Investigation into the causes of Alder (*Alnus glutinosa*) mortality in Scotland

Project Final Report

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Content

1 Executive Summary

The primary aim of this project was to determine whether field observations supported the view that alders in Scotland have suffered a recent and rapid decline in condition and to identify the agents currently affecting alders in poor health. In light of these findings, the project further aimed to identify appropriate approaches to future monitoring of alder health and highlight key issues for future management and establishment of riparian alders.

Common alder (*Alnus glutinosa*) is a key component of freshwater ecosystems delivering important benefits to biodiversity, water quality and temperature, bank stability and flood alleviation. In the more impoverished riparian ecosystems of upland Scotland, it is frequently the only tree species present, with no obvious alternatives available to fill its niche should it be lost. Even in richer lowland riparian systems, historic loss of elm due to Dutch elm disease and increasing levels of ash mortality due to Chalara dieback suggest that there will be an increasing dependence on alder to provide the ecosystem services noted above in the future.

As a result, an understanding of the nature and extent of current threats to the health of alder in Scotland, as well as an appreciation of potential future threats to the condition of the species, is of importance. Historically, there have been low levels of surveillance and reporting of alder health problems in Scotland and consequently there is little evidence against which to benchmark new observations of potential deteriorations in the condition of alder or of changes in the causes of such declines. This is of particular concern at a time when the risk of introducing new pests or pathogens may be increased as a result of efforts to restore riparian woodlands in various river catchments by planting of alder.

Following expressions of concern over the condition of alder in the north of Scotland and in particular the Spey valley during 2019, surveillance carried out by Scottish Forestry personnel identified a range of sites at which further study of the condition of the tree populations would be warranted. This project built on these initial observations by engaging with the Observatree citizen science programme to encourage additional reports of locations at which alders were apparently in decline and by carrying out surveys at a range of sites selected from the combined Scottish Forestry and Observatree volunteer reports in order to determine the current condition of the trees and identify the agents affecting their health.

Key findings:

- The surveys did not indicate the occurrence of a dramatic recent decline in the health of alders in the north of Scotland, or detect a particular agent associated with damage to trees across all of the sites surveyed.

- Trees at a variety of locations displayed evidence of historic episodes of dieback, with little apparent change in condition having occurred over many subsequent years. As a result, populations of alders with prominent dead limbs evident in many crowns were not uncommon but the living portions of the branching structures were often free from signs of recent damage or disease.

- Causes of current alder decline at the sites surveyed included waterlogging and competition from invasive tree species as well as infection by *Phytophthora alni*, crown dieback associated with colonisation of branches and stems by the weak pathogen *Valsa oxystoma*, infection by *Armillaria* spp., with occasional instances of infection by *Heterobasidion annosum* detected. At one location, a small number of trees with potential bacterial infection of the bark and underlying xylem was also noted. In some instances, predisposition of trees to damage by short-or long- term changes in site conditions was considered probable.

- There was a marked tendency for alder populations to be even-aged, with few instances of regeneration following their initial establishment, even in the oldest stands and those with extremely open canopies. Although grazing may be curtailing regeneration in some cases, the key factors limiting the survival of seedlings and saplings were not always clear at sites which were studied and would be worthy of further study. In addition, the lack of regeneration could give the impression that there are more older alders in decline, however, caution needs to be applied to this assumption as it would require many more observations to confirm.

- Improved reporting of alder health problems in Scotland will be required to ensure that the causes of any future declines, including the advent of new threats to the species, are investigated in a timely manner. The variable pathology of alder and the existing range of damaging agents affecting the species present challenges in terms of effective monitoring and reporting of alder health and means of addressing these based on the surveys carried out in this project are suggested in the report.

- Serious consideration needs to be given to the best way to introduce or regenerate alder in catchments. Whilst there are a number of causes of alder decline, one clear element that can be addressed immediately, is biosecurity. Planting stock needs to be disease free, and machinery, tools and equipment should be clean. In addition, encouraging natural regeneration [1] or employing direct seeding [2] may well be more effective approaches than planting in the long term although more research is required on the most effective ways to carry these out. Initially, such techniques might be best targeted at sites where maximum environmental benefits (and maximum risks associated with pest and disease introductions) are anticipated – for example in river headwaters.

- The adaptation of small groups of alders to very specific local environmental conditions over long periods of time may have taken place at some sites. This should be recognised when conserving a site because introduced trees may be maladapted, therefore natural regeneration or direct seeding may again be more effective approaches for establishing new cohorts of trees.

- Grazing pressure is an issue with alder establishment and spread so planting projects should consider how best to protect trees from grazing.

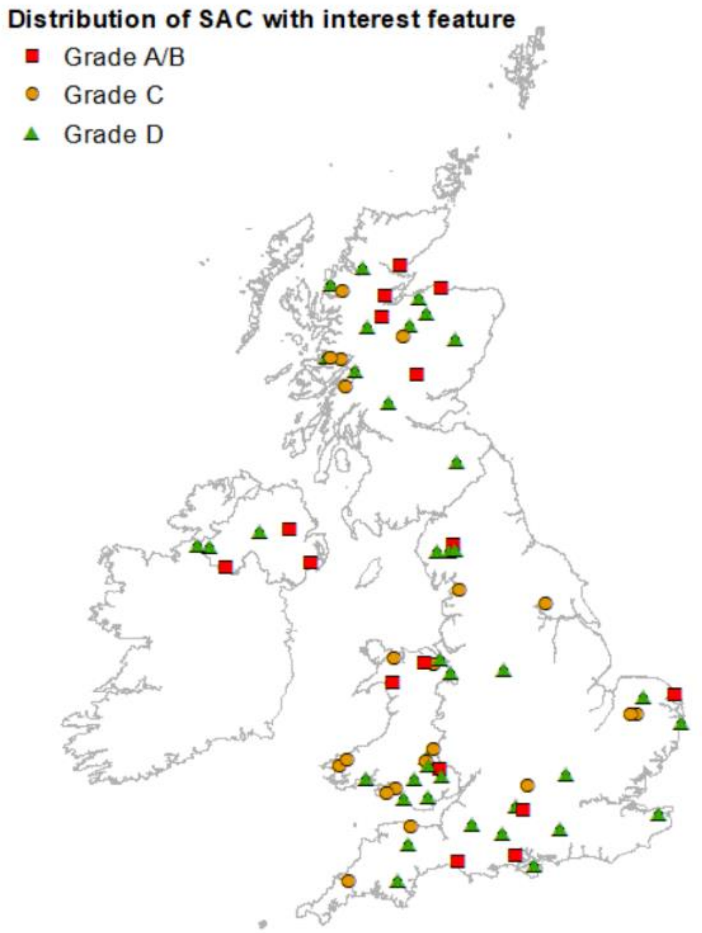
[1] Natural regeneration is the process by which woodlands are maintained by trees that develop from seeds that fall naturally and germinate *in situ*.
[2] Direct seeding is the process of sowing tree seed in its final growing position. The seeds may originate from trees on the site at which they are sown or may be collected from suitable trees at other sites (e.g. in circumstances where no trees of a particular species are present at a location where their establishment is desired).

2 Introduction

Alder (*Alnus glutinosa*) is a moderate sized tree which grows to 10 – 40 ft (3 – 12 m) when not in cultivation. It has a variable habit from a multi-stemmed bush to single bole tree (McVean, 1953).

Alder is a hydrophytic species which makes it a particularly important component of riparian habitats across its range. More specifically, it is the dominant species of the "91E0 Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*" habitat (JNCC, 2019). This habitat type occurs throughout Scotland, albeit in small and fragmented areas due to historic clearance of riverine woodland which has eliminated most true alluvial forests in the UK (Figure 1).

Figure 1. Distribution of SACs/SCIs/cSACs containing species 91E0. JNCC, 2022.



Grade A; Outstanding examples of the feature in a European context.

Grade B; Excellent examples of the feature, significantly above the threshold for SSSI/ASSI notification but of somewhat lower value than grade A sites.

Grade C; Examples of the feature which are of at least national importance (i.e. usually above the threshold for SSSI/ASSI notification on terrestrial sites) but not significantly above this. These features are not the primary reason for SACs being selected.

Grade D; Features of below SSSI quality occurring on SACs These are non-qualifying features ("non-significant presence"), indicated by a letter D, but this is not a formal global grade.

The role played by alder in riparian habitats in Scotland is complex and unique among native trees. For example, alder dominated woodlands play a major role in thermal regulation of stream water. The cooling effects caused by the shade cast by alder woodland improves freshwater ecology, thereby providing conducive conditions for fish reproduction and survival, particularly salmonids (Malcolm, et al., 2008). Alder provides a very specific habitat to many species, both in the tree itself and in the flooded root system (Dussart, 1999). It assists with water filtration and purification in waterlogged soils (Claessens, et al., 2010; Alonso, et al., 2022) and the root system helps to control floods and stabilize riverbanks (Claessens, et al., 2010). Another ecologically important feature of alder is that it forms a symbiosis with the nitrogen-fixing actinomycete *Frankia alni*. This species is present in the root nodules of alder and provides the trees with nutrients when colonising extreme sites (Claessens 2003; Sellstedt & Richau, 2013).

In nutrient-poor riverside ecosystems in Scotland, alders are often the only trees which are present and, in the event of their decline or loss, there are no obvious alternative species which could take their place. Even in lowland river systems, which are richer in nutrients and support a wider range of tree species, historic loss of elm due to Dutch elm disease and increasing levels of ash mortality due to Chalara ash dieback suggest that there will be an increasing dependence on alder to provide the ecosystem services mentioned above in future.

