burn
		Cut and remove material
	Widespread	Treatment with Timbrel or glyphosate
		Cut and remove material and then spot treat with herbicide
Infected heathland	Limited	Spot treatment with glyphosate, including a 10m buffer zone around infected plant
		Spot burn
	Widespread	Burn and then spot treat with herbicide
		Cut and remove material and then spot treat with herbicide

Table 1: *Phytophthora* management options based on outbreak type and extent (Adapted from FERA, 2012)

Suspicion of *Phytophthora ramorum* or *Phytophthora kernoviae* outbreaks must be reported to APHA and following testing and lab conformation APHA will issue a Statutory Plant Health Notice (SPHN). Any control measures required under the statutory notice must be complied with. *Phytophthora pseudosyringae* is not a Statutory Quarantine pest so any control measures taken are at the discretion of the site managers. However, if the site is a SSSI/ ASSI or SAC then assent from the relevant country agency (Natural England, Scottish Natural Heritage, Natural Resources Wales, Northern Ireland Environment Agency) will be required for widespread destruction of vegetation. Of the *P. ramorum* and *P. kernoviae* infections found in *Vaccinium* in 2014, most have been assumed to be the first localised outbreak of disease infection at a site, and eradication has been implemented to remove the infection source before it spreads more widely. This has involved spraying infected plants and a 10m radius buffer zone around them with glyphosate, combined with biosecurity measures.

In one historical woodland infection site in Britain, *Vaccinium* was cut to the ground and arisings burnt, with the intention of spot spraying infected regrowth with herbicide. The activity demonstrated the challenges and practicalities of large scale management, the potential for altering species composition, and for re-growth to be susceptible to re-infection. In heathlands containing infected *Vaccinium*, burning may be part of the existing management regime, and this can double up as disease control as long as it is followed up by appropriate herbicidal control. Codes of practice associated with burning for heathland management should be abided by[3].

The alternative management route is to leave the infected areas untreated, allowing the infection to run its course, alongside implementing practices to contain the spread. There is a legal requirement for all land managers to at least implement measures to contain *P. ramorum* and *P. kernoviae* infections. Five infection sites identified in 2014 in south-west England have implemented very few treatment measures due to a variety of the criteria outlined below, with access restrictions for treatment across extensive areas being a recurrent problem (see section 5).

[3] England and Wales: http://www.naturalengland.org.uk/ourwork/regulation/burning/default.aspx
Scotland: http://www.scotland.gov.uk/resource/doc/158517/0042975.pdf

3.2 Impacts on values associated with *Vaccinium* caused by *Phytophthora* or its treatment

Both *Phytophthora* and its treatment can have negative impacts on various ecosystem values associated with *Vaccinium* (table 2). The extent of these impacts should be considered at a site-specific level when evaluating the pros and cons of treatment in an area.

Value	Impact of Treatment	Impact of disease
Soil Carbon	Some carbon will be lost due to burning - mostly vegetation rather than soil. Removal of *Vaccinium* and other vegetation roots can cause soil erosion and carbon loss.	Less carbon loss will occur because root systems binding soil remain, and remaining vegetation covers bare ground.
Water regulation (quality & storage)	Erosion of land will occur with movement of equipment- this can change sediment levels in water courses. Compaction of land from equipment may temporarily reduce water storage capacity and/or movement. Chemical treatment may reduce water quality.	Not much impact on water regulation when infection is relatively contained as effects localised. However there may be issues with water regulation if disease destroys plants on a wider scale, due to reduced water uptake by vegetation, increased water movement through soil and a possible increase in the water table.
Biodiversity	Potential to spread spores when surveying for the disease or during treatment. Species diversity (especially of those dependent on *Vaccinium*) constrains choice of treatment. Likely to be impacts on other species but targeted applications may minimise impact. Burning is equivalent to standard management if code of practice is followed. Treatment has the potential to convert heathlands to grasslands and change woodland understory composition, and is thus likely to affect associated species in the same way that the disease would.	Natural spread of disease will cause loss of *Vaccinium* but will have limited impact on other species unless transfers to new hosts occur. May impact species dependent upon *Vaccinium,* but these may be able move to another species. There are some species monophagous on *Vaccinium*, which may be affected to a greater extent. Extent of impact at a site is dependent upon density of *Vaccinium*.
Recreation	Public perception is that treatment is not attractive in the landscape, but this is scale dependent. Possible damages to tourist trade. Negative perception of large scale use of herbicides, cutting or burning. Reactive spot treatment at early stages of the disease has less visual impact. Timing of management and how this affects visits needs consideration. Fencing or path closure is disruptive. Small scale bilberry collection and trade is reduced.	Small scale impact on recreational values. Visual landscape changes are more gradual with disease. Recreation is likely to facilitate disease spread. Disease could lead to complete loss of *Vaccinium*, destroying bilberry trade, but unlikely.
Land use	Potential spread of spores via grazing animal feet. Alternative grazing may be required if treatment occurs. Cover for shooting game birds may be lost.	Reasonably small scale impacts on land use. Impact on grazing could be more significant if widespread infection on a heath leads to a lack of forage. Reduced cover for shooting game birds, but depends upon scale of infection.

Cultural	Will impact bilberry picking by reducing *Vaccinium* rapidly in the short term (and possibly long term at the site if a shift to grassland occurs).	Will impact bilberry picking by reducing *Vaccinium* gradually at the site in the short term (and possibly dramatically in the long term).

Table 2: Impacts on values associated with *Vaccinium* caused by *Phytophthora* or its treatment

Note that many of the values that will be affected by an outbreak of disease are likely to gradually influence the land owner in terms of ecosystem regulation and land use to an uncertain extent. Disease is also likely to gradually influence the wider environment through ecosystem regulation and the human population through changing land use. In contrast, many of the costs and impacts of treating the disease such as land degradation will be much more localised and will be felt directly and immediately by the land owner. Due to this, if there are *Phytophthora* outbreaks in areas where control is important (see section 5.6), targeted funding in these areas could be beneficial to incentivise treatment.

3.3 Biosecurity

If treatment is deemed to be unfeasible or ineffective at a site, at the very least biosecurity measures should be implemented to reduce the spread of *Phytophthora*. Biosecurity measures can include:

- Closure of susceptible or infected sites in their entirety to prevent access and reduce the chance of humans acting as vectors for spores.
- Closure of infected areas within sites, to prevent movement through the areas and reduce the chance of humans acting as vectors for spores.
- Restriction of access only to designated routes on site, to reduce the chances of widespread infection. This would aim to limit any infection that does occur to areas that are easy to access, monitor and treat.
- Removal of livestock from infected sites to reduce the risk of them acting as vectors.
- Fencing infected areas to reduce movement of wild animals or livestock through them.
- Avoiding site visits unless absolutely necessary. There is a fine balance to strike between monitoring the disease spread to determine its extent, and spreading the disease through excessive movement through infected areas.
- Disinfecting vehicles and clothing on entry and exit from the site.

The level of biosecurity possible at different sites will vary, due to factors such as site size and access. In Scotland, closing infected sites is difficult because of open access rights under the Land Reform (Scotland) Act 2003. Infected sites in Scotland should, at the very least, aim to educate site users about the threat posed by *Phytophthora*, causes of spread and recommended behaviour for visitors. Requesting that visitors disinfect their footwear at frequently-used site entrances, and providing the facilities to do this, would also be advisable.

Sites close to areas where *Phytophthora* infections are confirmed should also consider implementing biosecurity measures. The extent of biosecurity implemented will depend on the site value, use, and proximity to the infection source. Site managers are likely to be unwilling to close their uninfected sites unless there is very high value at risk, especially if closure would prevent income from the sites. For these sites near to infected areas, restricting access to designated pathways if possible and requesting that visitors disinfect their footwear would be highly advisable. Close monitoring of susceptible areas near to pathways should occur so any *Phytophthora* outbreaks that do occur are treated rapidly.

For all infected sites, it is good practice for land owners to communicate with others nearby, raising disease awareness among responsible bodies.

3.4 Deciding whether to treat or not

For non-native plant species in the natural environment infected by *Phytophthora*, such as *Rhododendron ponticum*, destruction of infected material is the clear course of action because it removes both the invasive non-native plant and pathogen. However, *Vaccinium myrtillus* is a British native species, and is valued for the biodiversity it supports, its contribution to ecosystem services and its cultural history. Therefore, the choice of whether to remove infected plants is more complicated due to the more extensive impacts it is likely to have on semi-natural habitats.

The treatments suggested by FERA (table 1) generally involve spot treating limited outbreaks of disease, or more widespread *Vaccinium* removal for cases of extensive infection. It is assumed that widespread treatment, especially if repeated extensively over the course of several years, may eliminate up to 100% of the *Vaccinium* population on a site. If an infected area of *Vaccinium* is left untreated, there is uncertainty over exactly how the population will fare in the long term. However, evidence from five untreated UK sites suggests that *Phytophthora* is unlikely to eradicate *Vaccinium* entirely, so this assumption is made throughout this framework. Of these sites, all are infected with *P. kernoviae*, with one having an additional *P. ramorum* infection. These sites have not been treated due to attributes which hinder treatment. Although infections have spread and site responses are hard to compare due to differences in situation, topography, management and ecology, *Vaccinium* has thus far persisted in all of them. The extent of *Vaccinium* persistence is likely to be dependent on the species of *Phytophthora* involved in the infection. *P. kernoviae* more commonly kills *Vaccinium* on infection and has a higher sporulation potential in *Vaccinium* than *P. ramorum*, so the likelihood of host persistence is lower if *P. kernoviae* is involved. Despite this, in all of these five untreated sites infected with *P. kernoviae*, there is still *Vaccinium* persistence at this stage.

Although spot treatment is usually only used to treat limited outbreaks of disease, it has been applied to some wider outbreaks of *Phytophthora* in an effort to avoid complete removal of large areas of *Vaccinium*. Managers of Cannock Chase SAC[4], Staffordshire, which is designated for dry heath, have annually treated an outbreak of *P. pseudosyringae* on a wide scale using herbicidal spot treatment, in an effort to retain the uninfected *Vaccinium*. At this site, however, the recommended 10m buffer zone around infected plants has not been treated, so treated areas do not encompass most of the site. The disease has not yet been eliminated, but further spread from the site has been minimised and *Vaccinium* has thus far been retained in this Annex I habitat. However, a recent reduction in disease surveillance effort from biannually to annually may lead to slower responses to outbreaks, reducing the efficacy of this treatment approach without buffer zones.

The long term outcomes of both widespread spot treatment and no treatment are uncertain. If the expense of continued treatment can be justified by site values, then slowing the spread of disease through spot treatment may be a feasible course of action. This is the case particularly where there is a risk of the pathogen inoculum levels accumulating to such a level as to facilitate transfer to other native ericaceous species on site.

The choice to eradicate infected plants or not involves taking many factors into account, and is hugely situation-dependent. It is recommended that land managers and decision makers should consider the decision framework and following criteria with regard to site value, the impacts of treatment, and the difficulties of treatment caused by certain site attributes. In simplistic terms, if a decision to leave a *Phytophthora* infection untreated is made, it should be because the combined impacts of not controlling the disease are less than the impacts

[4] http://jncc.defra.gov.uk/protectedsites/sacselection/sac.asp?EUCode=UK0030107

and costs associated with treatment. It should be remembered, however, that *P. ramorum* and *P. kernoviae* containment through implementation of biosecurity measures is the EU minimum requirement.

4 Decision framework

Every site infected by *Phytophthora* will have different circumstances. Consequently, there may be exceptions where the most appropriate course of action varies from the framework recommendations. The framework is designed to act as guidance, and should, at the very least, encourage consideration of all the criteria that should be taken into account before a course of action is chosen. In section 5, factors underlying the framework which should guide decision-making are discussed in detail.

List 1
If the answer to any of the questions in list 1 is Yes with regard to a *Phytophthora* infection, consider treating the infection as soon as possible as opposed to solely implementing biosecurity measures. If the answer to all these questions is no, consider list 2.

Question	Considerations	
Is there an uninfected site of exceptionally high ecological or economic value within 10km (with habitat integrity or value dependent on a susceptible host)?	Eliminate disease outbreak when small scale to preserve an area with identified value	Preserving Value
Is the infected site highly connected to a site of high value (with integrity or value dependent on a susceptible host)? e.g. via footpaths, roads, water courses or animal movements		
Is the site a SAC/NNR whose ecological integrity is dependent on *Vaccinium*?		
Is the infected habitat in bad condition and/or declining? Would the loss of *Vaccinium* alter the habitat type?	Preserving a vulnerable area	
Is the outbreak *Phytophthora kernoviae*?	More lethal to *Vaccinium* and less widespread than other *Phytophthora* species; higher chance of stopping extensive outbreaks through treatment	Controlling Disease spread
Is it impossible to restrict access to infected areas or the site? e.g. on open access land in Scotland	If biosecurity options are limited, target outbreaks early through treatment to prevent spread	Factors influencing treatment success
Is the infected area limited/localised within site or the wider landscape?	Higher chance of successful elimination of outbreak when at small scale	
Relative to the size of the site, are resources for effective disease surveillance and treatment sufficient or good, and are they certain to remain so into the future?	Treatment has a higher chance of success if adequate resources are available	

List 2

If the answer to 3 or more of the questions in list 2 is Yes with regard to a *Phytophthora* infection, consider treating the infection as soon as possible as opposed to solely implementing biosecurity measures. If the answer to fewer than 3 questions is yes, consider list 3.