A number of pests and pathogens with the potential to be highly damaging to alder are present in Britain but knowledge of their current distributions and impacts in Scotland is either fragmentary or lacking. This reflects both a lack of relevant research in recent decades and low levels of surveillance and reporting of problems affecting the health of alders in Scotland generally. As a result, there is currently little evidence upon which to base a determination of the level of threat which recognised damaging agents pose to the existing alder population and a low probability that any emerging problems on this host will be speedily detected and reported.

Concerns over the condition of alder in the north of Scotland and, in particular, the Spey valley were raised by key stakeholders to PHC in 2019, but insufficient information was available to pursue specific site investigations into the cause(s) of the apparent decline in the health of the trees, and the COVID pandemic restricted opportunities for targeted fieldwork to be carried out immediately. The project reported here builds on work previously supported by PHC (Hendry, 2021) to improve understanding of alder health in Scotland by reviewing relevant literature and by the study of a range of sites at which a deterioration in the health of trees has recently been reported.

2.1 Previously recorded threats to alder

2.1.1 Environmental

Although alder is recognised as a hydrophytic species, not all hydrological conditions are ideal for its establishment and vigorous growth. McVean (1953) noted that where the water-table is close to the surface throughout the year, growth tends to be shrubby and poor. If the water-table sinks during the summer months, growth is much better.

Conditions for germination are also very specific for alder. Seedlings will only establish on soil which remains continuously moist for 20 – 30 days in the period April – June. This is achieved through capillary action with the water-table and therefore periods of drought or flooding during this critical period will result in failed germination. In addition, seedlings are very sensitive to shading and require high light intensity to establish, they are also liable to damage by late frosts and frost heaving in winter (See section 4.1.1, seedling survival and establishment).

All of these factors, singularly or in combination, can make natural regeneration of alder challenging which has an impact on its long-term survival and distribution.

In addition, Shaw, et al. (2014) noted that subpopulations of alder are often scattered which has resulted in high genetic variation between subpopulations and high specificity to local conditions. This means that a major disturbance or sudden negative change in environmental conditions could result in a narrowing of the gene pool which may not be able to be addressed with planting new individuals which will be less-well adapted to local conditions.

2.1.2 Pests and pathogens recorded on alder

A range of pests and pathogens affects alders in Britain and the most important of these are listed in Table 1.

The insects *Plagiosterna aenea*, *Galerucella lineola* and *Agelastica alni* are all chrysomelid beetles and damage to alder is caused by their larval stages which feed mainly on the foliage of trees, causing browning and loss of leaves which can be severe in some years. Whilst alder is the main host of *P. aenea*, *Galerucella lineola* is primarily associated with willows although there is evidence to suggest that a host race particularly adapted to alder may exist (Ikonen *et al.*, 2003). *Agelastica alni* is widespread throughout Europe and was thought to be extinct in the UK until its rediscovery in 2004 in northwest England. It has since rapidly spread, and it is now locally common and often abundant in England and Wales (UK Beetles, 2023), though it is not currently known to be present in Scotland. *Alnus glutinosa* is, however, reported to possess physiological adaptations and defence mechanisms to counteract the negative effects of herbivory by the alder leaf-beetle (Oleksyn, et al., 1998).

Insect outbreaks can result in severe defoliation of local and regional populations of alders in Scotland in particular years but so far have rarely been harmful to the health of trees in the longer term. Repeated defoliations over a number of consecutive growing seasons could, however, result in decline and render trees more susceptible to attack by facultative pathogens. The potential for climatic changes to increase the incidence and severity of damaging insect attacks (e.g. by improving overwintering success) is currently unknown. Alder is noted as a host for some insect pests of particular concern in the UK Plant Health Risk Register (Defra, 2023), but as yet these are not present in the UK (see Table 2, section 4.1.3.1).

Periodic episodes of alder decline have been reported from both continental Europe and the UK for over a century and have been attributed to various factors including drought, use of poorly adapted planting stock, and infection of hosts subjected to various environmental stresses by weak pathogens (Cech & Hendry, 2003). In Scotland, crown dieback of alder was noted in the 1980s and 1990s which was characterised by the rapid death of one or more large branches on the affected trees associated with the formation of elongated bark lesions underlain by dysfunctional and stained sapwood. Lesions frequently extended from affected branches into the main stem and, in cases where necrosis associated with several such branches coalesced, could result in girdling of the stem and mortality of much of the crown or occasionally the entire tree. A range of fungi were associated with lesions including *Ophiovalsa suffusa*, *Melanconis alni*, *Crytosporiopsis* sp. and *Valsa oxystoma* (Gregory et al., 1996; Webber, Gibbs & Hendry, 2004). **Dieback of this nature still occurs in Scottish alders and, in order to identify clearly when the set of symptoms just described is being discussed, it will be referred to hereafter as "alder dieback *sensu* Gregory".**

Prior to the 1990s, reports of alders suffering from root diseases were extremely rare except for cases of *Armillaria mellea* infection in plantation trees (Peace, 1962). In 1993 however, a new and lethal *Phytophthora* disease of alder was identified at several locations in southern Britain (Gibbs, 1994). In 1994, surveys conducted in England & Wales indicated that an average of 5.2% of riverside trees were dead or had symptoms of the disease and that more than 20% appeared to be infected in certain parts of the country (Gibbs, et al., 1999). The hybrid species concerned was initially called the "alder Phytophthora" (Brasier, Rose & Gibbs, 1995) but was eventually given the name *Phytophthora alni* subspecies *alni* (Brasier, et al., 2004).

Table 1. Pests and pathogens currently affecting alders in Britain

Agent	Recorded in Scotland?	Nature of damage	Timing of damage	Scale of damage	Potential for recovery
Insects					
Plagiosterna aenea	Yes	Defoliation	Spring / Summer	Local to regional	High
Galerucella lineola	Yes	Defoliation	Spring / Summer	Local to regional	High
Agelastica alni	No	Defoliation	Spring / Summer	Local to regional	High
Epinotia tenerana	Yes	Bud mining / Flush failure	Spring	Local to regional	High
Fungi & oomycetes					
Phytophthora alni	Yes	Tree dieback & mortality	Spring / Summer/ Autumn	Local to regional (catchment)	Low to moderate
Ophiovalsa suffusa / Melanconis alni / Valsa oxystoma **	Yes	Tree dieback & mortality	Summer	Usually local	Low to moderate
Melampsoridium betulinum	Yes	Defoliation	Autumn	Local to regional	High
Melampsoridium hiratsukanum	No Present in Wales	Defoliation & dieback	Summer / Autumn	Local to regional	Not known
Phytophthora siskiyouensis	No Present in SW England	Probable tree dieback & mortality	Spring / Summer/ Autumn	Local to regional (catchment)	Not known

** The degree of pathogenicity of these fungi is unclear, since they may be present as endophytes in functional branches and capable of rapidly colonising host tissue compromised by other factors (Mejia *et al*., 2008; Fisher & Petrini, 1990; Pisetta *et al*., 2012)

Soon after its discovery, the *Phytophthora* affecting alder in the UK was found to be infecting alders across much of Europe but other closely related *Phytophthora* hybrids with more restricted distributions were also detected: *P. alni* subsp. *uniformis* in Sweden, Latvia, Germany, Austria, Italy and Hungary, and *P. alni* subsp. *multiformis* in the Netherlands, Germany and the UK (Brasier, et al., 2004). More recently, molecular techniques have been applied to this group of pathogens to clarify their status and it has been proposed that the taxa concerned should be named: *Phytophthora* × *alni*, *Phytophthora uniformis* and *Phytophthora* × *multiformis* (Husson et al. 2015). However, this change has not been generally adopted and the use of *Phytophthora alni* is preferred here.

Both the distribution and impact of *Phytophthora alni* in Scotland are poorly understood– it has primarily been found on larger rivers in the east of Scotland but is almost certainly more widespread than the few confirmed records suggest. Since infected trees frequently die, this lack of information is of particular concern.

In addition to *Phytophtora alni*, there are several other *Phytophthora* species known to cause disease in alder globally, including: *P. cactorum*, *P. gonapodyides*, *P. plurivora*, *P. polonica*, *P. lacustris* and *P. siskiyouensis* (Jung, et al., 2018). A recent study along the river Lagan in Belfast found *P. gonapodyides*, *P. lacustris* and additionally *P. chlamydospore* on infected alders, as well as another oomycete *Phytopythium litorale* (O'Hanlon, et al., 2019). However, these species are not considered to be significant pathogens except for *P. lacustris* which has been noted causing mortality of alder in Europe (Kanoun-Boulé, et al., 2016).

Foliar rust fungi can have severe impacts on the health of certain tree species as a result of reduction in vigour associated with persistent defoliation. There are currently four rust fungi which parasitise representatives of the family Betulaceae (Moricca & Ginetti, 2015):

- *Melampsoridium carpini* occurs on hornbeam and is not known to infect hosts within the genus *Alnus*.
- *Melampsoridium alni* occurs on certain *Alnus* species in southeast Asia but is not known to be present in Europe (Hantula et al., 2009). Historic records of *M. alni* in Europe appear to have arisen due to the misidentification *of M. betulinum* as *M. alni* (Roll Hansen & Roll-Hansen, 1981).
- *Melampsoridium betulinum* occurs on both birch and alder species in the UK and historic records suggest that it is native to Scotland and probably much of northern Europe. On alder, signs of infection are rarely evident until shortly before leaf-fall and are not usually severe. As a result, it is not generally damaging to the health of trees.
- *Melampsoridium hiratsukanum* is native to Asia but was first recorded in continental Europe in the mid-1990s associated with damaging infection of *Alnus incana*. Subsequently, it has apparently spread across much of Europe and its presence in Wales was confirmed in 2012 by molecular analysis of sample material collected in 2009 (Hantula et al. 2012). This rust causes considerable damage to alder foliage in late summer when the leaves turn brown and curl inwards, and severe successive infections can lead to tree death (Lilja et al., 2011). Young plants are likely to be at most risk of severe damage and, whilst infection of seedlings or small saplings may be overlooked, mortality of such trees may prejudice the longer-term survival of native alder populations.

2.1.3 Herbivore grazing

Current estimates suggest that there are over 1 million deer in Scotland, double the number that there were in 1990 (Forestry & Land Scotland, 2023). According to the Deer Working Group (Nature Scot, 2024), 10 red deer per km^2 should be used as an upper benchmark of a sustainable population. The latest figures (2018/19) stated that there were 9.35 deer per km^2 which is close to the upper benchmark (Nature Scot, 2024). This high density of deer in Scottish native woodlands is having a detrimental effect on the natural regeneration of trees, including alder (Nature Scot, 2024; Holl & Armstrong, 2014).

For alder specifically, Gullett et al. (2023) observed that alder was one of the native species which regenerated quickly in response to reduced deer numbers (roe and red deer) in the Scottish Highlands along with birch (*Betula pubescens*, *B. pendula*) and eared willow (*Salix aurita*).

When sufficiently intense, herbivore grazing can severely impact the natural regeneration of trees (Mitchell and Kirby, 1990). Albon, et al. (2007) showed that sheep grazing has the highest impact in upland *Calluna vulgaris*-dominated habitats in Scotland, followed by cattle grazing and red deer grazing. Notably, with red deer, the impact increased with increasing deer density at both land-ownership and regional scales whereas sheep damage was not found to be density dependent.

3 Methods

3.1 Overview

- A literature review was undertaken to provide further information on alder ecology, threats to alder, and to establish what previous research had been undertaken.
- Previous survey data from Scottish Forestry and new reports of alder decline made by Observatree volunteers were utilised to identify areas where deteriorations in alder health were evident and of particular concern.
- Eight sites were selected for in depth surveys to gauge whether declines in the condition of trees were recent or of longer standing and to establish the causes of current poor health in the alders at these locations.

3.2 Site selection

3.2.1 Alder locations notable in the literature

The Joint Nature Conservation Council (JNCC) hold data on a number of particularly important "91E0 Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*" sites (JNCC, 2019). These include:

<u>Mound Alderwoods</u> in north-east Scotland is the most northerly site selected and is the largest estuarine alder *Alnus glutinosa* wood in Britain. It provides examples of successional stages from estuarine mud to dense woodland and is representative of the more stable form of the habitat. A few dry ridges have an open growth of Scots pine *Pinus sylvestris* with a dry ground flora beneath. The alderwoods have both dry and waterlogged areas. In the former, characteristic plants include remote sedge *Carex remota*, Yorkshire fog *Holcus lanatus* and tufted hair-grass *Deschampsia cespitosa*. The swamp areas are generally richer and include species such as fen ragwort *Senecio paludosus*, marsh pennywort *Hydrocotyle vulgaris*, marsh bedstraw *Galium palustre* and meadowsweet *Filipendula ulmaria*.

<u>The Lower River Spey</u> in north-east Scotland is unique within Britain in comprising an extensively braided channel along the whole length of the river. The active river channel provides a mosaic of substrates, and in more stable, damper situations large stands of valley alder *Alnus glutinosa* woods occur, along with willows *Salix* spp., ash *Fraxinus excelsior* and bird cherry *Prunus padus*. The ground flora includes both southern and northern elements such as wood speedwell *Veronica montana* and wood stichwort *Stellaria nemorum*.

<u>Urquhart Bay Wood</u> has developed on an alluvial delta at the confluence of the Rivers Enrick and Coiltie as they flow into Loch Ness. There are extensive stands of alluvial forests on the wetter ground associated with the river channels, with transitions on gradually rising land to stands of lowland broad-leaved woodland containing ash *Fraxinus excelsior*, alder *Alnus glutinosa*, wild cherry *Prunus avium*, rowan *Sorbus aucuparia*, wych elm *Ulmus glabra*, white willow *Salix alba* and bird cherry *Prunus padus*. There are also characteristic transitions to swamp and open freshwater.

3.2.2 Recent records of poor alder condition

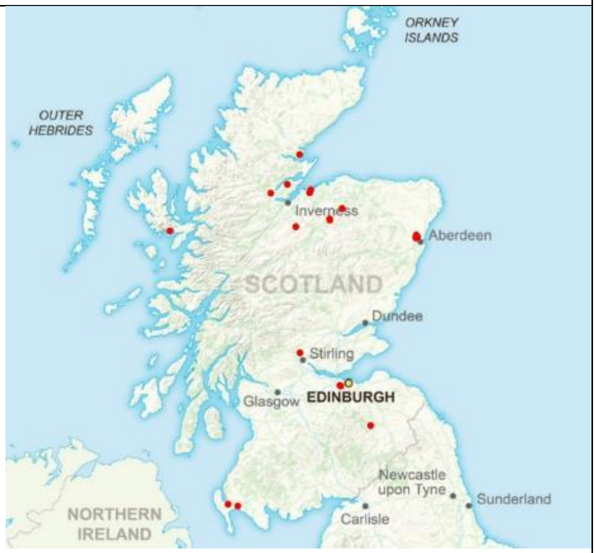
Following initial reports of apparently rapid alder decline in some areas of Scotland in 2019, records of poor alder health received by the Forest Research Tree Health Diagnostic & Advisory Service and reports of declining trees provided by Tree Health Officers in Scottish Forestry in response to a call for information under a previous PHC project in 2020 (Hendry, 2021) were collated with a view to carrying out detailed surveys of selected alder populations when possible (Figure 2a).

3.2.3 *Citizen science alder survey 2022*

Additional information on sites in Scotland where alders are currently displaying signs of poor health was sought by engaging with the ongoing [Observatree citizen science programme](). Project volunteers were initially briefed on alder health in Scotland and the range of symptoms which might be encountered on the species. Supporting information additionally supplied to volunteers is included as Appendix 1. Volunteers chose the sites that they wished to survey and completed reports using an adaptation of the Observatree site survey procedure and returned to the programme managers who collated the data and shared the resultant dataset with this project (an example volunteer report is included as Appendix 2). The locations of the sites concerned are shown in Figure 2b.

Figure 2a Post-2019 alder decline records

Figure 2b Observatree 2022 alder decline records



3.2.4 *Final selection of sites for detailed survey in 2022*

The sites shown in Figures 2a & 2b were sifted on the basis of the following criteria to create a short-list of suitable locations for conducting detailed surveys of alder condition & health:

- Evidence of ongoing decline in the health of trees
- Population of >50 & where possible >100 alders
- Located in areas corresponding with 2019 & 2020 reports of alder health issues
- Proximity allowing a number of sites to be visited in a single tour
- Potential for *ad hoc* observations of alder health during travel between main survey locations
- Access permissions and background data in place

The sites meeting these criteria which were chosen for investigation are shown in Figure 3.

Figure 3. Sites selected for detailed survey of alder health in 2022

3.3 Site Assessment

Site assessments were carried out by Steven Hendry (Forest Research) and Matt Elliot (Royal Botanic Garden Edinburgh). At each location included in the survey, a general assessment of the condition of the alder population was made as well as an evaluation of the site conditions which might influence the overall health of the trees. Where present, evidence of herbivore damage to the alders was noted but an exhaustive attempt to detect damage to other tree species / vegetation was not made. Care was taken to record any instances of recent natural regeneration since local populations of alder are frequently even-aged.

3.4 Diagnostics

In the field, individual alders displaying signs of recent decline were first examined for evidence of bark lesions on their branches or stems, and for any signs of fungal fruiting associated with regions of dead bark. Where lesions were detected, samples consisting of bark material or of entire branches / stems were taken for subsequent laboratory investigation. In cases where bark killing by a *Phytophthora* species was suspected based on the symptoms displayed, field testing of fresh lesion material using a *Phytophthora*-specific lateral flow device (LFD) was typically undertaken to confirm the preliminary diagnosis and direct subsequent laboratory investigations.

Where indicated by symptomatology, root excavations were carried out on particular trees to determine whether bark death was evident in the structural roots, or necrosis of the fine root system could be detected. If required (typically but not exclusively when junctions between dead and living tissues were evident), root material was excised for later laboratory study.

In the laboratory, fungal fruiting bodies present on sample material were examined macroscopically and microscopically and identified with reference to standard taxonomic texts.

Isolations from bark lesions which did not display characteristics suggestive of *Phytophthora* infection were made by excising small pieces of necrotic phloem and placing them onto 2% Malt Extract Agar (MA) in 9cm Petri dishes. MA isolation plates were incubated in darkness at 20°C and fungi developing upon them were identified as far as possible by morphological means or by appropriate molecular identification methods.

Lesion material which had tested positive for the presence of *Phytophthora* by use of LFDs, or with the water-soaked appearance, which is often associated with *Phytophthora* infection, was subjected to isolations as described above but employing Synthetic Mucor Agar (SMA) as the cultivation medium. In addition, thin slivers of necrotic bark were inserted into apple baits which were then incubated for up to 14 days at room temperature. Material from lesions developing within the flesh of the apples was sub-cultured onto Cornmeal Agar (CMA) in 9cm Petri dishes and incubated in darkness at 20°C. To encourage sporulation of *Phytophthora* isolates obtained by either of these methods, sub-cultures were made onto V8 juice agar and incubated in darkness at 20°C. Isolates were then identified as far as possible by morphological means or by appropriate molecular identification methods.