<table>
<tr><th>Question</th><th colspan="2">Considerations</th></tr>
<tr><td>Is the site a SSSI/ASSI/Annex 1 habitat whose ecological integrity is dependent on Vaccinium?</td><td rowspan="3">Eliminate disease outbreak when small scale to preserve an area with identified value</td><td rowspan="4">Preserving Value</td></tr>
<tr><td>Is the site of exceptionally high value either economically, ecologically or socially? (with habitat integrity or value dependent on Vaccinium)</td></tr>
<tr><td>Is the site an undesignated site in which Vaccinium is a dominant species on which many others depend?</td></tr>
<tr><td>Are other susceptible hosts or species shown to be potential hosts present in high abundance in close proximity to the infection?</td><td>Many hosts means greater potential for Phytophthora spore build up, increasing the likelihood of host species transfer</td></tr>
<tr><td>Is the infected area easily accessible (preferably to humans and machinery)?</td><td>An accessible site means treatment is actually possible</td><td>Difficulties implementing treatment</td></tr>
<tr><td>Are the soils reasonably resistant to erosion or compaction by heavy machinery or vegetation removal?</td><td>A resilient environment reduces the chance of adverse impacts of treatment</td><td>Environmental damage</td></tr>
<tr><td>Is there little or no scrub present, including bracken, to conceal Vaccinium and facilitate disease spread?</td><td>It is possible to treat all infected Vaccinium more effectively with less ground cover</td><td rowspan="2">Factors influencing treatment success</td></tr>
<tr><td>Is it possible to get a coordinated approach to treatment across all land owners of the infected area (including agreement over and funding for the long-term approach into the future)?</td><td>Treatment is more likely to be effective if there is a targeted and coordinated strategy</td></tr>
</table>

List 3

If the answer to 4 or more of the questions in list 3 is Yes with regard to a *Phytophthora* infection, consider treating the infection as soon as possible. Otherwise implement biosecurity measures to prevent the spread of the disease.

<table>
<tr><th>Question</th><th colspan="2">Considerations</th></tr>
<tr><td>Is the site a reasonable distance from a water course? (see section 5.6)</td><td>Treatment is unlikely to cause damaging environmental contamination</td><td>Environmental damage</td></tr>
<tr><td>Are visitor numbers to the infected area reasonably low? (see sections 5.4.1 and 5.4.2)</td><td rowspan="4">Higher chance of treatment success due to limited disease vectors</td><td rowspan="5">Factors influencing treatment success</td></tr>
<tr><td>Is there little evidence of wild animal presence/movements? (e.g. mammals, ground nesting birds) (see section 5.4.3)</td></tr>
<tr><td>Can livestock be excluded from the site if needed?</td></tr>
<tr><td>Can bilberry picking and shooting be excluded from infected areas?</td></tr>
<tr><td>Are visitors restricted to access routes around site with minimal access to the site elsewhere?</td><td>Spread is likely to be more limited and treatment can be more targeted</td></tr>
</table>

Is the climate dry? Or if the climate is wet, can the outbreak be treated rapidly?	Infection spread is fast when wet; it is desirable to stop disease spreading through treatment if it can be done before spread is likely to have occurred. Disease spread is slower in dry conditions; it is preferable to clear isolated sites whenever identified to prevent further spread.	

5 Decision-making criteria

5.1 Characteristics of the infection

5.1.1 Scale of the infection

One of the most important factors to establish having identified the symptoms of *Phytophthora* in *Vaccinium* is the scale of the infection. If the infected area is limited, it may be fully possible to treat that area - destroying the localised *Vaccinium* completely but retaining uninfected plants in the wider habitat. Even in this scenario, *P. ramorum* produces resting chlamydospores that may remain on site in the soil for several years, so ongoing vigilance is likely to be needed to ensure new outbreaks do not occur, or are at least dealt with rapidly. However, if the infection is already widespread on detection, the level of damage caused to the ecosystem by treating the entire area in accordance with APHA guidance may be greater than the disease will cause. It should be noted that even if only a small number of plants is infected, it is advisable to remove a larger buffer zone around them due to the potential for disease spread via root systems or soils.

5.1.2 Disease resistance in hosts

On detection, it should be established whether the disease is infecting large continuous areas of *Vaccinium* or whether there are plants that demonstrate disease resistance. If the latter is true then it may be beneficial to maintain these resistant areas; they may be able to repopulate the site with unaffected *Vaccinium* after damages from *Phytophthora* have occurred. However, there is a cryptic stage in the *Phytophthora* infection cycle, so it is possible that apparently uninfected plants will display symptoms at a later date.

5.1.3 Phytophthora species

Although hard to establish in the field, it is useful to know the *Phytophthora* species involved in a *Vaccinium* infection. *P. kernoviae* and *P. ramorum* are very difficult to distinguish from each other based on the visual symptoms they cause in the aerial parts of *Vaccinium* (FERA, 2012). *P. pseudosyringae* can cause similar symptoms as the other two species, but can also cause symptoms in *Vaccinium* roots. Species identification is undertaken based on analysis of DNA, oomycete colony or reproductive characteristics.

Currently, *Phytophthora kernoviae* has a narrower British distribution on all hosts than *P. ramorum*, and outbreaks are limited to the south-west of England and localised areas of Wales and Scotland. *Vaccinium* is highly susceptible to *P. kernoviae* and infections occur in both woodland understories and heathland, frequently resulting in host mortality. Although it is thought that complete elimination will not be possible, ongoing measures to contain further spread of this pathogen are underway. Therefore, if a *Phytophthora* infection in *Vaccinium* is diagnosed as *P. kernoviae*, treatment, or at least careful containment methods, should be seriously considered once the other criteria discussed have been taken into account. Due to the limited number of outbreaks, targeted clearance and aggressive action have a higher chance of successfully preventing disease spread than for other *Phytophthora* species infections. The increased risk of fatality that this species poses to *Vaccinium* compared to *P. ramorum* and *P. pseudosyringae* also makes it a high priority to manage carefully. The importance of attempting to restrict *P. kernoviae* outbreaks by destroying infected plants should not be underestimated; consideration of this criterion should be ranked as high priority when decisions over treatment are being made.

The British distribution of *Phytophthora ramorum* is much more widespread in all hosts, likely due to the pathogen being less environmentally sensitive than *P. kernoviae* (Kliejunas, 2010). *Vaccinium* is a susceptible host plant, but *P. ramorum* does not kill it as frequently as in *P. kernoviae* outbreaks. This extended host life can result in higher levels of spore production from infected *Vaccinium*. *P. ramorum* to date has only been found to present in *Vaccinium* in woodland understories and some more open settings, including those in proximity to heathlands, but not in expanses of open heathland. Due to its distribution, it will not be possible to eradicate *P. ramorum* in the wider environment but it can be managed at a site level if the impacts and costs of management do not outweigh the impacts of the disease. Current government policy on *P. kernoviae* and *P. ramorum* is to reduce the spread and the impact of the pathogens on the wider environment (DEFRA, 2014).

Phytophthora pseudosyringae has been found infecting *Vaccinium* at a limited number of sites. It is thought to have a similar range and host species to *P. ramorum*. However, after a Pest Risk Assessment (PRA) it was considered a native species and no statutory action has been recommended (FERA, 2013). This does not mean that the impact on *Vaccinium* populations is negligible; it can be highly damaging. For example, at Cannock Chase, *P. pseudosyringae* infection has led to the removal of 26 hectares of *Vaccinium*. As the only one of the three species to infect the roots and rhizomes of *Vaccinium*, this can increase its persistence in soil even after aerial plant tissue is removed. The decision to treat the pathogen is site-dependent; the other criteria outlined in this framework are still applicable but there are no statutory obligations.

5.2 Geographical characteristics of the site

5.2.1 Size of the infection

Once the nature of the infection has been established, it is important to consider the geographical characteristics of the infected site with regard to their impact on ease of treatment. If the size of the site is very large, then dependent on resources it may not be possible to carry out sufficient surveillance to identify infected plants and carry out targeted spot treatment. In contrast, smaller sites can be more carefully monitored for new outbreaks of infection, leading to a rapid response and a higher chance of successful elimination. Site managers should carefully evaluate the level of resources available for monitoring, treatment or both with respect to site size. To give an idea of possible costs, Cannock Chase spends around £8500 annually on surveying 1000 hectares of heathland with around 65% *Vaccinium* cover, with a team of six surveyors. This is an ongoing cost as each year the infection continues to spread.

5.2.2 Climate and altitude

Optimal growth conditions for *Phytophthora* species are a temperature of 20^{o}C combined with moisture (Fensom, 2014). Therefore, the climate of an area can have an impact on the rate of spread of a *Phytophthora* infection. Outbreaks of infection in the western side of the British Isles are most likely to spread, due to higher levels of rainfall and humidity, which facilitates oomycete sporulation. Conversely, recent dry summers in 2010 and 2011 have reduced the rate of *Phytophthora* infection spread (DEFRA, 2011). There is an indication that altitude can influence the likelihood of an outbreak: *P. ramorum* outbreaks are found more commonly at 50-100m altitude than would be expected from random outbreaks (DEFRA, 2011). No significant association was found between altitude and *P. kernoviae* outbreaks, but this may be due to the small sample size available. If an infection is identified in a site where spread is likely to be rapid due to the climate or altitude, there are certain questions to be asked. Can the infected area be treated rapidly and effectively enough to eliminate it before the infection spreads? This is likely to be dependent on time of year; if possible, treatment before the peak sporulating period for *Phytophthora* of July to December is desirable. However, wet climates can hamper burning treatments, and may lead to leaching of herbicides.

At a microclimatic scale, close proximity to water courses can increase local humidity and localised misting, facilitating the spread of an infection. Treatment of the disease with herbicides near water courses should be carefully considered due to the risk of leaching and potential damage to the wider environment.

5.2.3 Terrain, soils and water catchment areas

The terrain and soils of a site are also likely to have an impact on the success of *Phytophthora* treatment, and in turn are likely to be affected. *Vaccinium* is commonly found growing on steep slopes, which can limit access, especially to machinery. Limited access can lead to incomplete clearance and difficulties in disposing of arisings if treatment occurs. If plants are physically removed or burned, it is likely to reduce the soil stability, especially on steep slopes, leading to erosion and reduced carbon sequestration. Herbicide application on steep slopes may result in extensive runoff especially in wet climates, not only reducing its efficacy but also having negative impacts on biodiversity and water quality. Weed wiping is a highly targeted alternative and reduces risk of run-off, but is a much slower treatment process to implement.

Access for treatment may also be impaired by the boggy soil types frequently encountered in moorlands, a common habitat for *Vaccinium*. Boggy soils have a high carbon content, so have great potential to suffer large carbon losses from soil erosion should clearance occur. Peat soils also have great value for water retention, so their loss may alter the hydrology of a site. In addition, soil compaction that could occur from machinery involved with treatment can impact the water retention ability of remaining soils. *Vaccinium* also commonly grows in high altitude, rocky environments, which can be dangerous or impossible to access by surveyors, let alone large machinery used for treatment.

These site factors have been encountered in some areas of infection in Britain, and in some cases treatment has not occurred because its impacts are too great when considered alongside the likelihood of elimination. Removal of infected plants does not guarantee removal of inoculum from the area, and this may pose as great a risk to re-growing vegetation of becoming infected as the original infected plants. It has been questioned whether young re-growth is actually more sensitive to infection than mature tissue (DEFRA, 2011). Leaving the infected plant means root systems binding soils are retained, and less bare soil is left exposed. However, if treatment is a necessity on steep or boggy sites having taken other decision-making criteria into consideration, then some mitigation against soil erosion and carbon loss is possible. In the short term following treatment, replanting and diversification of site assemblages with species unsusceptible to *Phytophthora* can increase soil binding by roots. However, depending on the site, this could alter the ecosystem in undesirable or unknown ways. In the long term, rewetting of a site could occur; however this may not be a sustainable solution if soil losses have been substantial.

5.3 Ecological characteristics of the site

5.3.1 Diversity

In sites with low diversity, where *Vaccinium* is one of the dominant species on which many others depend, there is much to lose if large areas of it are destroyed, either through the disease or treatment. There are at least 28 species that are monophagous on *Vaccinium*, and others, such as *Melitaea athalia* (heath fritillary butterfly), that are indirectly dependent on it (DEFRA, 2011). These species may be able to move to feeding on other plants if large areas of *Vaccinium* are lost, but this is uncertain. If dependent species are able to migrate or adapt to new plant hosts, then slower removal of *Vaccinium* either by targeted spot treatment or disease pathogenicity would be more preferable than rapid widespread treatment. In these sites, monitoring and prompt spot treatment of *Vaccinium* is the most preferable course of action to reduce spread of infection at an early stage, so the species may be healthily preserved in the wider environment. If the disease is already widespread on detection, it is assumed that not treating the infected plant is likely to be least destructive course of action, though *P. kernoviae* outbreaks which kill *Vaccinium* may present an exception to this rule.