In a few cases, the presence of bacteria within bark lesions was suspected and isolations were made in these cases by excising small pieces of necrotic phloem and placing them onto Nutrient Agar (NA) in 9 cm Petri dishes which were incubated in darkness at 20°C. Bacterial growth which developed on isolation plates was streaked onto NA and individual colonies were then identified as far as possible by biochemical means or by appropriate molecular identification methods.

4 Results

4.1 *Characteristics of alder from published sources*

4.1.1 Seedling survival and establishment

Alder fruits are small (1-2 mm. in diameter) and light (about 320,000 to the pound). They possess two lateral float chambers of corky tissue and an oily outer coat so that they will float for over 12 months in still water. The average dispersal range of alder is 30 – 60 m, although saplings are seldom found beyond 20 – 30 m from the parent tree when water transport is precluded (McVean, 1955).

Alder seedlings will only establish on soil which remains continuously moist for 20 – 30 days in the period April – June. The water-table needs to be close to the surface so that capillary action can keep the soil moist (McVean, 1953). Periods of drought or flooding during this critical period will result in failed germination. In addition, seedlings are very sensitive to shading and require high light intensity to establish, they are also liable to damage by late frosts and frost heaving in winter.

Interestingly, McVean (1955) suggests that certain aspects of an Atlantic climate may be considered unfavourable to alder seedling establishment. In particular, the cold winters which condition the seeds so that they will germinate in the first relatively mild spell of the year but then leave them vulnerable to late frosts which kill the seedlings completely. This was shown experimentally where the minimum germination temperature was reduced from 18 to 7°C by the cold treatment of damp seeds at 0 – 4°C for 6 weeks. Few alder seeds remain dormant in the soil past the first germination season.

McVean (1956) suggests that sapling populations can be divided into 4 categories which give an idea of the conditions required for successful establishment:

1 <u>Linear flood populations</u>. These are found on strand lines along steams or areas of standing water and can mark the high water-level of a past flood events. High winds during the winter months can often lead to concentrations of alder seeds being driven onto lee shores where they can germinate. The frequently observed lines of alderwoods by streams may therefore owe their existence primarily to the mechanics of distribution. It is also notable that while seedlings establish readily on river alluvium, only old trees are to be found on the eroded banks, often with roots awash.

2 <u>Non-linear flood populations</u>. These are frequently found on low-lying alluvial land, especially where it has been under cultivation or grazed. Where the vegetation of the alluvial flats has not been greatly modified by man, the alder finds greater difficulty in establishing within the beds of *Carex* and *Phragmites*.

3 <u>Wind-disseminated populations</u>. These are usually found either as (a) dense clusters of saplings of the same age close to one or more seed parents, or as (b) linear populations along the edge of an alderwood. These populations have potentially come about as a result of favourable establishment conditions in the following spring on suitable ground. A number of observers have noted that the outskirts of many alderwoods can be seen to consist of several lines of trees, successively younger towards the outside due to saplings avoiding the neighbourhood of mature trees because of light and root competition (Kujala, V., 1924; McVean, 1953). It occasionally happens that the blown seeds reach a marshy spot nearby where the summer water-table is close to the surface and the vegetation not too dense. Seedlings will then

establish themselves each season for four or five years until the saplings have formed a closed canopy and excluded further seedlings.

4 Scattered establishment. Alder, though usually gregarious, are sometimes found as single individuals at some distance from the nearest population.

4.1.2 Ecological relationships

Alder is a keystone tree species within riparian habitats. It is deep rooted and so can stabilise banks, where the roots are above ground within water, they can provide shelter and hiding places for young fish. Alderwoods close to rivers provide shade and therefore cool the water and the falling leaves provide nutrients for many insect species which are food for fish (McVean, 1956; Featherstone, 2012).

Featherstone (2012) reports that more than 140 phytophagous insects have been recorded on alder. This include *Hemichroa crocea* (striped alder sawfly), *Cimbex connatus*, a rare sawfly in the UK, and *Hydriomena impluviata* (the May highflyer moth), which is only found in alder. The larva of the latter forms a shelter using two leaves that have been sewn together by silk.

Most of the dominant ectomycorrhizal (ECM) fungi found in forests have a low specificity (Molina, et al., 1992). The exception to this is the ECM community associated with alder which is characterized by low species richness and a high proportion of genus-specific species (Molina 1981). The reasons for this are yet to be fully understood but a number of theories have been put forward including that this phenomenon is an artifact of past soil conditions, or that the presence of *Frankia* disrupts the formation of the ECM community in some way (Kennedy, et al., 2015).

In addition to ECM fungi, some aquatic hyphomycetes (a class of endophytic fungi) can also grow on woody litter which has fallen into streams and on submerged roots of riparian species such as alder and willow. Fisher, et al., (1991) isolated sixty-six fungal endophytes, mainly *Deuteromycotina*, from the aquatic and terrestrial root systems of *Alnus glutinosa*. Other species of interest included *Heliscus lugdunensis*, *Dactylella aquatica* and *Tricladium chaetocladium*.

4.1.3 Future threats

4.1.3.1 Pests and pathogens

The UK Plant Health Risk Register (UKPHRR) (Defra, 2023) contains more than 1400 pests and pathogens of concern to agriculture, forestry, horticulture and the natural environment. It gives a risk score to pest and disease species dependant on several factors including the likelihood of introduction, establishment and spread, and the social, environmental, and economic impact (Defra, 2023). There is an unmitigated risk score to demonstrate the risk without regulatory measures (from 0 – 125), and a mitigated score to show current risk with measures in place (such as heat-treating timber before importing). Mitigated risk scores range from 0 – 100.

The risk register (as of 11th January 2023) records *Alnus* as a host for 49 pests and pathogens. Within this dataset, 17 are genus-level risks and 8 are specific to *A. glutinosa*. Combining these 17 and 8 species and interrogating the risk register provides 13 species with a mitigated risk score of over 30 (table 2). Some of these are already present in the UK but some potentially damaging species are not.

Table 2: UKPHRR data for pests and pathogens of Alnus as of 11th January 2023 (Defra, 2023). The higher the risk score, the higher the risk of a pest becoming established and spreading.

Pest or Pathogen	**UKPHRR Risk Score (mitigated)**	**UKPHRR further information**
Xylosandrus germanus (alder ambrosia beetle)	60	Ambrosia beetle affecting a wide range of trees and woody hosts. Widespread in Europe and elsewhere and now present in the south of England.
Phytophthora alni	48	Spread to most areas of the UK. No prospect of eradication or containment but possible co-ordinated action to mitigate impacts to be considered with stakeholders.
Anoplophora glabripennis (Asian Longhorn Beetle)	40	Recognised threat to a wide range of deciduous trees native to the UK. Single outbreak in the UK confirmed as eradicated in 2019. Already Regulated.
Xylotrechus namanganensis (namangan longhorn beetle)	40	Polyphagous longhorn beetle pest originating in Asia. Some uncertainty regarding risk to UK; but statutory action would be taken against findings on a precautionary basis.
Melampsoridium hiratsukanum (a rust fungus)	36	Fungal pathogen of alder; established locally in southern Britain.
Phytophthora siskiyouensis	36	Pathogen causing disease of alder and other tree species in the USA and Australia; now detected in the UK.
Anoplophora chinensis (Citrus Longhorn beetle)	30	Longhorn beetle native to Asia which has been introduced to parts of Europe; where there are ongoing eradication and containment efforts. Recognised threat to a wide range of deciduous trees native to the UK. Already regulated; it is a priority for continued surveillance and statutory action.

Pest or Pathogen	**UKPHRR Risk Score (mitigated)**	**UKPHRR further information**
Euwallacea fornicatus (Polyphagous Shot Hole Borer)	30	A disease complex involving an ambrosia beetle and fungus (*Neocosmospora euwallaceae*); native to Asia but now present in a number of other countries. Hosts potentially at risk in the UK include English oak and other broad leaved tree species. Climate is likely to be a limiting factor regarding establishment. Watching brief needed for any pest spread into areas with cooler climates. Regulation is being considered to help mitigate the risks to the UK.
Euwallacea Kuroshio (Kuroshio Shot Hole Borer)	30	A disease complex involving an ambrosia beetle and fungus; native to Asia and Oceania but now invasive in other countries. The UK climate is likely to be a limiting factor regarding establishment. Watching brief needed for any pest spread into areas with cooler climates.
Lepidosaphes ussuriensis (Ussuri oystershell scale insect)	30	Scale insect affecting a range of broadleaved trees in Asia. Regulation of some hosts and import inspections mitigate the risk of introduction.
Malacosoma disstria (Forest tent caterpillar moth)	30	Serious moth defoliator of trees in North America.
Rusticoclytus rusticus (a longhorn beetle)	30	Polyphagous longhorn beetle pest of deciduous trees; widely recorded across Europe and Asia. Limited impacts in Europe but is a damaging pest of poplar in parts of China.

Pest or Pathogen	UKPHRR Risk Score (mitigated)	UKPHRR further information
Xylosandrus crassiusculus (Asian ambrosia beetle)	30	Ambrosia beetle which can affect a wide range of broadleaved trees; widespread in Africa; Asia and parts of the US; with outbreaks in France and Italy. The UK climate is unlikely to be suitable for the pest to thrive and cause significant damage but needs to be investigated through research. Premises involved in importing wood and host plants from Italy in particular; where official measures are not being taken; should source material carefully.