In more diverse systems, *Vaccinium* is less likely to be such a major component of the ecosystem: there is more likely to be a degree of ecological redundancy. There is less to lose from the loss of *Vaccinium* through disease, but much more diversity to be lost if *Phytophthora* treatment occurs at any scale. In this circumstance, it is preferable to avoid implementing disease treatment if possible. If treatment implementation occurs due to impetus from other decision making criteria (dealing with a *P. kernoviae* outbreak, for example) it should be as targeted as far as possible, with a carefully selected and approved herbicide (see table 1), to minimise collateral damage to other species.

5.3.2 Potential for host transfer between sympatric species

A caveat to the previous section on diverse systems exists if *Phytophthora* transfers to new host species. If this occurs, management may need to be reconsidered and more extensive treatment implemented to prevent further losses to the ecosystem. There is laboratory evidence to suggest that *Vaccinium vitis-idaea* (cowberry), *Arctostaphylos uva-ursi* (bearberry) and *Calluna vulgaris* (common heather) may all be susceptible to the disease, though this has not been observed in wild UK populations (Conyers, 2011). However, these are all species which can grow sympatrically with *Vaccinium*, so could be at high risk should a host transfer occur. Evidence suggests that high *Phytophthora* sporulation levels in hosts contribute to the transfer of *Phytophthora* to new hosts: for example, numerous new hosts have been infected under the canopy of highly sporulating Japanese larch (EFSA, 2011). If transfer to new hosts were to occur from *Vaccinium*, it would likely be in low diversity systems with high densities of *Vaccinium*, where high spore levels can build up. *Phytophthora* sporulation potential can be high per unit area of tissue in *Vaccinium* but the low growth habit of *Vaccinium* means the distance that spores are broadcast is likely to be much lower than larch. However, site mangers should be aware of the possibility of pathogen transfer, and should investigate any suspicious symptoms of disease in susceptible species growing amongst *Vaccinium*.

Treatment of *Vaccinium* in an area may be futile if there are other infected hosts in the vicinity left untreated, from which the transmission of *Phytophthora* can still occur. Site managers may be able to pre-emptively manage this situation before infection; pro-active clearance of *Rhododendron ponticum* should be prioritised in areas where it grows alongside high levels of *Vaccinium*, to minimise available hosts (FERA, 2013). If infected *Vaccinium* is found in otherwise uninfected Japanese larch stands, it may be desirable to rapidly remove the infected plant material before infection of forestry stock occurs. However, larger scale outbreaks may be very hard to manage in woodlands due to difficult access and detection. In addition, the low growth habit of *Vaccinium* likely reduces the chances of spore transfer to tree species, compared to the probability of infection of *Vaccinium* from infected trees.

5.3.3 Difficulties created by other sympatric flora

Although not a host species, it is postulated that sympatry of susceptible species with *Pteridium aquilinum* (bracken) may facilitate *Phytophthora* infection by creating a suitable microclimate for reproduction. Sites where bracken is present in abundance could also be considered at greater risk from rapid spread of infection, especially in the summer months before bracken dies back. At Cannock Chase, most outbreaks of *Phytophthora pseudosyringae* originated from within woodlands or dense bracken areas. Disease advancement has been slower in more open heathland areas.

In the five untreated sites where infected *Vaccinium* has been identified, access for monitoring or treatment has been hindered due to the flora, including high densities of *Pteridium aquilinum, Rubus fruticosus* and *Ulex europaeus.* These species can conceal *Vaccinium* in their understories, preventing identification of unaffected populations, let alone those that are infected.

5.3.4 Site designation

If a site in which infection is identified is designated, for example as a SSSI/ASSI or SAC, it may influence the choice of management implemented- though this is dependent on the reasons for site designation (see section 5.6 for ranked prioritisation of sites with designations for treatment).

Having an ecological designation demonstrates a site’s importance with regard to some aspect of its biological community. The designation will be due to specific features on the site, and if these features include communities in which *Vaccinium* is a key component, its preservation should be promoted. Only in this situation should this criterion be given weight in decision-making; a site designation for reasons unrelated to *Vaccinium* should not be a critical factor. However, if treatment will endanger populations of other species, it may do more harm than good. The importance of *Vaccinium* within the community of interest and the presence of other potential host plants should determine whether any *Phytophthora* treatment should occur (see section 5.6 and 5.3.5, and the appendices). Treatment, if any, should be prompt and targeted. A site’s ability to retain ecological SSSI/ASSI elements may be dependent on abiotic features such as peat soils, so damaging these through widespread treatment may be just as damaging as *Vaccinium* loss by disease. Widespread treatment is not recommended unless there is a nearby area which is deemed higher priority than the infected SSSI/ASSI, and the integrity of the infected area is sacrificed to reduce the infection risk to these offsite values (see section 5.6). However, this would only be applicable in exceptional cases as sacrificing the infected area would by no means guarantee offsite protection due to potential infection from other sources.

SSSI/ASSIs may also be designated for geological reasons. In these cases, site designation does not per se provide an over-riding reason to preserve *Vaccinium*. Other criteria should be used to decide whether to treat the disease or not.

5.3.5 Site condition and conservation objectives

Many *Vaccinium* habitats are protected sites and listed as Annex I habitats by the Habitats Directive. Species protected under other Directives are also dependent on *Vaccinium*: for example, for the capercaillie (*Tetrao urogallus*), an Annex I species in the EU Birds Directive, *Vaccinium* cover is amongst the most important aspects of the woodland structure for this species’ survival and reproduction. In 2011, Conyers *et al.* identified 44 invertebrate species vulnerable to the loss of *Vaccinium myrtillus, Vaccinium vitis-idaea* and *Arctostaphylos uva-ursi* , five of which were BAP priority species. When deciding on treatment it is critical to consider the conservation objectives for the site in relation to these designations. This needs to be done in conjunction with the site's current condition, as this can be used as an indicator of the value the site has to lose.

Vaccinium is a major, often dominant, component of the Annex I habitats (see Appendix 2). These include the following habitats with current status indicated in parentheses:

- European dry heaths (Bad-stable)
- Alpine and boreal heaths (Bad-stable)
- Temperate Atlantic wet heaths (Bad-stable)
- Northern Atlantic wet heaths (Bad-stable)
- Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels (Bad-improving)
- Blanket bogs (Bad-declining)
- Sub-arctic Salix species scrub (Bad-declining)
- Siliceous alpine and boreal grasslands (Bad-stable)
- Species-rich *Nardus* grassland, on siliceous substrates in mountain areas (Bad-declining)
- *Juniperus communis* formations on heaths or calcareous grasslands (Bad-stable)
- The ground flora of Bog woodland (Inadequate-stable)
- The ground flora of Atlantic acidophilous beech forests (Bad-stable)
- The ground flora of old acidophilous oak woods (Bad-stable)
- The ground flora of old sessile oak woods (Bad-declining)
- The ground flora of Caledonian forest (Bad-declining)

The majority of these habitat types are currently listed as having a Bad status by the 2013 Article 17 reporting; only hydrophilous tall herb fringe communities are improving in condition and many others are declining. Widespread loss of *Vaccinium* from these habitats would lead to further habitat deterioration. In particular, the primary conservation objective for Annex I heathland sites should be to retain them as this habitat type. In deteriorating heathlands, *Vaccinium* may be one of the last remaining dwarf shrub species, so maintaining the species is key as its loss is likely to lead to a conversion to grassland. In terms of SSSI assessment using common standards monitoring (CSM) guidelines (Appendix 1), vulnerable heathlands losing *Vaccinium* are highly likely to be classed as being in an unfavourable condition, because they would almost certainly fail in the dwarf shrub cover and composition attributes. In these heathlands, monitoring should be a priority as it is important to detect any *Phytophthora* infections early and proactively prevent their spread, so widespread *Vaccinium* losses are not caused by either the disease or treatment.

However, in more stable heathlands such as Northern Atlantic Wet Heath, where there are other dwarf shrub species present, *Vaccinium* is not as essential a component for maintaining the habitat type. Similarly, where *Vaccinium* is a component of understory flora in forest habitats, its loss will not cause as fundamental a change in the habitat as a shift from heathland to grassland would be. Treatment of the sites for *Phytophthora* would likely be highly damaging to the other biodiversity and managers should not be duty bound to attempt to save *Vaccinium.* In woodland sites with an infected *Vaccinium* understory, treatment using herbicides, burning and cutting have all led to a change in understory community composition. Vac*cinium* has, at some sites, been replaced by more opportunist plants such as *Hedera helix* and *Rubus fruticosus*. In this case, it is likely that refraining from treatment may have led to less of a change in species composition than the disease would have caused.

In sites where *Vaccinium* is a less essential component of Annex I habitats, its loss will not necessarily create an unfavourable site condition report. CSM guidelines for site monitoring have a degree of flexibility in the species used to determine whether the site is in a favourable or unfavourable condition. Appendix 1 highlights the relevant CSM targets that may be influenced by *Phytophthora* or its treatment, in relevant habitat types where *Vaccinium* frequently and/or abundantly occurs. It also indicates how compliance to these targets may be influenced by disease and treatment. In many cases, targets take into account the percentage cover of dwarf shrubs or indicator species collectively, not only specifically *Vaccinium*, so if other species are present on sites when disease or treatments occur then targets may still be met. It is important to consider the wider conservation status rather than just the percentage cover of *Vaccinium*. Treatment is likely to influence compliance with acceptable percentages of bare ground on site and any increases in this measure may lead to a change in composition of exotic or invasive species. Treatment is also highly likely to influence any disturbance targets.

However, some sites infected by *Phytophthora* will undoubtedly be reported as unfavourable after losses of *Vaccinium* through disease, either due to no treatment or failed treatment. There needs to be some acceptance of these disease-induced losses as natural and inescapable changes due to the numerous limiting factors prohibiting effective treatment. Despite the original introductions of at least two of the strains of *Phytophthora* having anthropogenic origins, plant diseases and their selection for resistant strains of host are natural processes. Acceptance of disease-induced change may require a review and adjustment of regional conservation objectives or definitions of favourable condition in Article 17 reporting of Annex I reporting. However, these reviews should not occur until impacts caused by *Phytophthora* have stabilised, and the new status of the habitat has been established. Note that even if site treatments are unsuccessful, disease management through restricting access in England and Wales and limiting anthropogenic spread should remain a priority, to try and avoid reaching a situation in which conservation objectives need to be altered on a wide scale. Restricting access in Scotland is difficult due to land being open access; here the risks should be explained and members of the public can be asked to take account of them.

5.4 Site Use

Due to the nature of the sites at which infected *Vaccinium* may be found, there are several ways the land may be used. These uses may influence the spread of a *Phytophthora* infection or be affected by disease treatment if it occurs.

5.4.1 Public Access

Many sites in which *Vaccinium* grows are highly valued as sites for numerous leisure activities, including walking, horse-riding and cycling. In areas with wide public access, high visitor numbers can have implications for biosecurity, as humans can transport *Phytophthora* spores both around the site and offsite. Many of the recorded outbreaks of *Phytophthora* in *Vaccinium* have been close to footpaths. Therefore, if there are high offsite values (see section 5.6), then restricted access to infected *Vaccinium* may be desirable. Fencing off areas or closing paths may be publically unpopular, disruptive, or impossible, and local considerations should be taken into account. For example, if the site is near an urban area and provides a significant local amenity, then highly restricted access may be very damaging to recreational use. Negative feeling over closures is less likely to be a problem if the infection and restricted area is small compared to the size of the site. Note also the regulations that surround the closure of public rights of way[5], and the very limited restrictions

[5] https://www.gov.uk/right-of-way-open-access-land/public-rights-of-way

which are possible in Scotland[6]. A less officious method of restricting access is to create brash barriers around infected or vulnerable areas, to try and restrict disease spread. Very large moorland sites with extensive open access and few channelled access routes are particularly difficult to manage and restrict access. The feasibility and likely effectiveness of any possible biosecurity measures should be carefully evaluated for these sites.

The visual perception of the public may be that the landscape looks better with no *Phytophthora* treatment, as changes caused by the disease will be more gradual. A willingness-to-visit study (ADAS, 2011) showed that the majority of respondents in a survey would be as likely to visit an infected, untreated site before and after infection. It could be detrimental to tourism in heritage sites if the aesthetics of the area are deemed to be rapidly spoiled through treatment. The timing of any management needs to be carefully considered so as not to dissuade or endanger visitors. Perception of large scale herbicide use is negative, and may also pose a health risk if access passes nearby. Despite being a common management tool, burning large areas can pose a health and safety risk and is very difficult in damp conditions- potentially leading to a mosaic of burned and unburned areas and not providing disease control. The impacts of leaving the disease untreated will still lead to reduced *Vaccinium* cover, but may well be smaller scale than proactive treatment.

5.4.2 Business

Businesses that may directly suffer as a result of treating infected *Vaccinium* include commercial shooting and commercial bilberry picking. Both industries are likely to contribute to the spread of *Phytophthora* as they both promote human movements within and between areas of *Vaccinium*. Game bird populations and Bilberry trade may decline due to a loss in *Vaccinium* cover: either slowly (and potentially extensively) due to *Phytophthora*, or more rapidly (but hopefully more locally) with treatment. There will also be cultural losses if the Bilberry picking industry declines. From this cultural point of view, older heathlands have more value to lose due to their heritage. In localised outbreaks where spot treatment can be implemented, a temporary depression in bilberry trade may occur, but in the long term some *Vaccinium* populations may be salvaged. Widespread treatment in larger areas of infection will destroy the *Vaccinium* completely in the short term and it may never recover if opportunist grasses regrow first, leading to a habitat conversion. If the disease is left untreated, it could lead to a slower but complete loss of the *Vaccinium* on which trade is reliant, although current evidence suggests complete losses are unlikely.