The UKPHRR does not represent an exhaustive list of potential threats to particular hosts. For example, the bacterium *Brenneria alni* which causes cankering of the stems, branches and shoots of both common and Italian alders is not currently included in the register. The pathogen was first described (as *Erwinia alni*) following investigations of diseased trees in northern Italy in the early 1990s (Surico *et al.*, 1996), though identical symptoms had been noted on alders in Tuscany more than 30 years before (Moriondo, 1958). Subsequently, the pathogen has also been found to be associated with bleeding cankers on the stems of Caucasian alder (*Alnus subcordata*) in Iran (Moradi-Amirabad & Khodakaramian, 2020) but the degree of risk which it may pose to alders in northern Europe is currently unknown.

4.1.3.2 Climate change

The precise effects of climate change on woodlands is currently uncertain (Nature Scot, 2022). Ray (2008) carried out a modelling exercise which found that winter flooding in wet woodlands, which are dominated by alder, birch and willow, will become more frequent in future climate scenarios. In addition, wet conditions are likely to be maintained in wet woodland habitats in major valleys in Scotland, although this is dependent on rainfall occurring in the headwater tributaries, often in the central Highlands. These conditions are likely to favour alder if conditions are favourable for natural regeneration.

However, in some parts of Scotland there will be an increased chance of drought which will have an impact on drought-sensitive species such as alder (Ray, 2008). This is particularly the case in eastern Scotland. A greater frequency of hot and dry summers in eastern and southern Scotland will also increase the risk of fire in woodlands. For alder, the impact of winter waterlogging followed by summer drought is currently unknown.

The cumulative impacts on forest ecosystems by pests and diseases will also be exacerbated by climate change (Ramsfield, et al, 2016). The drivers of climate change in native and invasive pest population outbreaks are complex and there is considerable uncertainty about the shape and nature of their interactions. However, it is likely that such interactions will become a major consideration in woodland management in the future.

Another climatic consideration for alder is that it exhibits high genetic variation between subpopulations, but over time, subpopulations have developed high specificity to local conditions (Shaw et al., 2014). This may leave them vulnerable to changes in climate which alter local conditions in the future resulting in a narrowing of the gene pool.

4.1.3.3 Woodland creation

Local genetic specificity in alder subpopulations challenges planting efforts because of alders limited ability to survive outside of specific conditions (Shaw, et al., 2014). Selecting stock from a seed zone may not be specific enough for the development of a healthy alderwood into the future.

However, the most significant threat to alderwood creation is the inadvertent introduction of a pathogen during planting. This is particularly the case with *Phytophthora* pathogens which are very well adapted to surviving and spreading in plant production nurseries (Green, et al., 2021). Therefore, biosecurity should be upmost in the planning and delivery of alder planting (e.g., biosecurity guidance provided by the Forestry Commission & APHA (2021)).

4.2 Site assessments: details of site characteristics, general tree health and specific pathology of alders with current symptoms

4.2.1 Site 1

<u>NGR</u>: NH6661

<u>Site & stand characteristics</u>: A 30-year-old stand of *Alnus glutinosa* established by planting on previously wooded land within a conifer-dominated forest block. The northern edge of the stand is adjacent to a feeder stream for the Allt Dubhach.

<u>Soil</u>: Flushed, loamy surface-water gley

<u>Area inspected</u>: ~0.5 Ha

<u>Natural regeneration</u>: present (scattered outwith main stand)

<u>Herbivore damage</u>: absent, though the current form of trees suggests that herbivore activity has influenced their growth. (NWSS high)

<u>Tree condition</u>: 80 / 20 / <5

<u>Insect damage to foliage</u>: slight

The majority of trees (~80%) were in good condition, with no signs of current disease or historic dieback and only slight levels of insect damage to foliage. Approximately 20% of trees displayed some degree of crown thinning but severe defoliation and yellowing of crowns, which was consistently associated with the presence of tarry or rusty exudations on the lower stems, was confined to about 5% of the population. Local concentrations of trees with stem bleeding were evident, however. Scattered dead trees accounted for approximately 1% of standing stems.

Stem bleeds were always associated with basal lesions on affected trees and in many cases were due to infection by *Phytophthora alni*. However, *Armillaria ostoyae* was also found to be acting as a primary pathogen in a proportion of alders with tarry spots at the site. Fruiting bodies of *Heterobasidion annosum* associated with decay columns at the bases of two living trees were also noted.

Figure 4a. Tarry spotting on stem at site 1 associated with Phytophthora alni infection

Figure 4b. Mycelial fan of Armillaria beneath living bark of tree at site 1

The foliar pathogen *Taphrina tosquinetii* was present on the leaves of epicormic shoots produced by certain trees with thinning crowns but no signs of infection within the main crowns of trees was evident. Removal of a bark panel for laboratory investigation of a stem lesion revealed galleries of the cambium miner *Phytobia betulae* in one instance.

4.2.2 Site 2

NGR: NH5399

Site & stand characteristics: A riparian strip and associated floodplain with *Alnus glutinosa* the principal tree species. Distinct zonation of tree cover and condition associated with variations in groundwater levels / associated vegetation.

Soil: Gleyed podzol on higher elevation ground to north descending into valley complex and standing water.

Area inspected: ~2 Ha

Natural regeneration: present but scattered and primarily in wettest areas where alder is of shrubby form, with insufficient root stability to form trees.

Herbivore damage: present (NWSS medium)

Insect damage to foliage: slight

Tree condition: 20 / 40 / 40

The majority of trees were not in good condition but the nature of the symptoms displayed varied markedly across the site from severe crown dieback and mortality of alders closest to the river (associated with ground vegetation of grasses, sedges, *Ribes* & *Rubus*), through top dying of trees (ground vegetation dominated by *Equisetum*, with scabious also present), uniformly chlorotic individuals with a shrubby growing habit (*Sphagnum* dominated areas), to patchy dieback of large trees (associated with grasses & *Ribes*).

The crown dieback and mortality of trees was mostly of long-standing as indicated by the advanced deterioration of the branching structure and loss of bark within the crowns of affected individuals. Recent dieback was comparatively rare (<5% of stems) and primarily encountered on the lower branches of trees which had already been in decline for an extended period. However, strong growth of the lower crown and the production of healthy epicormic shoots on trees with dead tops was more commonly noted (>5% of stems).

***Figure 5a**. Historic dieback of stem with strong regrowth of basal shoots at site 2*

***Figure 5b**. Shrubby habit of alders in wettest parts of site 2*

***Figure 5c**. Ingress of water into soil pit illustrating high water table at site 2*

***Figure 5d**. Root system of shrubby alder with poor nodulation and lenticel enlargement.*

Branches affected by recent dieback characteristically bore long lesions colonised by *Ophiovalsa suffusa* or *Valsa oxystoma*, which fruited abundantly on the killed bark. No evidence of basal lesions was found on any of the affected stems examined and tarry spotting was absent in all cases. Excavation of the root systems of two mature trees near the river which displayed severe crown dieback revealed dense rooting in the top 15cm of the soil profile with moribund and dead roots present in strongly gleyed material between 15 and 45 cm just above the level of the water table. The xylem of dead and dying roots was darkly stained indicating waterlogging and no root pathogens were isolated from samples subsequently examined in the laboratory. Excavation of a chlorotic shrubby alder growing in *Sphagnum* revealed no necrosis in the rooting system but minimal evidence of root nodulation by *Frankia*. Ground conditions in this area of the site were not sufficiently stable to support the rooting of alders with a height of more than a few metres.

4.2.3 Site 3

NGR:NH7789

Site & stand characteristics: A strip of mature alder lining the southern edge of a lochan and associated water course.

Soil: Indurated podzol

Area inspected: ~0.25 Ha

Natural regeneration: absent

Herbivore damage: present (NWSS medium)

Insect damage: slight

Tree condition: 65 / 30 / 5

The majority of trees (~65%) were in good condition with no signs of current disease or historic dieback and only slight levels of insect damage to foliage. Moderate to severe dieback of long standing was evident on approximately 15% of stems and was most pronounced on edge trees growing amongst *Calluna* and occasional Scots pine regeneration in drier parts of the site. In these areas, more recent dieback of the branching structure and in some cases the tops of alders was noted, with the affected parts of the trees bearing long lesions colonised by *Valsa oxystoma* and occasionally *Melanconis alni*, which fruited on the dead regions of bark. Tarry exudations were present on the stems of less than 5 % of trees examined, which were concentrated along the edge of the lochan. Crown symptoms were not always displayed by trees so affected but dieback of the upper crown which was not associated with a reduction in leaf size or discolouration of the foliage was present in some cases. Exudation was present to above 3 m on some stems and the associated necrotic bark, which was water-soaked, was present in isolated patches with no direct connection to the stem bases. Field testing of lesion material with lateral flow devices returned negative results and no fungi or oomycete species were isolated during subsequent laboratory studies. Copious bacterial growth was obtained in initial isolations onto Nutrient agar but subsequent subculturing onto a range of bacteriological media produced no viable colonies and investigation of the identity of the bacterial species concerned is ongoing.

Figure 6a. *General view of alders and associated vegetation at site 3.*

Figure 6b. *Dieback of stems associated with Valsa colonisation at margin of site 3.*

***Figure 6c**. Lesion of Valsa oxystoma on major branch of young alder with dieback*

***Figure 6d**. Cross-section of branch with Valsa oxystoma lesion showing colonisation of wood*

4.2.4 Site 4

NGR: NC5700

Site & stand characteristics: An area of mature alder bounding a seasonal pond associated with drainage channels feeding the river Fleet.

Soil: 1uv

Area inspected: ~1 Ha

Natural regeneration: absent

Herbivore damage: absent (NWSS high)

Insect damage: slight

Tree condition: 60 / 30 / 10

The majority of alders surveyed (~60%) displayed minimal signs of damage or disease. Thinning of crowns and localised dieback of twigs and branches affected approximately 20% of trees. Severe dieback involving death of a large proportion of the crown was observed in approximately 15% of trees, with variations in the condition of the dead parts of the branching structure indicating that decline had been progressive and protracted. Occasional dead stems (~5%) were scattered throughout the tree population, with dead and living stems frequently found together within individual alder stools.

Occasional stems and branches which had died back in 2022 bore long lesions colonised by *Ophiovalsa suffusa* or *Valsa oxystoma*, but the majority of trees at the site with symptoms of current disease displayed tarry or rusty spotting on the bark near the bases of their stems. The lesions associated with exudation from the bark were generally connected to the root collars of affected trees, tested positive in the field for the presence of *Phytophthora* using lateral flow devices, and gave rise to cultures of *Phytophthora alni* during subsequent laboratory investigations. A single tree with a basal lesion as described above proved to be infected by *Armillaria mellea*. Two trees with stem bleeding associated with isolated patches of necrosis which were not connected to the stem bases tested negative in the field for the presence of *Phytophthora* using LFDs but yielded cultures of *Phytophthora alni* during subsequent laboratory investigations.

Figure 7a. Tarry spotting on stem at site 4 associated with Phytophthora alni infection

Figure 7b. Margin of basal lesion on alder at site 4 showing Armillaria mellea infection

Figure 7c. Isolated stem lesion at site 4 associated with Phytophthora alni infection

Figure 7d. Staining of sapwood beneath phloem colonised by Phytophthora alni

Excavation of soil pits adjacent to two symptomatic trees (one with *Valsa* infection and the other with *Phytophthora* disease) indicated that the soil at the site was predominantly a well-drained upland brown earth with a sandy texture. The soil profile was dry to a depth of 60 cm at the time of investigation but slight greying below 30cm indicated the occurrence of seasonal fluctuations in the level of the water table.

4.1.1 Site 5

NGR: NJ1831

Site & stand characteristics: An area of mature alder on the bank and adjacent floodplain of the river Avon. Location of first confirmed cases of *Phytophthora alni* in northern Scotland.

Soil: **3xs**/5v/1v

Area inspected: ~0.2 Ha + 0.2 Ha

Natural regeneration: present (scarce)

Herbivore damage: absent (NWSS high)

Insect damage: slight

Tree condition: 40/40/20

The stand concerned was the only location selected for survey on the basis of historic rather than recent evidence of tree decline, with infection of trees by *Phytophthora alni* first having been confirmed at the site in 1997 and a plot to monitor the condition of trees established in 1998. There was insufficient time to re-locate and assess all of the trees in the original monitoring plot and, as for the other locations visited, a general assessment of the symptoms displayed by the trees was therefore undertaken. However, the presence of all of the alder stools originally included in the plot was confirmed (with a single stool at the southern end of the plot only represented by low stumps due to the loss of all standing stems). A few alder saplings which had recently established by natural regeneration were noted on the riverside edge of the plot.

Symptomatic trees predominantly displayed thin crowns with some evidence of historic dieback and approximately 10% of the standing stems were long-dead (frequently associated with healthy and symptomatic stems within particular stools). Less than 5% of the alders examined displayed signs of recent decline (predominantly minor dieback of twigs and small branches) and only a single tree displayed tarry spotting on its stem. Examination of the tree revealed no signs of *Phytophthora* infection but mycelial fans of an *Armillaria* species were found at the margin of an extensive bark lesion, with subsequent laboratory investigation identifying the species concerned as *Armillaria mellea*.

Figure 8a. *General view of alders and associated vegetation at site 5.*

Figure 8b. *Infection by A. mellea associated with tarry spotting on one stem at site 5*

Figure 8c*. Mechanical damage to alder stem at site 5 due to impacts from flood debris*

Figure 8d*. Healthy young alder (~20 yo) adjacent to monitoring plot at site 5*

Outwith the original monitoring plot, the condition of a younger population of alders which became established by natural regeneration in a single growing season in around 2000 was also evaluated. With the exception of a few stems which were long dead, the younger trees were completely healthy and showed no signs of either historic or recent decline.

4.2.5 Site 6

NGR: NJ1838

Site & stand characteristics: A strip of mature riparian alder and scattered individual trees on the adjacent floodplain of the river Spey, with extensive recent planting of *Alnus glutinosa* on the associated open ground.

Soil: 3xs/**5v**/1v

Area inspected: ~1.5 Ha

Natural regeneration: absent

Herbivore damage: present

Insect damage: slight

Tree condition: 20/30/50 (mature trees)

The natural population of trees at the site consisted of large mature / overmature single-stemmed alders, of which the majority were in poor condition. The primary symptom displayed by the trees was moderate to severe crown dieback of long standing, with many stag-headed individuals evident at the edge of the river and on the adjacent floodplain. More recent dieback, where present, was of scattered branches in the crowns of trees already displaying signs of historic dieback. Apparently healthy individuals were concentrated along the edge of the river but a small proportion of these displayed tarry / rusty spotting on the bark at or near the bases of their stems. Field testing of the lesions associated with stem bleeds with LFDs gave positive results and subsequent laboratory investigations of lesion material confirmed the presence of *Phytophthora alni*.

Recent plantings of *Alnus glutinosa* had been carried out on the floodplain areas where established alders were absent and few of these young trees displayed symptoms of disease with the exception of a small patch of chlorotic individuals centred on a sapling with a basal stem lesion due to *Phytophthora alni* infection and a larger group of trees with severe leaf-rolling associated with rust infection of their foliage. Laboratory investigations of leaf samples from the latter trees revealed that the rust concerned was *Melampsoridium betulinum*.

Figure 9a. *Marked variation in condition of mature alder at site 6.*

Figure 9b. *Veteran alder at site 6 in poor condition but with healthy remnant crown.*

Figure 9c. *Phytophthora alni lesion at base of recently planted stem at site 6.*

Figure 9d. *Foliar infection of young alder by Melampsoridium betulinum at site 6.*

4.2.6 Site 7

NGR: NJ0628

Site & stand characteristics: A riparian strip of predominantly mature alder within a fenced enclosure along the banks of the Allt an Fhithich above its confluence with the river Spey.

Soil: **3xs**/5v/1v

Area inspected: ~0.75 Ha

Natural regeneration: present (common)

Herbivore damage: present – scarce. (NWSS very high)

Insect damage: slight

Tree condition: 70/25/5

The majority of trees (~70%) were in good condition, with no signs of current disease or historic dieback and only slight levels of insect damage to foliage. Close to the confluence of the river with the main stem of the Spey, a few alders with uniform crown thinning and decline displayed tarry / rusty spotting on the bark at and near the bases of their stems. The lesions associated with exudation from the bark were connected to the root collars of affected trees, tested positive in the field for the presence of *Phytophthora* using lateral flow devices, and gave rise to cultures of *Phytophthora alni* during subsequent laboratory investigations.

Further upstream, tarry spotting on stems which was associated with isolated patches of bark necrosis which were not connected to the stem bases tested negative in the field for the presence of *Phytophthora* using LFDs and yielded cultures of a range of opportunistic fungi during subsequent laboratory investigations.

Scattered individual alders growing at distance from the edge of the water course displayed recent dieback of major branches and the entire tops of some of these trees had died during the 2022 growing season. In all cases, the affected parts of the branching structure bore long lesions colonised by *Valsa oxystoma*, which fruited abundantly on the killed bark.

A single young alder with chlorotic foliage was found to have been infected by *Heterobasidion annosum* which was fruiting at the base of its stem. It appeared that transmission of the fungus to the alder had occurred via contact with a diseased root of Scots pine.

Figure 10a. General view of alders and associated vegetation at site 7.

Figure 10b. Recent dieback of scattered young alders at site 7 (Valsa oxystoma present).

Figure 10c. Isolated stem lesion on young alder at site 7 – cause unknown.

Figure 10d. Fruiting bodies of Heterobasidion annosum at base of young alder at site 7

4.2.7 Site 8

NGR: NH8753

Site & stand characteristics: Damp woodland area adjacent to water course and associated riparian strip.

Soil: 3x/3xs

Area inspected: ~0.5 Ha

Natural regeneration: present (scarce)

Herbivore damage: absent (NWSS medium)

Insect damage: slight

Tree condition: 20 / 60 /20

The condition of trees differed markedly between the area of closed canopy woodland and the associated riparian strip at this location. Dead stems and trees with thin and moribund crowns were common within the woodland area, becoming less common towards the open edge of the stand adjacent to the water course. The decline of the trees in this area was not associated with obvious signs of historic or ongoing damage or disease but it was evident that long-established alders were in the process of being overtopped and shaded out by invasive sycamore which was already well established. The elevation of the woodland area above the normal river level was sufficient for relatively deep rooting of the sycamore without waterlogging, whilst the associated area of riparian strip immediately upstream was lower lying, subject to inundation and thus less favourable for its establishment and survival.

Correspondingly, alder in the riparian strip were generally in good condition, though a number of stems displayed tarry or rusty spots on the bark near the bases of their stems. Samples from a representative tree tested positive in the field for the presence of *Phytophthora* using a lateral flow device and gave rise to cultures of *Phytophthora alni* during subsequent laboratory investigations. Killing of one tree by *Armillaria mellea* was also noted. Occasional alder regeneration was only noted in scoured areas of gravel well separated from existing tree cover but was highly vulnerable to physical damage during floods.