5.4.3 Grazing by livestock and wild animal movements

Grazing may occur in and around *Vaccinium* by wild fauna such as deer, as part of heathland management, or as part of an agricultural system. Just as humans can act as vectors for *Phytophthora* spores, so too can grazing animals. Disease spread has been rapid in areas where livestock is grazing, though other site factors may have additionally influenced this spread. In light of this, management of *Phytophthora* requires careful management of grazing in infected areas. Livestock may need to be excluded from areas as a biosecurity measure to prevent further disease spread. The presence of animal tracks on sites ungrazed by livestock can indicate high levels of wild animal movements, which are likely to be impossible to control and may impact on the efficacy of biosecurity measures. Exclusion of livestock and provision of alternative grazing may also be required with treatment, as herbicides can be harmful and burning may reduce grazing fodder substantially. It may help to treat areas on a rolling basis, where livestock are excluded from a proportion of the site at a time.

Grazing has been suggested as a treatment method for *Phytophthora*; there is observational evidence from Wales that grazed *Vaccinium* which has adopted a low growth habit is more

[6] http://www.snh.org.uk/pdfs/publications/access/full%20code.pdf

robust and resilient to *Phytophthora* (J. Barbrook, personal communication). It is possible that plants with different growth habits have different susceptibilities to the disease- with the taller, leafier forms being more susceptible. However, grazing as a treatment strategy can also be damaging: livestock can act as vectors for increased spread of spores. There is also evidence to suggest that young, re-growing *Vaccinium* plants may be more susceptible to the pathogen (DEFRA, 2011), so in areas where grazing has not previously occurred to encourage the more resistant growth forms, it may be an unwise treatment choice.

5.4.4 History

Historical site uses have in some locations been found to hinder *Phytophthora* treatments. The presence of disused mineshafts, for example, has impeded access for treatments and monitoring of the disease in some heathlands.

5.5 Site ownership and location

5.5.1 Ownership and Funding

When deciding how to deal with a Phytophthora outbreak in *Vaccinium*, it is vital to take into account who owns the land, and who will fund and manage the treatment. If the infection spans land with multiple ownerships then it may be problematic deciding on whose responsibility it is to undertake treatment. Careful consideration needs to be taken as to whether there are enough resources to effectively undertake the most appropriate strategy. Ongoing treatment involves indefinite costs. After many years of treatment does it become too costly to continue the course of treatment chosen, and what is the exit strategy at that point? Monitoring must continue after clearance as infected re-growth needs to be rapidly detected; FERA suggests between one and four plant health inspections per year, depending on site risk, though this may be insufficient (FERA, 2013). Identification of infected plant tissue can be difficult and may require contracted professionals, particularly if infected plants are demonstrating atypical symptoms. Site management practices such as sheep grazing can impact on the growth habit of *Vaccinium*, which can make it hard to locate the plants and infection, even when it is a major component of the flora.

If containment is chosen rather than eradication, the ongoing management costs such as those associated with biosecurity, communication and monitoring need to be considered. It is also important to have an exit strategy if containment is attempted and proves ineffective or impractical; what are the management goals and what course of action occurs if they have not been met after a certain timeframe? Any exit strategy needs to take into account any compliance required by the SPHN. There is a continuing possibility that new treatments for *Phytophthora* may become available, and all management decisions should remain flexible. It should be remembered that any action involving movement on infected areas, be it for treatment, research or monitoring, has the potential to facilitate the spread of the disease.

5.5.2 Multiple ownership compliance

All management decisions must be made within a landscape context. This will include a consideration of whether multiple landowners will comply with a particular management prescription. If some landowners will not comply, this may ultimately lead to an alteration in the prescription for the whole area. The potential impacts on management success of any non-compliant sites should be considered based on their site attributes and how they may influence infection spread.

5.5.3 Proximity to other sources of infection

The location of an infected site needs to be considered with respect to other infected sites. If an infected site is isolated, targeted treatment of *Vaccinium* is more worthwhile, as chances of rapid re-infection from nearby sites are lower. Treating the isolated infected site reduces the chances that it will act as a nucleus of infection for other nearby sites. However, if a newly detected outbreak is surrounded by other infected sites, treatment may not be a long-term cost-effective option due to the high probability of re-infection. It has been highlighted that the creation of a searchable, regularly updated database collating relevant information from all sites with *Phytophthora* infections would enable better monitoring and contextualisation of newly infected sites, thus enabling effective prioritisation of resource allocation (FERA, 2013). There is currently a policy of not disclosing site locations widely, though there may be capacity to share information between agencies.

5.6 Offsite values

5.6.1 Proximity to sites of importance

If considering an infected site in isolation, often the impacts caused by the available treatment options are as or more damaging than the impacts of *Phytophthora* on *Vaccinium*. In particular, this is likely to be true where the infection is already widespread. Favoured management would be to leave infected plants and to implement biosecurity measures. This is partly because of the rapid and widespread damage caused by treatment and also due to the possibility that intervention may increase risk of re-infection, both by increasing movement to and from the infected area and because young regrowth seems to be more susceptible to infection. However, when set in a wider landscape context, offsite values need to be considered when deciding whether to treat diseased populations or not. Offsite values may include nearby SAC or SSSI/ASSI whose ecological integrity depends on *Vaccinium*, local heritage gardens or important national collections of susceptible species such as *Rhododendron.* Allowing the spread of infection in *Vaccinium* in one area could increase the likelihood of huge losses in these valued sites, and taking into account their presence nearby should therefore be a priority in decision making.

Prioritising protection of offsite values

Sites may be of variable value due to environmental, social or economic reasons, and often have value for more than one of these three reasons. Different site values will be affected to different extents by *Phytophthora* outbreaks. The extent to which an offsite value should be considered as an important factor in deciding whether or not to treat a nearby infection or not depends on the offsite value's importance, the extent of damage that could be caused to it, and the likelihood of spread of the pathogen to the site (linked to proximity and access).

(Due to numerous designations or uses, some values listed here as lower priority to protect will exist in sites already covered by a higher priority list. Categories are guide thresholds.)

Offsite values that should be considered high priority to protect

Sites with these values include habitats that have the potential to completely change type should *Vaccinium* be lost through disease e.g. heathlands converting to grassland. Areas of these habitats with conservation designations are a particular priority to protect as they are recognised sites of importance. Some site designations are based on species dependent on *Vaccinium*, and these sites are also high priority. This category also includes heritage gardens due to their very high social value concentrated in a limited area, and those at high risk with susceptible collections of species should certainly be taken into account when deciding whether to treat an infected area nearby.

- Special Areas of Conservation (SAC) heathlands, particularly those in which *Vaccinium* is present frequently and in high abundance e.g. European dry heaths such as the Dorset and Exmoor Heaths.
- SACs or SPAs for species dependent on *Vaccinium*, e.g. Capercaillie sites such as the Cairngorms.

- Annex I, SSSI/ASSI heathlands of European importance, in which *Vaccinium* is an important component of the biota e.g. Alpine and Boreal heaths (See appendix 2 for a list of Annex I habitats in which *Vaccinium* frequently occurs and/or is abundant).
- Annex I habitats that are otherwise undesignated e.g. large areas of heathland across the UK.
- Priority habitats in which *Vaccinium* is an important component of the biota, as listed/referred to under section 41 and 42 of the NERC Act, section 2(4) of The Nature Conservation (Scotland) Act 2004 and section 3 of the Wildlife and Natural Environment Act (Northern Ireland) 2011.
- Nationally important heritage gardens (especially those which contain national collections of susceptible species such as *Rhododendron*.)
- Regionally important heritage gardens (especially those which contain national collections of susceptible species such as *Rhododendron*.)

Offsite values that should be considered medium priority to protect

Designated woodlands in which *Vaccinium* makes up part of the ground flora are of high value. However, they are a lower priority to consider than some heathlands, because were they to lose the species, the habitat would not cease to be woodland. Commercially important larch stands are also in this category because despite infection, timber can still be used. Thus, should infection occur, it will not lead to complete loss of value associated with the larch plantations.

- Ancient semi-natural woodland in which *Vaccinium* is a major component of the ground flora e.g. Old sessile oak woods with *Ilex* and *Blechnum* and Caledonian Forest such as Abernethy. SAC site protection prioritised first, followed by NNRs, other Annex I habitats, SSSIs/ASSIs and local and county wildlife sites.
- Plantations on ancient woodland sites in which *Vaccinium* is a major component of the ground flora. SAC site protection prioritised first, followed by NNRs, other Annex I habitats, SSSIs/ASSIs and local and county wildlife sites.
- Secondary woodlands in which *Vaccinium* is a major component of the ground flora. SAC site protection prioritised first, followed by NNRs, other Annex I habitats, SSSIs/ASSIs and local and county wildlife sites.
- Large areas of newly planted, commercially important, susceptible *Larix kaempferi* (individual larch trees or small stands are neither of high commercial value nor hugely susceptible as there is an insufficient density of hosts for *Phytophthora* spore build up).
- Large areas of old, commercially important, susceptible *Larix kaempferi* (older trees are less costly to clear and can be cleared more in line with normal rotational management.)
- Local and county wildlife sites in which the ecological integrity is dependent on *Vaccinium*
- Non-Annex I, SSSI habitats in which *Vaccinium* is part of the biota e.g. Acid grasslands and grass-dominated snow bed.

Offsite values that should be considered lower priority to protect

Sites with values in this category may be covered by higher priority categories, due to multiple site values. Loss of these values would generally have lower impact socially, environmentally and economically.

- Ancient heathlands with high use for bilberry trade
- Newer heathlands with high use for bilberry trade
- Heathlands used for commercial shooting

- Other Annex I habitats in which *Vaccinium* is part of the biota but not as essential for retaining the habitat type e.g. *Juniperus communis* formations on heaths or calcareous grasslands (see appendices 2 and 3).
- Populations of *Vaccinium* in degraded habitat types not previously mentioned.
- SAC, SSSIs/ASSIs and NNR in which the presence of *Vaccinium* does not influence a notified feature, and loss would not dramatically influence the habitat
- Areas of high tourism value with susceptible species
- Parks with susceptible plantings, but in which substitution with non-susceptible species will ultimately retain value
- *Vaccinium* in a horticultural context e.g. parks, gardens

It needs to be established what constitutes a "nearby" offsite value. The distribution of new infections surrounding an infected site is highly variable and uncertain, with the distance by which 95% of new *P. ramorum* infections will occur varying between 1.5km and 60km from the infection source (with an average of 4km) (M. Castle, personal communication). The probability of dispersal occurring at distances near the upper bound of this range is very low, and would only be likely to occur in rare weather events. These figures are based on data from Japanese larch and as such are a worst case scenario for *Vaccinium*, whose dispersal distance is likely to be somewhat shorter due to its low growth habit. *P. ramorum* sporangia dispersal has been recorded over distances of 6km in water courses (Davidson *et al*, 2005). It would be prudent to consider at least a 10km radius around an infected site with regard to offsite values: with particular priorities placed on higher risk areas within 5km, and areas downstream and downwind. There is still potential for dispersal over distances greater than this, but it is highly unpredictable. If there is a very high offsite value beyond 10km, it could still inform treatment decisions, but this is highly dependent on the sites concerned.

Offsite values are complex in terms of the funding implications. Landowners told that their management actions are necessary to protect a nearby area could justifiably consider that the land manager of this other area should bear a proportion of the cost. Where the ecosystems being protected are publically owned or of high public value, there may be a feeling that government funding should be available for treatment. In these situations, targeted government funding could have the greatest impact, to protect both offsite and onsite values.

5.6.2 Connectivity

The level of connectivity from the infected site to sites of value should also be considered, as there may be increased risk of disease transmission and damages from treatments across continuous habitats. Note that sites may be connected by habitat corridors, but also through water courses, grazing or human movements via footpaths or roads. For example, if there is a SSSI downstream from an infected site, treatment should be considered due to the potential for *Phytophthora* sporangia to be transmitted by the watercourse. *P. ramorum* sporangia have been detected in water courses up to 6km from the inoculum source (Davidson *et al*, 2005). Even if sites of value are further than 10km from an infected area, if they are highly connected the potential risks should be evaluated and may inform treatment.

6 Further research

There is still overall uncertainty about *Phytophthora* and the extent of the threat to *Vaccinium* populations. Currently, apart from in Cannock Chase, the rate of infection and number of infected sites are relatively low, but the consequences of inaction are uncertain. Key questions that would benefit from further research are:

- Will biodiversity losses be greater overall if *Vaccinium* loss is gradual (due to disease) or rapid (due to treatment)? Will treatment reduce *Vaccinium* populations to a point at which they fare worse than the diseased populations?
- Do infected plants always die?
- If wild, uninfected *Vaccinium* populations are left untreated, will the inoculum build up to become a major threat to *Vaccinium* and British heathlands?
- Could the inoculum build up to such high levels in *Vaccinium* that the disease transfers to other species in the wild such as *Empetrum nigrum* and *Calluna vulgaris*? Might there be any risk to commercially valuable crop species in addition to larch?
- What sort of level of resistance to *Phytophthora* might we see in various hosts?
- How quickly can *Phytophthora* spread in *Vaccinium* populations, as well as in other susceptible hosts such as *Rhododendron*?
- Is regrowth always infected?
- Why are some sites more susceptible to infection than others?
- Are sites in favourable condition according to Common Standards Monitoring more or less, or similarly, susceptible to outbreaks? (e.g. heaths with open structure may be more aerated and less susceptible)
- Why are the symptoms of *Phytophthora* so variable in *Vaccinium*, and how can we cost effectively improve diagnostics? (Note, symptoms can be very difficult to identify in the field. This is important to address because there is a possibility of outbreaks going un-noticed and acting as a source of re-infection for other sites undergoing treatment.)
- What relevance does different *Vaccinium* growth habits have on susceptibility and potential for spread?
- What level of spores do infected *Vaccinium* produce?
- Are chlamydospores retained in soil after spot treatment has been applied?
- Can birds act as a vector for the disease?
- What effect does elevation have on restricting opportunity for infection and spread?
- What other factors are currently causing widespread *Vaccinium* dieback and how are these pressures interacting with the effects of *Phytophthora*?
- How effective are different treatment options and for how long does treatment need to be carried out to be effective?

It is also noted that greater certainty of the location of infections would be useful to improve our understanding of the diseases' pathogenicity, as well as helping in making decisions on whether and how to treat *Phytophthora* infections. A regularly updated publically available map of outbreak locations would be useful in helping decision-makers to apply this decision making framework.

7 Conclusion

This decision framework will allow a land manager to understand the possible management options for *Phytophthora,* and which are most likely to be beneficial for their site, but it is not intended to deliver rules about the appropriate prescription for a site. It will also encourage an auditing of why management might deviate from national norms. There are a wide range of potential site factors that could lead a manager to be more or less precautionary than the national norm, and this framework cannot cover every possible circumstance. Any decisions made using this framework should adhere firstly to the statutory minimum requirements set out in a site's SPHN. In future, Plant Health Management Plans (PHMPs) will support SPHNs by setting out good practices and additional advised action when faced with a *Phytophthora* outbreak. Alongside this, a clear set of monitoring criteria connected with an exit strategy is an important component of every site management plan. This can set out conditions suggesting that management measures are leading to successful containment and hence continue to be beneficial.

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Appendix 1 – Common Standard Monitoring Guidance relevant to *Vaccinium myrtillus* habitats

The relevant common standards monitoring guidance (CSM) targets applicable to habitats containing communities in which *Vaccinium* is either frequently present, highly abundant when it is present, or both (see appendix 3). Included is a consideration of how *Phytophthora* infections and their treatment would influence the CSM targets. Targets listed are indicative only and should be considered on a site-specific basis. For more detailed CSM guidance, including complete lists of positive and negative indicator species and definitions of sensitive areas, see http://jncc.defra.gov.uk/page-2199.

	Is a measurable decline in habitat area acceptable?	Is *Vaccinium* an indicator species?	Indicator species cover	Dwarf Shrub/Ericaceous sp. Target	Bare Ground Target	Other species composition Target	Disturbance Target	Considerations over the impacts of disease on targets	Considerations over the impacts of treatment on targets
Subalpine dry dwarf-shrub heath	No	Yes	For herb-rich heaths (NVC communities H7, H10d, H16a), 50-75% of vegetation cover should be made up of indicator species. For all other types of heath, at least 50% of vegetation cover should be made up of indicator species.	At least 25% of dwarf-shrub cover should be made up dwarf shrub indicators. For all types of heath at least two dwarf shrub indicator species should be present. This is not applicable to heath in sensitive areas which may go through prolonged phases of *Calluna* dominance.	Less than 10% of the ground cover should be made up of disturbed bare ground.	Less than 1% of the vegetation cover should consist of invasive "weedy" species (collectively *Cirsium arvense, Cirsium vulgare,* large docks (excluding *Rumex acetosa*), *Ranunculus repens,* or *Urtica dioica*). Less than 10% of the vegetation cover should consist of *Juncus effusus.*	There should be no signs of burning inside the boundaries of sensitive areas.	If *Vaccinium* were to be lost completely through disease, will there still be two dwarf-shrub indicator species on site, making up 25% of vegetation cover? What is the maximum percentage of *Vaccinium* that could be lost before the site becomes unfavourable? Is the site biodiverse enough that there are enough other indicator species to make up 50-75% of vegetation cover even after *Vaccinium* loss? Bare ground will not be rapidly created as it would be with treatment as diseased and dead *Vaccinium* will form cover; less likely to allow expansion of weedy species.	Burning treatments may mean disturbance targets are not met. Will *Vaccinium* and other indicator species regrow to maintain the area of the habitat? Or is the area likely to convert to grassland after clearance due to few other dwarf shrubs, leading to a decline in habitat area? In a widespread outbreak, or even through spot treatment with buffer zones, the bare ground limit may be exceeded. Rapid clearance of *Vaccinium* will create bare ground that will encourage establishment of weedy species, potentially failing to meet the other species composition target. Treatment will likely affect numerous other indicator species, altering their cover.

Acid Grassland	No	Yes, in community U3 (*Agrostis curtisii* grassland)	Targets should be set to register a low or declining frequency of key indicators as unfavourable. As a generic standard, the frequencies of positive indicators should at the very least, confirm the presence of the target community. Local targets could also be set for site-specific positive indicator species, to register a decrease in frequency of 20% or more as unfavourable.		As a generic standard, total extent of bare ground should be no more than 10% of the sward.	Targets should be set to register high or increasing frequency/cover as unfavourable in any of the following species: Agricultural weeds species should not be more than occasional throughout the sward or together more than 5% cover. Agriculturally favoured species should not be individually at more than 10% cover, or collectively at more than 20% cover. As a generic standard, *Arrhenatherum* and *Dactylis* together should cover less than 10% of the sward. Scrub, *Rubus fruticosus*, tree species and bracken together should be no more than 5% cover, or *Rhododendron* spp. no more than rare.		*Vaccinium* is only rarely present in both high frequency and abundance in acid grassland. Only in community U3 (*Agrostis curtisii* grassland) is it a positive indicator species. Its gradual loss through disease is unlikely to have a dramatic effect on the habitat type, and is unlikely to cause a decline in area. Small areas in which infected growth dies are likely to be grown over by surrounding plants.	As *Vaccinium* is more likely to be in lower abundance in acid grasslands, it is likely that spot treatment with a buffer zone will be the most effective treatment. However, rapid clearance of vegetation with a 10m radius would create large patches of bare earth (possibly exceeding the 10% limit) that may well be infilled by agricultural weeds or more invasive species.
Lowland dry heath	No unconsented decline in the area of the habitat is acceptable, except where a target has been set to increase the extent of other habitat features on the site at the expense of lowland heathland.	Yes, one of the dwarf shrubs		Dwarf shrubs should cover 25-90%. At least two species of dwarf shrubs should be present and at least frequent (excluding *Ulex gallii*). Ericaceous shrubs growth phases should be found in the following percentages (each site will have narrower, tailored targets): Pioneer phase (including pseudopioneer): 10-40% Building/mature phase: 20-80% Degenerate phase: <30% Dead: <10%, of total ericaceous cover.	At least 1% but not more than 10% cover of the area of the feature should consist of firm, sunlit, horizontal, sloping or vertical, exposed bare ground.	<1% exotic species < 1 % ragwort, nettle, thistles and other herbaceous spp . < 15% trees & scrub <10% bracken (dense canopy) Acrocarpous mosses <occasional	<1% of habitat heavily eroded.	If *Vaccinium* is lost completely through disease, will there still be two dwarf-shrub indicator species on site, making up 25%-90% of vegetation cover? If *Vaccinium* currently makes up 80% of the cover, clearly its loss will be fairly disastrous to maintaining the habitat type. Is there Is the site biodiverse enough that there are enough other indicator species to make up 50-75% of vegetation cover, after disease losses? If large areas of *Vaccinium* die, the total cover of dead	There are fairly low upper limits in the targets for exotic and invasive species in this habitat type. Rapid creation of bare ground is likely to facilitate their spread. *Vaccinium* is more abundant in this habitat type so reasonably extensive treatments are likely to be implemented. Machinery use while undertaking this treatment could cause excessive habitat erosion. Burning large areas may also cause erosion due to loss of vegetation cover. Will *Vaccinium* and other indicator species regrow to maintain the area of the habitat? Or is the area likely to convert to grassland after

								ericaceous shrubs may exceed 10%. Bare ground will not be rapidly created as it would be with treatment as diseased plants will form cover; less likely to allow expansion of weedy species.	clearance due to few other dwarf shrubs, leading to a decline in habitat area?
Blanket Bog and Valley Bog (upland)	No	Yes	At least 6 indicator species should be present. At least 50% of vegetation cover should consist of at least 3 indicator species.	Any one of *Eriophorum vaginatum*, Ericaceous species collectively, or *Trichophorum* should not individually exceed 75% of the vegetation cover.	Less than 10% of the total feature area, should be disturbed bare ground and/or show signs of active drainage, resulting from ditches or heavy trampling or tracking. Less than 10% of the Sphagnum cover should be crushed, broken, and/or pulled-up.	Less than 1% of vegetation cover should be made up of non-native species. Less than 10% of vegetation cover should be made up of scattered native trees and scrub. Less than 1% of vegetation cover should consist of, collectively, *Agrostis capillaris, Holcus lanatus, Phragmites australis, Pteridium aquilinum, Ranunculus repens.*	There should be no observable signs of burning into the moss, liverwort or lichen layer or exposure of peat surface due to burning. There should be no signs of burning or other disturbance (e.g. mowing) in sensitive areas. The extent of eroding peat should be less than the extent of stable re-deposited peat and new growth of bog vegetation within the feature.	*Vaccinium* can be present in high abundances in this habitat, reasonably frequently. Although it is an indicator species, targets suggest that at least 6 indicator species should be present, and *Vaccinium* plus other ericaceous species cover should not exceed 75%. It is unlikely that this habitat type would be lost completely or reduced in area if *Vaccinium* were to die back, unless it was already highly impoverished. Bare ground will not be rapidly created as it would be with treatment as diseased plants will form cover; less likely to allow expansion of weedy species.	This is a vulnerable habitat to all forms of treatment. Burning would need to be very carefully controlled if used at all to still meet disturbance targets. It is an unsuitable management method to use at all in sensitive areas. Manual removal of infected material would likely involve machinery use, which would be very damaging to the peat, causing erosion or compaction. Spot treatment with a general herbicide would be likely to reduce the biodiversity in indicator species that is encouraged. Rapid clearance of vegetation with a 10m radius would create large patches of bare, disturbed ground (possibly exceeding the 10% limit) that may well be infilled by non-native or more invasive species.
Alpine dwarf-shrub heath	No	Yes	The collective cover of indicator species should make up at least 66% of the vegetation cover	At least one dwarf shrub species should be present	Less than 10% of the ground cover should be disturbed bare ground	Less than 1% of the vegetation cover should be made up of non-native species.	There should be no signs of burning inside the feature boundaries.	If all the *Vaccinium* on site were to die through disease, would there still be another dwarf shrub species on site, to retain the habitat type? If not, treatment may be appropriate to make	If treatment is implemented in attempts to preserve *Vaccinium* on site, it is possible that more than 10% bare ground will be created. It is hard to be certain what will colonise this bare ground, so may promote non-native

								great efforts to retain *Vaccinium*. Is *Vaccinium* the dominant indicator species; would its loss mean the collective cover of indicator species was less than 66%? If it is dominant, again, treatment may be appropriate.	species establishment. Will *Vaccinium* and other indicator species regrow to maintain the area of the habitat? Or is the area likely to convert to grassland after clearance due to few other dwarf shrubs, leading to a decline in habitat area?
Tall Herbs (upland)	No	Yes, for U16 (*Luzula sylvatica-Vaccinium myrtillus* tall-herb community) and U19 (*Juniperus communis ssp. communis-Oxalis acetosella* woodland)	In U16 and U19 communities, at least 50% of vegetation should be made up of indicator species.	In U16 communities, at least one dwarf shrub species must be present.	Less than 25% of the ground cover, of each patch or stand, should be disturbed bare ground. Over the whole feature scanned from sample locations, less than 10% of the ground cover should be disturbed bare ground.	Less than 1% of vegetation cover should be made up of non-native species.		In U16 communities, *Vaccinium* occurs frequently and in high abundance. It is less extensively found in U19 communities. If all the *Vaccinium* on site died through disease, would there still be another dwarf shrub species on site, to retain the habitat type? If not, treatment may be appropriate to make great efforts to retain *Vaccinium*. Is *Vaccinium* the dominant indicator species; would its loss mean the collective cover of indicator species was less than 50%? If it is dominant, again, treatment may be appropriate.	If treatment is implemented in attempts to preserve *Vaccinium* on site, it is possible that more than 10% bare ground will be created. It is hard to be certain what will colonise this bare ground, so may promote non-native species establishment.
Lowland wet heath	No unconsented decline in the area of the habitat, except where a target has been set to increase the	Yes, one of the dwarf shrubs		Dwarf shrub should cover 25-90%. At least two species of dwarf shrubs present and at least frequent.	At least 1% but not more than 10% cover of the area of the feature should consist of muddy exposed	<1% exotic species < 1 % ragwort, nettle, thistles and other herbaceous spp < 10% trees & scrub <5% bracken (dense canopy) <10% *Ulex europaeus* Acrocarpous mosses < occasional	<1% of habitat showing signs of trampling/paths.	If *Vaccinium* is lost completely through disease, will there still be two dwarf-shrub species on site, making up at least 25% of vegetation cover? Bare ground will not be rapidly created as if treatment occurred as	In a widespread outbreak, or even through spot treatment with buffer zones, the bare ground limit may be exceeded. Rapid clearance of *Vaccinium* will create bare ground that will encourage establishment of opportunistic species, potentially failing to meet the other species composition