***Figure 11a**. Declining crown of mature alder surrounded by dense sycamore crowns at site 8*

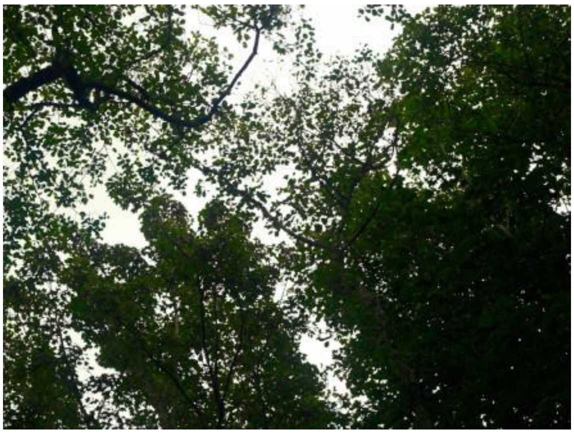


***Figure 11b**. Alder regeneration on scoured gravel bank at site 8*

4.2.8 Summary of damaging agents identified at survey sites.

Site	Alder dieback	*Phytophthora alni*	*Armillaria spp*	*Melampsoridium betulinum*	Physical	Abiotic	Other
1		✓	✓		✓		✓
2	✓					✓	
3	✓					(✓)	✓
4	✓	✓	✓			✓	✓
5			✓		✓		
6	✓	✓		✓		(✓)	
7	✓	✓					✓
8		✓	✓		✓		✓

5 Discussion / Conclusions

5.1 Alder health – context and need for site assessment

The primary rationale for conducting the project reported here was to ensure that concerns relating to an apparently rapid decline in the condition of alder in the north of Scotland first raised in 2019 were thoroughly investigated. A limited study previously conducted under Plant Health Centre project PHC2019/09 reviewed reports of alders displaying symptoms of poor health provided by Scottish Forestry (SF) tree health officers in 2020 and found that the majority related to alder populations in the north of Scotland. Although insect damage to the foliage of alders was locally severe in 2019 and was also frequently noted by SF staff in 2020, symptoms of decline were also displayed by a proportion of trees at most of the sites which were visited by them. However, the symptoms manifested by the declining trees at different locations varied widely and it was therefore considered unlikely that a single agent was associated with widespread damage to the species. Nevertheless, it was recommended that surveys of selected sites by tree pathologists should be undertaken in order to investigate the range of symptoms displayed and the damaging agents concerned given the potential for a previously unrecorded pest or disease to be present.

Whilst the SF reports made in 2020 provided a sound basis for identifying sites at which field surveys might subsequently be carried out, they did not represent an unbiased sample of alder populations which displayed signs of poor health. The preponderance of reports from the north of the country could potentially have been due to changes in the condition of alder being more immediately apparent in riparian woodlands where it is the sole or dominant tree species, and that similar decline was present but undetected in more southerly woodlands where alder is typically found in mixture with other species such as ash and birch. Seeking new records of alder decline was therefore included as an element in the current project both in order to provide a separate indication of the geographical distribution of alder populations in which trees judged to be in poor condition were present and to supplement the pool of sites from which to select locations for detailed study. The Observatree alder survey initiated for this purpose also served to establish whether an approach to assessment of sites focussed on describing the overall condition of the tree population, with description of the detailed symptoms displayed by trees being a secondary objective, could provide a useful model for future reporting of alder health.

In agreement with both the SF reports of alder decline from 2020 and older records of alder dieback and *Phytophthora* disease in Scotland (Webber, Gibbs & Hendry, 2004), the majority of the alder populations containing trees in poor condition highlighted by the Observatree survey carried out in 2022 were located in the north of the country. This indicated that a programme of site visits to investigate recent alder decline should be focussed on the Highland and Moray districts, and provided information on ten additional locations in that area which were worthy of study. The quantity and quality of the information provided in the Observatree reports allowed for the identification both of sites with evidence of recent alder decline and with tree populations which were sufficiently large to allow detailed surveys to be undertaken. The focus on the collection of population-level observations with supporting photographic evidence did not prove problematic to the surveyors, provided a clear insight into the condition of trees at particular locations to those reviewing the reports. It might usefully be employed in further efforts to capture information on alder health where reporters are not specialists in the identification of tree pests and diseases. Problems which may arise when attempting to gather highly specific data on alder condition are considered further in the discussion of site surveys below.

Permission to access the survey sites selected for the project, and to obtain samples from the trees at these locations for subsequent laboratory investigation, was granted in all cases where it was sought. However, identifying ownership in those instances where trees were not located on the public forest estate or under the stewardship of public bodies was occasionally problematic. Inability to trace woodland owners in a timely manner, which most frequently occurred in cases where fishing rights and riparian ownership were held separately, led to the rejection of some potential sites from inclusion in the current survey. Communication with local fisheries trusts was not only helpful in establishing contact with woodland owners of potential survey sites but also in gaining an overview of ongoing activities within catchments including riparian woodland restoration schemes, which are apparently increasing in number and scale (e.g., Scottish Forestry has identified 175,000 hectares of riparian land across Scotland that has the potential for woodland planting. This is eligible for increased grant support (Scottish Forestry, 2023). Whilst the benefits which these schemes can potentially deliver is clear, the risks attendant on planting of riparian woodlands in terms of the introduction or spread of pests and diseases does not appear to be widely recognised or acknowledged and this is a cause for concern.

The detailed surveys which were carried out at each of the sites selected for study in this project aimed to determine whether a recent and rapid decline in the condition of any trees had occurred, and to identify the agents affecting alders which were currently unhealthy. Whilst a small proportion of alders inspected at each location displayed symptoms of recent decline, there was no evidence to suggest that a high percentage of alders was currently affected by a single aggressive pest or disease. Indeed, the pathology of unhealthy trees varied markedly both between and within sites and this was reflected by the range of damaging agents identified.

Damage by defoliating insects was minor at all sites and bore the hallmarks of feeding by chrysomelid beetle larvae, though these were rarely observed; adults of *Chrysomela aenea* were noted at site 1, however. In accordance with previous findings (section 2.1.2), the most common damaging agents associated with alders displaying current symptoms of poor health were *Phytophthora alni* and *Valsa oxystoma* / *Ophiovalsa suffusa* (which were present in bark lesions and the underlying sapwood in trees suffering from alder dieback *sensu* Gregory). Trees affected by current crown dieback were generally associated with drier locations within sites where low-water stress was more likely to occur, with the exception of site 2 where the symptomatic trees were suffering from root mortality as a result of waterlogging. Contrastingly, trees affected by *Phytophthora alni* were usually located close to the local water course, the clear exception being at site 1 where the affected trees were scattered in loose groups throughout the stand at varying distances from the associated stream. However, it is probable that the pathogen was introduced to site 1 at the time of its establishment and that the current distribution of affected trees reflected the locations at which diseased saplings were originally planted.

Killing of riparian alders by *Armillaria* spp. was inoted as relatively uncommon on the sites visited, its occurrence at sites 1, 4 and 8 may well have resulted from the establishment of the pathogen on other tree species in adjacent woodland; the occurrence of *Heterobasidion annosum* on trees at sites 1 and 7 may be similarly explained. The only other fungal pathogen found to be affecting alder at the survey sites in 2022 was a *Melampsoridium* rust detected on the foliage of a group of planted saplings at site 6: laboratory investigation showed the species concerned to be the native rust *Melampsoridium betulinum* and not the potentially invasive *M. hiratsukanum* (section 2.1.2).

Direct physical damage to trees as a result of impacts from water-borne debris were noted at three sites and damage from herbivores in the form of (occasional) browsing or fraying damage were noted at a further four locations. Unexplained disease symptoms were encountered on a limited number of trees at site 3, where water-soaked bark lesions which yielded only bacteria were encountered on two stems. However, subculturing onto a range of bacteriological media failed to produce viable colonies and identification of the species was not possible. No recognised bacterial disease of alder has been recorded in Britain to date but infection of *Alnus glutinosa* by the species *Brenneria alni* (syn *Erwinia alni*) has previously been reported in Italy (section 4.1.3.1) and efforts to obtain cultures of bacteria from the trees concerned at site 3 in order to achieve a definitive identification of the species concerned are ongoing.

Although symptoms of current disease were confined to a relatively small percentage of the trees examined in the current study, mature alders at sites 2 and 6 in particular displayed evidence of historic dieback which had not resulted in mortality. Otherwise, intact crowns containing one or more large, dead limbs and stag-headed trees with strong regrowth from epicormic shoots emanating from major branches and stems were observed at these locations. Investigation of the potential cause(s) of these symptoms was outwith the scope of the current project but they were not consistent with the pattern of branch mortality which might be expected as a result of infection by an aggressive root pathogen such as *Phytophthora alni*; rather, they corresponded with symptoms previously recorded in association with environmental stresses to alders, or to crown dieback *sensu* Gregory.

5.2 Alder health – insights from site assessment

Observations of a limited number of alder populations with moderate levels of crown dieback over an extended period has indicated that the condition of affected trees frequently alters very little over time and that, rather than being progressive, crown dieback is frequently episodic in nature (Hendry, unpublished). Gaining a better understanding of both the timing and the duration of historic episodes of alder decline would be of considerable value in establishing whether such events are consistently correlated with high levels of particular environmental stresses and, if so, the thresholds beyond which damage to trees occurs. Although historic records and aerial photographs may shed some light on past changes in the extent and condition of alder cover at particular sites, the temporal resolution of these sources of information is not sufficiently fine to allow the onset of episodes of tree decline to be dated, or their duration determined, with the accuracy required. Tree ring analyses comparing healthy and symptomatic trees at particular sites can, however, accurately date past declines and their longevity (Gagen *et al.*, 2019). Dendrochronological study may also allow the timing of past phases of tree mortality to be established. Of the areas surveyed during this project, site 2, where extensive historic dieback of older trees was evident, would be most suited to an investigation of this type. Catchments in which additional studies of *Phytophthora* disease and crown dieback of alder would be justified are included as Appendix 3 to this report.