	extent of other habitat features on the site at the expense of lowland heathland.				bare ground.			diseased plants will form cover; less likely to allow expansion of weedy species. Increased trampling through disease monitoring may exceed the disturbance target.	target. Increased trampling through treatment implementation may exceed the disturbance target. Will *Vaccinium* and other indicator species regrow to maintain the area of the habitat? Or is the area likely to convert to grassland after clearance due to few other dwarf shrubs, leading to a decline in habitat area?
Calcareous grassland (upland)	No	No			Less than 10% of ground cover should be disturbed bare ground.	Less than 1% of vegetation cover should be made up of non-native species. Less than 10% of vegetation cover should be made up of bracken and/or scattered native trees and scrub. The percentage of vegetation cover made up collectively, of *Bellis perennis* and/or *Ranunculus repens* should be less than 25%. Less than 1% of vegetation cover should consist of, collectively, *Arrhenatherum elatius, Cirsium arvense, Cirsium vulgare, Cynosurus cristatus,* large docks (excluding *Rumex acetosa), Lolium perenne, Senecio jacobaea, Urtica dioica.* Less than 10% of the vegetation cover should consist of *Juncus effusus*.		*Vaccinium* is usually only present at low abundance calcareous grassland. It is not an indicator species and its loss or decline would not lead to a change in habitat type.	Treatment implementation may well create large areas of bare ground which could noticeably alter the species composition.

Wet Heath (upland)	No	Yes	Indicator species should cover at least 50% of ground area.	At least 20% of the vegetation cover should consist of ericoid species. Dwarf shrub cover should be less than 75% of vegetation cover.	Less than 10% of the ground should be disturbed bare ground. Less than 10% of the *Sphagnum* cover should be crushed, broken, and/or pulled-up.	Less than 20% of vegetation cover should be made up of scattered native trees and scrub. Less than 10% of vegetation cover should be made up of bracken. Less than 1% of vegetation cover should be made up of non-native species. Less than 1% of vegetation cover should consist of, collectively, *Agrostis capillaris, Holcus lanatus, Phragmites australis, Ranunculus repens.* Less than 10% of the vegetation cover should consist of *Juncus effusus*. Graminoids should not make up more than 75% of vegetation cover.	There should be no observable signs of burning into the moss, liverwort or lichen layer or exposure of peat surface due to burning. There should be no signs of burning and other disturbance inside the boundaries of sensitive areas. Less than 10% of the total feature area, should show signs of active drainage, resulting from ditches or heavy trampling or tracking. The extent of eroding peat and/or mineral soil should be less than the extent of re-deposited peat and/or mineral soil and new growth of wet heath and/or bog vegetation within the feature.	If *Vaccinium* is lost completely through disease, will there still be 20% vegetation cover by ericoid species? Will indicator species still cover 50% of ground area? Bare ground will not be rapidly created as if treatment occurred as diseased plants will form cover; less likely to allow expansion of weedy species.	This is a vulnerable habitat to all forms of treatment. Burning would need to be very carefully controlled if used at all to still meet disturbance targets. It is unsuitable to use at all in sensitive areas. Manual removal of infected material would likely involve machinery use, which would be very damaging to the peat, likely causing erosion or compaction. Spot treatment with a general herbicide would be likely to reduce the biodiversity in indicator species that is encouraged. Rapid clearance of vegetation with a 10m radius would create large patches of bare, disturbed ground (possibly exceeding the 10% limit) that may well be infilled by non-native or more invasive species. Will *Vaccinium* and other indicator species regrow to maintain the area of the habitat? Or is the area likely to convert to grassland after clearance due to few other dwarf shrubs, leading to a decline in habitat area?

Alpine summit communities of moss, sedge and three-leaved rush	No	Yes	At least 25% of vegetation cover should consist of indicator species.		Less than 10% of the ground cover should be disturbed bare ground	Less than 20% of vegetation cover should consist, collectively, of *Agrostis capillaris, Agrostis vinealis, Anthoxanthum odoratum, Deschampsia flexuosa, Festuca ovina / vivipara, Galium saxatile, Poa spp*. (other than arctic-alpine spp.) and *Potentilla erecta*. Less than 1% of vegetation cover should be made up of non-native species.	There should be no signs of burning inside the feature boundaries.	If *Vaccinium* is lost completely through disease, will there still be 25% vegetation cover by other indicator species?	Any burning treatments will mean disturbance targets are not met. Rapid clearance of vegetation with a 10m radius would create large patches of bare, disturbed ground (possibly exceeding the 10% limit) that may well be infilled by non-native or more invasive species.
Moss, dwarf-herb and grass dominated snow bed	No	No			Less than 25% of ground cover, for each snowbed, should be disturbed bare ground. Over the whole feature scanned from sample location, less than 10% of the ground should be disturbed bare ground.	Less than 1% of vegetation cover should be made up of non-native species.		*Vaccinium* is not an indicator species. There are no specific targets related to it.	Rapid clearance of vegetation with a 10m radius would create large patches of bare, disturbed ground (possibly exceeding the 10% limit) that may well be infilled by non-native or more invasive species.
Juniper heath and scrub (upland)	No	No specified indicator species				Less than 1% of vegetation cover should be made up of non-native species. Less than 1% of vegetation cover should consist of, collectively, *Cirsium arvense, Cirsium vulgare, Pteridium aquilinum, Rhododendron spp., Urtica dioica*.	Less than 5% of the feature area should show severe disturbance (e.g. by heavy browsing and trampling or fire).	*Vaccinium* is not an indicator species. There are no specific targets related to it. It is unlikely its loss would alter the habitat type.	Rapid clearance of vegetation with a 10m radius would create large patches of bare, disturbed ground that may well be infilled by non-native or more invasive species.

Montane Willow Scrub	No	No specified indicator species				Less than 1% of vegetation cover should be made up of non-native species.		*Vaccinium* is not an indicator species. There are no specific targets related to it. It is unlikely its loss would alter the habitat type.	Rapid clearance of vegetation with a 10m radius would create large patches of bare, disturbed ground that may well be infilled by non-native or more invasive species.
Woodland	CSM guidelines referring to entire habitat area focus on the tree composition and cover. Loss of ground flora not specified in this category.	No specified indicator species However, if susceptible woodland types were considered individually, *Vaccinium* would be considered a key species for Caledonian pinewood (a constant in W18b, c, d and e) and Old sessile oakwoods (a constant in W17d and an important species in W17 more generally).		80% of ground flora cover should be referable to relevant NVC community. *Vaccinium* is a key part of the ground flora in W18 and W17. Target(s) to be set to maintain distinctive elements at current extent/levels and/or in current locations, e.g. to maintain important microhabitats (other than dead wood), patches of associated habitats, transitions between habitats, or existing populations of locally notable species (other than trees/shrubs).			There should be signs of seedlings growing through to saplings to young trees at sufficient density to maintain canopy density over a 10 yr period (or equivalent regrowth from coppice stumps). No more than 20% of areas regenerated by planting.	Importance of *Vaccinium* within habitat is very community specific; it is highly important in Caledonian pinewood and Old sessile oakwoods. Desirable ground cover of *Vaccinium* will be reflected in site-specific targets. Damages to habitat through loss of *Vaccinium* by disease are dependent on its abundance. Loss of *Vaccinium* from any woodland habitat may result in an unfavourable ground flora, but the area of woodland will persist as woodland.	Treatment of infected ground flora would likely destroy a cohort of tree seedlings, due to the lack of specificity in herbicides. This may have long term effects on canopy density.

Appendix 2 – *Vaccinium myrtillus* Annex I habitats

The table shows correspondence between Annex I habitats containing *Vaccinium myrtillus* NVC communities, and habitat categories used in Common Standards Monitoring (CSM) Guidance. Table only includes the CSM classifications which include communities in which *Vaccinium* occurs at least frequently (in at least 60% of that community type), or abundantly (making up 50% or more of the vegetation cover), or both (see appendix 3).

Common Standards Monitoring Classification	Annex I habitats of concern included within classification (where *Vaccinium* is present)
Subalpine dry dwarf-shrub heath	European dry heaths
Acid Grassland	No Annex I types
Lowland dry heath	European dry heaths Atlantic decalcified fixed dunes (*Calluno-Ulicetea*)*
Blanket Bog and Valley Bog (upland)	Blanket Bogs Depressions on peat substrates of the *Rhynchosporion**
Alpine dwarf-shrub heath	Alpine and Boreal Heaths
Tall Herbs (upland)	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
Lowland wet heath	Temperate Atlantic wet heaths with *Erica ciliaris* and *Erica tetralix* Northern Atlantic wet heaths with *Erica tetralix*
Calcareous grassland	Alpine and subalpine calcareous grasslands* Species-rich *Nardus* grassland, on siliceous substrates in mountain areas
Wet Heath (upland)	Northern Atlantic wet heaths with *Erica tetralix*
Alpine summit communities of moss, sedge and three-leaved rush	Siliceous alpine and boreal grasslands
Moss, dwarf-herb and grass dominated snow bed	No Annex I types
Juniper heath and scrub (upland)	*Juniperus communis* formations on heaths or calcareous grasslands
Montane Willow Scrub	Sub-Arctic *Salix* spp. scrub
Woodland	Caledonian forest Bog woodland Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (*Quercion robori-petraeae* or *Ilici-Fagenion*) Sub-Atlantic and medio-European oak or oak-hornbeam forests of the *Carpinion betuli* * Old sessile oak woods with *Ilex* and *Blechnum* in the British Isles

* low priority due to both infrequent occurrence and low abundance of *Vaccinium* in few of the NVC communities in habitat type (appendix 3)

Appendix 3 – Frequency and abundance of *Vaccinium myrtillus* in NVC Communities

The frequency and abundance of *Vaccinium myrtillus* in NVC communities, and the common standards monitoring guidance relevant to each community.

Species constancy values are defined as:

I	1–20% occurrence (i.e. 1 stand in 5)	*scarce*
II	21–40%	*occasional*
III	41–60%	*frequent*
IV	61–80%	*constant*
V	81–100%	*constant*

Maximum abundance of species values are defined in accordance with the Domin Scale:

10	91–100% vegetation cover
9	76–90%
8	51–75%
7	34–50%
6	26–33%
5	11–25%
4	4–10%
3	<4% (many individuals)
2	<4% (several individuals)
1	<4% (few individuals)

In the table, green rows highlight communities in which *Vaccinium* occurs at least frequently, and where it does occur it makes up 50% of the vegetation cover or more. These communities are likely to be greatly affected by *Vaccinium* losses.

Blue rows highlight communities in which *Vaccinium* can occur, and when it does occur it makes up 50% of the vegetation cover or more.

Yellow rows highlight communities in which *Vaccinium* occurs at least frequently, and where it does occur it can be present at any percentage of vegetation cover.

White rows indicate all other communities in which *Vaccinium* is only occasional or scarce, <u>and</u> where it makes up less than 50% of the vegetation cover.

Community or sub-community code	Community or sub-community name including *Vaccinium myrtillus*	Species constancy value	Maximum abundance of species	Affected CSM habitat types
H12	Calluna vulgaris-Vaccinium myrtillus heath	V	8	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H12b	Calluna vulgaris-Vaccinium myrtillus heath, Vaccinium vitis-idaea-Cladonia impexa sub-community	V	8	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H18	Vaccinium myrtillus-Deschampsia flexuosa heath	V	10	Subalpine dry dwarf-shrub heath
H18a	Vaccinium myrtillus-Deschampsia flexuosa heath, Hylocomium splendens-Rhytidiadelphus loreus sub-community	V	10	Subalpine dry dwarf-shrub heath
H18b	Vaccinium myrtillus-Deschampsia flexuosa heath, Alchemilla alpina-Carex pilulifera sub-community	V	8	Subalpine dry dwarf-shrub heath
H18c	Vaccinium myrtillus-Deschampsia flexuosa heath, Racomitrium lanuginosum-Cladonia spp. sub-community	V	10	Subalpine dry dwarf-shrub heath
H19	Vaccinium myrtillus-Cladonia arbuscula heath	V	8	Alpine dwarf-shrub heath
H19a	Vaccinium myrtillus-Cladonia arbuscula heath, Festuca ovina-Galium saxatile sub-community	V	8	Alpine dwarf-shrub heath
H19b	Vaccinium myrtillus-Cladonia arbuscula heath, Racomitrium lanuginosum sub-community	V	8	Alpine dwarf-shrub heath
H19c	Vaccinium myrtillus-Cladonia arbuscula heath, Empetrum nigrum ssp. hermaphroditum-Cladonia spp. sub-community	V	8	Alpine dwarf-shrub heath
H20	Vaccinium myrtillus-Racomitrium lanuginosum heath	V	8	Alpine dwarf-shrub heath
H20d	Vaccinium myrtillus-Racomitrium lanuginosum heath, Rhytidiadelphus loreus-Hylocomium splendens sub-community	V	8	Alpine dwarf-shrub heath
H22	Vaccinium myrtillus-Rubus chamaemorus heath	V	10	Alpine dwarf-shrub heath; Subalpine dry dwarf-shrub heath
H22a	Vaccinium myrtillus-Rubus chamaemorus heath, Polytrichum commune-Galium saxatile sub-community	V	10	Alpine dwarf-shrub heath; Subalpine dry dwarf-shrub heath
U5a	Nardus stricta-Galium saxatile grassland, species-poor sub-community	IV	8	Acid Grassland; Subalpine dry dwarf-shrub heath
U16	Luzula sylvatica-Vaccinium myrtillus tall-herb community	V	9	Tall herbs (upland)
U16a	Luzula sylvatica-Vaccinium myrtillus tall-herb community, Dryopteris dilatata-Dicranum majus sub-community	V	9	Tall herbs (upland)
W15c	Fagus sylvatica-Deschampsia flexuosa woodland, Vaccinium myrtillus sub-community	V	8	Woodland
W17	Quercus petraea-Betula pubescens-Dicranum majus woodland	IV	9	Woodland
W17b	Quercus petraea-Betula pubescens-Dicranum majus woodland, typical sub-community	IV	9	Woodland
W17d	Quercus petraea-Betula pubescens-Dicranum majus woodland, Rhytidiadelphus triquetrus sub-community	V	9	Woodland
W18	Pinus sylvestris-Hylocomium splendens woodland	IV	9	Woodland
W18b	Pinus sylvestris-Hylocomium splendens woodland, Vaccinium myrtillus-V. vitis-idaea sub-community	V	8	Woodland
W18c	Pinus sylvestris-Hylocomium splendens woodland, Luzula pilosa sub-community	V	9	Woodland

W18d	Pinus sylvestris-Hylocomium splendens woodland, Sphagnum capillifolium/quinquefarium-Erica tetralix sub-community	V	8	Woodland
W18e	Pinus sylvestris-Hylocomium splendens woodland, Scapania gracilis sub-community	V	8	Woodland
W19	Juniperus communis ssp. communis-Oxalis acetosella woodland	V	8	Juniper heath and Scrub (upland); woodland
W19a	Juniperus communis ssp. communis-Oxalis acetosella woodland, Vaccinium vitis-idaea-Deschampsia flexuosa sub-community	V	8	Juniper heath and Scrub (upland); woodland
H4	Ulex gallii-Agrostis curtisii heath	II	8	Subalpine dry dwarf-shrub heath; Lowland Dry Heath; Lowland Wet Heath
H4a	Ulex gallii-Agrostis curtisii heath, Agrostis curtisii-Erica cinerea sub-community	II	8	Subalpine dry dwarf-shrub heath; Lowland Dry Heath; Lowland Wet Heath
M19	Calluna vulgaris-Eriophorum vaginatum blanket mire	III	9	Blanket bog and valley bog (upland)
M19a	Calluna vulgaris-Eriophorum vaginatum blanket mire, Erica tetralix sub-community	III	8	Blanket bog and valley bog (upland)
M19b	Calluna vulgaris-Eriophorum vaginatum blanket mire, Empetrum nigrum ssp. nigrum sub-community	III	9	Blanket bog and valley bog (upland)
U5	Nardus stricta-Galium saxatile grassland	III	8	Acid Grassland; Subalpine dry dwarf-shrub heath
W11	Quercus petraea-Betula pubescens-Oxalis acetosella woodland	I	9	Woodland
W11c	Quercus petraea-Betula pubescens-Oxalis acetosella woodland, Anemone nemorosa sub-community	II	9	Woodland
W15	Fagus sylvatica-Deschampsia flexuosa woodland	II	8	Woodland
W16	Quercus spp.-Betula spp.-Deschampsia flexuosa woodland	II	10	Woodland
W16b	Quercus spp.-Betula spp.-Deschampsia flexuosa woodland, Vaccinium myrtillus-Dryopteris dilatata sub-community	III	10	Woodland
CG11	Festuca ovina-Agrostis capillaris-Alchemilla alpina grass-heath	IV	4	Calcareous grassland (upland)
CG11a	Festuca ovina-Agrostis capillaris-Alchemilla alpina grass-heath, typical sub-community	IV	4	Calcareous grassland (upland)
CG11b	Festuca ovina-Agrostis capillaris-Alchemilla alpina grass-heath, Carex pulicaris-Carex panicea sub-community	IV	4	Calcareous grassland (upland)
H2b	Calluna vulgaris-Ulex minor heath, Vaccinium myrtillus sub-community	V	7	Lowland Dry Heath
H4b	Ulex gallii-Agrostis curtisii heath, Festuca ovina sub-community	IV	4	Subalpine dry dwarf-shrub heath; Lowland Dry Heath; Lowland Wet Heath
H8e	Calluna vulgaris-Ulex gallii heath, Vaccinium myrtillus sub-community	V	5	Lowland Dry Heath
H9b	Calluna vulgaris-Deschampsia flexuosa heath, Vaccinium myrtillus-Cladonia spp. sub-community	IV	7	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H12a	Calluna vulgaris-Vaccinium myrtillus heath, Calluna vulgaris sub-community	V	4	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H12c	Calluna vulgaris-Vaccinium myrtillus heath, Galium saxatile-Festuca ovina sub-community	V	6	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H13c	Calluna vulgaris-Cladonia arbuscula heath, Cladonia crispata-Loiseleuria procumbens sub-community	IV	4	Alpine dwarf-shrub heath
H16b	Calluna vulgaris-Arctostaphylos uva-ursi heath, Vaccinium myrtillus-Vaccinium vitis-idaea sub-community	V	5	Subalpine dry dwarf-shrub heath
H20a	Vaccinium myrtillus-Racomitrium lanuginosum heath, Viola riviniana-Thymus praecox sub-community	V	6	Alpine dwarf-shrub heath
H20b	Vaccinium myrtillus-Racomitrium lanuginosum heath, Cetraria islandica sub-community	V	6	Alpine dwarf-shrub heath
H20c	Vaccinium myrtillus-Racomitrium lanuginosum heath, Bazzania tricrenata-Mylia taylori sub-community	V	4	Alpine dwarf-shrub heath

H21	Calluna vulgaris-Vaccinium myrtillus-Sphagnum capillifolium heath	V	5	Subalpine dry dwarf-shrub heath
H21a	Calluna vulgaris-Vaccinium myrtillus-Sphagnum capillifolium heath, Calluna vulgaris-Pteridium aquilinum sub-community	V	5	Subalpine dry dwarf-shrub heath
H21b	Calluna vulgaris-Vaccinium myrtillus-Sphagnum capillifolium heath, Mastigophora woodsii-Herbertus aduncus ssp. hutchinsiae sub-community	V	4	Subalpine dry dwarf-shrub heath
H22b	Vaccinium myrtillus-Rubus chamaemorus heath, Plagiothecium undulatum-Anastrepta orcadensis sub-community	V	6	Alpine dwarf-shrub heath; Subalpine dry dwarf-shrub heath
M15d	Scirpus cespitosus-Erica tetralix wet heath, Vaccinium myrtillus sub-community	IV	6	Blanket bog and valley bog (upland); Lowland Wet Heath; Wet Heath (upland)
M19c	Calluna vulgaris-Eriophorum vaginatum blanket mire, Vaccinium vitis-idaea-Hylocomium splendens sub-community	IV	5	Blanket bog and valley bog (upland)
U2b	Deschampsia flexuosa grassland, Vaccinium myrtillus sub-community	V	4	Acid Grassland
U4e	Festuca ovina-Agrostis capillaris-Galium saxatile grassland, Vaccinium myrtillus-Deschampsia flexuosa sub-community	V	6	Acid Grassland; Calcareous grassland (upland); Subalpine dry dwarf-shrub heath; Tall herbs (upland); Lowland dry acid grassland
U5d	Nardus stricta-Galium saxatile grassland, Calluna vulgaris-Danthonia decumbens sub-community	IV	6	Acid Grassland; Subalpine dry dwarf-shrub heath
U6c	Juncus squarrosus-Festuca ovina grassland, Vaccinium myrtillus sub-community	V	6	Acid Grassland; Blanket bog and valley bog (upland); Wet Heath (upland)
U7	Nardus stricta-Carex bigelowii grass-heath	V	6	Alpine summit communities of moss, sedge and three-leaved rush; Moss, dwarf herb and grass dominated snow-bed
U7a	Nardus stricta-Carex bigelowii grass-heath, Empetrum nigrum ssp. hermaphroditum-Cetraria islandica sub-community	V	4	Alpine summit communities of moss, sedge and three-leaved rush; Moss, dwarf herb and grass dominated snow-bed
U7b	Nardus stricta-Carex bigelowii grass-heath, typical sub-community	V	6	Alpine summit communities of moss, sedge and three-leaved rush; Moss, dwarf herb and grass dominated snow-bed
U7c	Nardus stricta-Carex bigelowii grass-heath, Alchemilla alpina-Festuca ovina sub-community	V	4	Alpine summit communities of moss, sedge and three-leaved rush; Moss, dwarf herb and grass dominated snow-bed
U9b	Juncus trifidus-Racomitrium lanuginosum rush-heath, Salix herbacea sub-community	V	6	Alpine summit communities of moss, sedge and three-leaved rush
U10	Carex bigelowii-Racomitrium lanuginosum moss-heath	IV	6	Alpine summit communities of moss, sedge and three-leaved rush
U10a	Carex bigelowii-Racomitrium lanuginosum moss-heath, Galium saxatile sub-community	IV	6	Alpine summit communities of moss, sedge and three-leaved rush
U10b	Carex bigelowii-Racomitrium lanuginosum moss-heath, typical sub-community	IV	4	Alpine summit communities of moss, sedge and three-leaved rush
U13b	Deschampsia cespitosa-Galium saxatile grassland, Rhytidiadelphus loreus sub-community	IV	4	Moss, dwarf herb and grass dominated snow-bed
U16b	Luzula sylvatica-Vaccinium myrtillus tall-herb community, Anthoxanthum odoratum-Festuca ovina sub-community	V	6	Tall herbs (upland)
U17b	Luzula sylvatica-Geum rivale tall-herb community, Geranium sylvaticum sub-community	IV	3	Tall herbs (upland)
U17c	Luzula sylvatica-Geum rivale tall-herb community, Agrostis capillaris-Rhytidiadelphus loreus sub-community	IV	6	Tall herbs (upland)
U20b	Pteridium aquilinum-Galium saxatile community, Vaccinium myrtillus-Dicranum scoparium sub-community	IV	4	Subalpine dry dwarf-shrub heath

W19b	Juniperus communis ssp. communis-Oxalis acetosella woodland, Viola riviniana-Anemone nemorosa sub-community	IV	7	Juniper heath and Scrub (upland); woodland
W20	Salix lapponum-Luzula sylvatica scrub	V	7	Montane willow scrub; woodland
CG10	Festuca ovina-Agrostis capillaris-Thymus praecox grassland	I	4	Calcareous grassland (upland); Limestone pavement; Tall herbs (upland)
CG10a	Festuca ovina-Agrostis capillaris-Thymus praecox grassland, Trifolium repens-Luzula campestris sub-community	I	4	Calcareous grassland (upland); Limestone pavement; Tall herbs (upland)
CG10b	Festuca ovina-Agrostis capillaris-Thymus praecox grassland, Carex pulicaris-Carex panicea sub-community	I	4	Calcareous grassland (upland); Limestone pavement; Tall herbs (upland)
CG10c	Festuca ovina-Agrostis capillaris-Thymus praecox grassland, Saxifraga aizoides-Ditrichum flexicaule sub-community	I	3	Calcareous grassland (upland); Limestone pavement; Tall herbs (upland)
CG12	Festuca ovina-Alchemilla alpina-Silene acaulis dwarf-herb community	I	2	Calcareous grassland (upland)
CG14	Dryas octopetala-Silene acaulis ledge community	II	3	Calcareous grassland (upland); Calcareous scree
H2	Calluna vulgaris-Ulex minor heath	II	7	Lowland Dry Heath
H4c	Ulex gallii-Agrostis curtisii heath, Erica tetralix sub-community	II	5	Subalpine dry dwarf-shrub heath; Lowland Dry Heath; Lowland Wet Heath
H4d	Ulex gallii-Agrostis curtisii heath, Scirpus cespitosus sub-community	II	3	Subalpine dry dwarf-shrub heath; Lowland Dry Heath; Lowland Wet Heath
H8	Calluna vulgaris-Ulex gallii heath	I	5	Subalpine dry dwarf-shrub heath
H9	Calluna vulgaris-Deschampsia flexuosa heath	II	5	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H9a	Calluna vulgaris-Deschampsia flexuosa heath, Hypnum cupressiforme sub-community	II	4	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H9c	Calluna vulgaris-Deschampsia flexuosa heath, species-poor sub-community	II	5	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H9d	Calluna vulgaris-Deschampsia flexuosa heath, Galium saxatile sub-community	I	4	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H9e	Calluna vulgaris-Deschampsia flexuosa heath, Molinia caerulea sub-community	I	3	Blanket bog and valley bog (upland); Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H10	Calluna vulgaris-Erica cinerea heath	II	6	Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H10a	Calluna vulgaris-Erica cinerea heath, typical sub-community	II	6	Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H10b	Calluna vulgaris-Erica cinerea heath, Racomitrium lanuginosum sub-community	II	4	Subalpine dry dwarf-shrub heath; Lowland Dry Heath; Alpine dwarf-shrub heath
H10c	Calluna vulgaris-Erica cinerea heath, Festuca ovina-Anthoxanthum odoratum sub-community	II	4	Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H10d	Calluna vulgaris-Erica cinerea heath, Thymus praecox-Carex pulicaris sub-community	I	1	Subalpine dry dwarf-shrub heath; Lowland Dry Heath
H11	Calluna vulgaris-Carex arenaria heath	I	2	Lowland Dry Heath
H11b	Calluna vulgaris-Carex arenaria heath, Empetrum nigrum ssp. nigrum sub-community	I	2	Lowland Dry Heath
H13	Calluna vulgaris-Cladonia arbuscula heath	III	4	Alpine dwarf-shrub heath
H13a	Calluna vulgaris-Cladonia arbuscula heath, Cladonia arbuscula-Cladonia rangiferina sub-community	II	4	Alpine dwarf-shrub heath

H13b	Calluna vulgaris-Cladonia arbuscula heath, Empetrum nigrum ssp. hermaphroditum-Cetraria nivalis sub-community	III	4	Alpine dwarf-shrub heath
H14	Calluna vulgaris-Racomitrium lanuginosum heath	II	4	Alpine dwarf-shrub heath
H14a	Calluna vulgaris-Racomitrium lanuginosum heath, Festuca ovina sub-community	II	3	Alpine dwarf-shrub heath
H14b	Calluna vulgaris-Racomitrium lanuginosum heath, Empetrum nigrum ssp. hermaphroditum sub-community	II	4	Alpine dwarf-shrub heath
H14c	Calluna vulgaris-Racomitrium lanuginosum heath, Arctostaphylos uva-ursi sub-community	II	4	Alpine dwarf-shrub heath
H15	Calluna vulgaris-Juniperus communis ssp. nana heath	I	3	Alpine dwarf-shrub heath
H16	Calluna vulgaris-Arctostaphylos uva-ursi heath	III	5	Subalpine dry dwarf-shrub heath
H16a	Calluna vulgaris-Arctostaphylos uva-ursi heath, Pyrola media-Lathyrus montanus sub-community	III	4	Subalpine dry dwarf-shrub heath
H17	Calluna vulgaris-Arctostaphylos alpinus heath	III	4	Alpine dwarf-shrub heath
H17a	Calluna vulgaris-Arctostaphylos alpinus heath, Loiseleuria procumbens-Cetraria glauca sub-community	III	3	Alpine dwarf-shrub heath
H17b	Calluna vulgaris-Arctostaphylos alpinus heath, Empetrum nigrum ssp. nigrum sub-community	III	4	Alpine dwarf-shrub heath
M15	Scirpus cespitosus-Erica tetralix wet heath	II	6	Blanket bog and valley bog (upland); Lowland Wet Heath; Wet Heath (upland)
M15b	Scirpus cespitosus-Erica tetralix wet heath, typical sub-community	I	3	Blanket bog and valley bog (upland); Lowland Wet Heath; Wet Heath (upland)
M15c	Scirpus cespitosus-Erica tetralix wet heath, Cladonia spp. sub-community	I	1	Blanket bog and valley bog (upland); Lowland Wet Heath; Wet Heath (upland)
M17	Scirpus cespitosus-Eriophorum vaginatum blanket mire	I	4	Blanket bog and valley bog (upland)
M17b	Scirpus cespitosus-Eriophorum vaginatum blanket mire, Cladonia spp. sub-community	I	3	Blanket bog and valley bog (upland)
M17c	Scirpus cespitosus-Eriophorum vaginatum blanket mire, Juncus squarrosus-Rhytidiadelphus loreus sub-community	III	4	Blanket bog and valley bog (upland)
M18	Erica tetralix-Sphagnum papillosum raised and blanket mire	I	3	Blanket bog and valley bog (upland)
M18a	Erica tetralix-Sphagnum papillosum raised and blanket mire, Sphagnum magellanicum-Andromeda polifolia sub-community	I	3	Blanket bog and valley bog (upland)
M18b	Erica tetralix-Sphagnum papillosum raised and blanket mire, Empetrum nigrum ssp. nigrum-Cladonia spp. sub-community	I	3	Blanket bog and valley bog (upland)
M20	Eriophorum vaginatum blanket and raised mire	II	5	Blanket bog and valley bog (upland)
M20a	Eriophorum vaginatum blanket and raised mire, species-poor sub-community	I	3	Blanket bog and valley bog (upland)
M20b	Eriophorum vaginatum blanket and raised mire, Calluna vulgaris-Cladonia spp. sub-community	III	5	Blanket bog and valley bog (upland)
M7	Carex curta-Sphagnum russowii mire	I	2	Spring-head, rill and flush (upland)
M7a	Carex curta-Sphagnum russowii mire, Carex bigelowii-Sphagnum lindbergii sub-community	I	2	Spring-head, rill and flush (upland)
M7b	Carex curta-Sphagnum russowii mire, Carex aquatilis-Sphagnum recurvum sub-community	I	1	Spring-head, rill and flush (upland)
U2	Deschampsia flexuosa grassland	II	4	Acid Grassland
U3	Agrostis curtisii grassland	III	4	Acid Grassland; Subalpine dry dwarf-shrub heath; Lowland dry acid grassland
U4	Festuca ovina-Agrostis capillaris-Galium saxatile grassland	II	6	Acid Grassland; Calcareous grassland (upland); Subalpine dry dwarf-shrub heath; Tall herbs (upland); Lowland dry acid grassland

U4a	Festuca ovina-Agrostis capillaris-Galium saxatile grassland, typical sub-community	II	6	Acid Grassland; Calcareous grassland (upland); Subalpine dry dwarf-shrub heath; Tall herbs (upland); Lowland dry acid grassland
U4c	Festuca ovina-Agrostis capillaris-Galium saxatile grassland, Lathyrus montanus-Stachys betonica sub-community	II	4	Acid Grassland; Calcareous grassland (upland); Subalpine dry dwarf-shrub heath; Tall herbs (upland); Lowland dry acid grassland
U4d	Festuca ovina-Agrostis capillaris-Galium saxatile grassland, Luzula multiflora-Rhytidiadelphus loreus sub-community	I	4	Acid Grassland; Calcareous grassland (upland); Subalpine dry dwarf-shrub heath; Tall herbs (upland); Lowland dry acid grassland
U5b	Nardus stricta-Galium saxatile grassland, Agrostis canina-Polytrichum commune sub-community	III	6	Acid Grassland; Subalpine dry dwarf-shrub heath
U5c	Nardus stricta-Galium saxatile grassland, Carex panicea-Viola riviniana sub-community	I	3	Acid Grassland; Subalpine dry dwarf-shrub heath; Calcareous grassland (upland)
U5e	Nardus stricta-Galium saxatile grassland, Racomitrium lanuginosum sub-community	III	6	Acid Grassland; Subalpine dry dwarf-shrub heath
U6	Juncus squarrosus-Festuca ovina grassland	II	6	Acid Grassland; Blanket bog and valley bog (upland); Wet Heath (upland)
U6a	Juncus squarrosus-Festuca ovina grassland, Sphagnum spp. sub-community	I	4	Acid Grassland; Blanket bog and valley bog (upland); Wet Heath (upland)
U6b	Juncus squarrosus-Festuca ovina grassland, Carex nigra-Calypogeia trichomanis sub-community	I	3	Acid Grassland; Blanket bog and valley bog (upland); Wet Heath (upland)
U8	Carex bigelowii-Polytrichum alpinum sedge-heath	II	4	Alpine summit communities of moss, sedge and three-leaved rush; Moss, dwarf herb and grass dominated snow-bed
U8a	Carex bigelowii-Polytrichum alpinum sedge-heath, Polytrichum alpinum-Ptilidium ciliare sub-community	I	3	Alpine summit communities of moss, sedge and three-leaved rush; Moss, dwarf herb and grass dominated snow-bed
U8b	Carex bigelowii-Polytrichum alpinum sedge-heath, Dicranum fuscescens-Racomitrium lanuginosum sub-community	III	4	Alpine summit communities of moss, sedge and three-leaved rush; Moss, dwarf herb and grass dominated snow-bed
U9	Juncus trifidus-Racomitrium lanuginosum rush-heath	III	6	Alpine summit communities of moss, sedge and three-leaved rush
U9a	Juncus trifidus-Racomitrium lanuginosum rush-heath, Cladonia arbuscula-Cetraria islandica sub-community	III	4	Alpine summit communities of moss, sedge and three-leaved rush
U10c	Carex bigelowii-Racomitrium lanuginosum moss-heath, Silene acaulis sub-community	III	4	Alpine summit communities of moss, sedge and three-leaved rush
U13	Deschampsia cespitosa-Galium saxatile grassland	III	4	Moss, dwarf herb and grass dominated snow-bed
U13a	Deschampsia cespitosa-Galium saxatile grassland, Anthoxanthum odoratum-Alchemilla alpina sub-community	III	4	Moss, dwarf herb and grass dominated snow-bed
U14	Alchemilla alpina-Sibbaldia procumbens dwarf-herb community	II	3	Alpine summit communities of moss, sedge and three-leaved rush; Moss, dwarf herb and grass dominated snow-bed
U16c	Luzula sylvatica-Vaccinium myrtillus tall-herb community, species-poor sub-community	III	3	Tall herbs (upland)
U17	Luzula sylvatica-Geum rivale tall-herb community	III	6	Tall herbs (upland)
U17a	Luzula sylvatica-Geum rivale tall-herb community, Alchemilla glabra-Bryum pseudotriquetrum sub-community	I	1	Tall herbs (upland)

U17d	Luzula sylvatica-Geum rivale tall-herb community, Primula vulgaris-Hypericum pulchrum sub-community	II	6	Tall herbs (upland)
U18	Cryptogramma crispa-Athyrium distentifolium snow-bed	II	2	Fern-dominated snow bed; Silaceous scree
U19	Thelypteris limbosperma-Blechnum spicant community	III	4	Tall herbs (upland)
U20	Pteridium aquilinum-Galium saxatile community	III	6	Subalpine dry dwarf-shrub heath
U20a	Pteridium aquilinum-Galium saxatile community, Anthoxanthum odoratum sub-community	I	6	Subalpine dry dwarf-shrub heath
U20c	Pteridium aquilinum-Galium saxatile community, species-poor sub-community	II	4	Subalpine dry dwarf-shrub heath
U21	Cryptogramma crispa-Deschampsia flexuosa community	III	7	Siliceous rocky slope; Silaceous scree; Subalpine dry dwarf-shrub heath
W4	Betula pubescens-Molinia caerulea woodland	I	6	Woodland
W4a	Betula pubescens-Molinia caerulea woodland, Dryopteris dilatata-Rubus fruticosus sub-community	I	5	Woodland
W4c	Betula pubescens-Molinia caerulea woodland, Sphagnum spp. sub-community	I	6	Woodland
W10	Quercus robur-Pteridium aquilinum-Rubus fruticosus woodland	I	5	Woodland
W10a	Quercus robur-Pteridium aquilinum-Rubus fruticosus woodland, typical sub-community	I	5	Woodland
W10c	Quercus robur-Pteridium aquilinum-Rubus fruticosus woodland, Hedera helix sub-community	I	5	Woodland
W10d	Quercus robur-Pteridium aquilinum-Rubus fruticosus woodland, Holcus lanatus sub-community	I	4	Woodland
W10e	Quercus robur-Pteridium aquilinum-Rubus fruticosus woodland, Acer pseudoplatanus-Oxalis acetosella sub-community	I	2	Woodland
W11a	Quercus petraea-Betula pubescens-Oxalis acetosella woodland, Dryopteris dilatata sub-community	I	5	Woodland
W11b	Quercus petraea-Betula pubescens-Oxalis acetosella woodland, Blechnum spicant sub-community	II	4	Woodland
W11d	Quercus petraea-Betula pubescens-Oxalis acetosella woodland, Stellaria holostea-Hypericum pulchrum sub-community	I	1	Woodland
W15d	Fagus sylvatica-Deschampsia flexuosa woodland, Calluna vulgaris sub-community	II	7	Woodland
W16a	Quercus spp.-Betula spp.-Deschampsia flexuosa woodland, Quercus robur sub-community	II	7	Woodland
W17a	Quercus petraea-Betula pubescens-Dicranum majus woodland, Isothecium myosuroides-Diplophyllum albicans sub-community	III	7	Woodland
W17c	Quercus petraea-Betula pubescens-Dicranum majus woodland, Anthoxanthum odoratum-Agrostis capillaris sub-community	I	5	Woodland
W18a	Pinus sylvestris-Hylocomium splendens woodland, Erica cinerea-Goodyera repens sub-community	I	3	Woodland