The varying condition of the trees and the range of damaging agents found to be associated with declining alders in this study has clear implications for the approaches which might be taken to routine monitoring of the condition of alders to improve our understanding of the health of the species in Scotland. Whilst recording a structured series of observations on the characteristics of individual trees is often useful for documenting their general condition, or the presence / severity of symptoms associated with a particular pest or pathogen, it is unlikely to be the most efficient or effective means of capturing relevant information where the baseline condition of trees is highly variable and current symptoms due to multiple damaging agents are present. General and specific issues which arise when attempting to monitor alder health *via* detailed field recording of traits indicating its condition include:

- *Accurate identification of individual trees*. The tendency of alders to form stools in which multiple stems share a common root system, and frequently a single functional crown, must be taken into account when distinguishing between individual "trees" for monitoring purposes. The crowding of stems within stools often renders accurate determination of condition at the level of individual stems extremely difficult.
- *Accurate assessment of healthy versus symptomatic individuals*. The crowns of healthy alders are typically not dense and may appear unnaturally thin, particularly in the case of older trees. Use of crown density as a general index of tree health should be

treated with caution and assessment of additional attributes conducted to gain a complete overview of tree condition.

- *Differentiating between transitory damage and decline*. Thinning of tree crowns as a result of insect-mining of buds and severe leaf browning or loss due to sporadic outbreaks of defoliating insects can often be mistaken for extensive dieback but these are transitory events and unlikely to have any long-term implications for the health of affected trees. Whilst currently rare, repeated defoliation of alders in consecutive growing seasons could potentially result in sufficient stress to predispose them to disease or other forms of damage and detection of such events would be valuable.
- *Distinguishing between historic dieback and current decline*. Historic dieback of alders (as discussed above) requires the age of any damage which trees display to be evaluated carefully since, whilst the condition of trees displaying old dieback may be less than optimal, they may not be in immediate poor health or in a state of ongoing decline.

Overcoming these issues is not impossible if repeated assessments of the trees in particular populations are made at appropriate intervals, but collection of sufficient data is likely to be time-consuming and beyond the scope of surveys undertaken as an adjunct to other activities by assessors who have not received specific training. Moreover, the dynamics of the pests and diseases affecting alder suggest that annual monitoring should be carried out in order to accurately determine the time of onset of any new decline in condition and facilitate the identification any predisposing factors.

The nature of riparian woodlands often renders the crowns of individual stems or stools clearly visible and distinguishable from those of neighbouring trees, making monitoring by means of ground-based fixed-point photography a realistic alternative to detailed recording of specific traits, particularly if the detection of potentially significant changes in tree condition rather than quantification of specific attributes is required. In uneven-aged stands, sub-division of the tree population into different diameter classes and obtaining a photographic record of the condition displayed by a representative sample of each class would be recommended in order to determine whether damage or disease occurs more frequently, or progresses at different rates, in older or younger trees.

If scoring and recording of particular tree attributes is preferred as an approach to monitoring subject to the *caveats* noted above, the suite of symptoms commonly encountered on alder in Scotland suggests that the following assessments detailed in Innes (1990) should be carried out as a minimum: crown density, foliar discolouration, defoliation type, crown dieback, epicormics, fruiting, leaf size, mechanical damage, butt and stem damage, insect damage. Additionally, assessments of tree dominance, canopy closure and an estimate of stem diameter would be recommended.

5.3 Consequences for policy and practice

Loss of mature alders at particular locations might be of less immediate concern if a cohort of younger, healthy trees which could exploit the emergence of canopy gaps resulting from the decline and death of older trees was also present. At most of the sites visited during the course of the current survey however, young trees which had established *via* natural regeneration were either absent or scarce and the populations of mature trees were generally even-aged. There were sufficient areas of open ground at each of the sites concerned to provide opportunities for natural regeneration to occur and the lack of sapling trees must therefore have resulted either from poor seedling establishment or survival, since local seed sources were always present. Beyond noting that, where present, surviving regeneration was generally unaffected by damage or disease, further investigation of this question was not possible. However, it is noteworthy that the one location at which recent regeneration of alders was relatively common was within an area where assiduous deer control had reportedly been implemented in order to preserve natural regeneration in Scots pine stands nearby. The issue of poor establishment / survival of alder regeneration at many locations is deserving of specific study so that appropriate management actions to ensure continuity of current alder populations can be identified.

Planting of alders to remedy lack of natural regeneration, or where no local seed sources are present, is frequently undertaken but should not be viewed as the only or best option for achieving alder cover in a riparian context. A supplementary discussion document which considers the biosecurity risks associated with planting of riparian alders is being prepared. This will draw upon the findings of this report and the recently published UKFS Practice Guide 'Creating and managing riparian woodlands' (Forest Research, 2024a), but the following points should be considered:

- Planting of alders carries an attendant risk of introducing pests and diseases at the time of tree establishment.
- *Phytophthora* species such as *P. alni* can be carried on asymptomatic plants or in soil and pose a particular problem in terms of detection both in the plant supply chain and immediately post-planting.
- Targeting the planting of alders towards the headwaters of catchments to maximise the potential environmental benefits of riparian woodland creation risks introducing *P. alni* into currently disease-free areas of rivers and ultimately exposing all of the trees downstream to inoculum of the pathogen.
- Alder establishment *via* natural regeneration or direct seeding carries a substantially lower risk of pest and pathogen introduction than planting. Limited evidence indicates the potential for successful use of both of these techniques for establishment or enhancement of riparian woodlands in the UK.

The level of reporting of alder health problems in Scotland has historically been low (Hendry, 2020) and, if this continues to be the case, there is a corresponding risk that any emerging pest or disease problems affecting the species may be overlooked for a considerable period before initial detection occurs. Recently planted alders should be monitored regularly and any signs of poor health which become evident should be investigated thoroughly since effective action to address the issue will require an accurate diagnosis of the cause(s) involved. Deteriorations in the condition of mature trees should not be overlooked however, since they may be more sensitive to environmental stresses and changes which will influence the longer-term survival of the species at particular locations. The need for further structured surveys focussing on alder health requires in-depth discussion in the light of policy priorities and available resources. However, fresh observations of recent decline and apparent impacts of pests or diseases are always helpful in providing the latest picture of tree health across the range of species found in Britain. TreeAlert (Forest Research, 2024b) provides a readily accessible portal for reporting such concerns and can be used by professionals and members of the public to provide observations on alder and other tree species.

Current catchment restoration schemes provide clear evidence that the value of riparian woodlands is recognised and of a willingness to commit time and resources to their creation and upkeep. This strongly suggests that the present lack of reports of alder health problems does not reflect a lack of concern for the species and therefore poses the challenge of improving the communication of the current and potential threats facing alder, as well as appropriate responses to them, to the woodland owners and managers whose awareness of these issues will be central to addressing them.

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7 Appendix 1: Observatree alder survey documentation including rationale, survey instructions and supporting material.

Why alder needs recording

Common alder (*Alnus glutinosa*) is a key part of freshwater ecosystems and delivers important benefits to wildlife, water quality and temperature, bank stability and flood alleviation. In many parts of upland Scotland, it is the only tree species present along riverbanks, with no obvious alternatives available to fill its role should it be lost. Even in the lowlands, where richer soils along watercourses are favourable for the growth of other tree species, historic loss of elm due to Dutch elm disease, and increasing levels of ash mortality due to Chalara ash dieback, suggest that there will be an increasing dependence on alder to provide the benefits to the environment which are noted above.

A number of pests and pathogens with the potential to be highly damaging to alder are present in Britain. Knowledge of their current distributions and impacts in Scotland is poor because of limited research and low levels of reporting. As a result, the level of threat to the existing alder population is difficult to determine, and there is a low probability that any emerging problems on this host will be speedily detected and reported.

Concerns over the condition of alder in Scotland and particularly in the northern uplands have been growing in recent years, with declines in the health of trees apparently being more widespread & rapid than before. This has resulted in a recognition of the need for better information on the condition of alder across Scotland so that the scale and severity of problems affecting its health can be properly understood.

What can you do to help?

Due to the range of pests and pathogens which affect alders, and uncertainty about which of these may currently be affecting trees, it is important that we gather reports of the condition of alder so that scientists can build a clearer understanding and make decisions about future management of this important tree species. Please consider completing a survey to help us find sites for further research.

The survey

Please conduct a 'woodland assessment' of any woodlands in your local area you know have alder. If you're unsure where alder might be present in your local area, look for sites with watercourses.

We're always interested in reports of alder in poor health, but please submit any woodland assessments by 15th July so we can inform the researchers of your findings.

How to complete a woodland assessment

- Visit a site and survey any alder trees for symptoms shown in the photo guide at the end of this document.
- Decide in the site which of the trees is healthiest, which is showing the worst symptoms, and which shows intermediate symptoms. Please take a photo of each. These will give us three representatives from the woodland.
- Estimate of the total number of alder trees (with and without symptoms).
- Estimate of the percentage of trees that fit closest to your three representatives; healthy, intermediate and worst symptoms (see example on the next page).
- If no symptoms are present, please still submit your survey saying all trees are healthy!

- Use the site survey form to submit the woodland assessment in one form. Include a central grid reference and if possible, the woodland name.
- Complete the tree information as usual, clicking any symptoms observed on the alder.
- In the additional symptoms free text box include your total estimated alder number, percentages of healthy, intermediate and worst symptoms, and any extra information about symptoms observed, frequency observed etc.
- Upload your three representative photos.

If you find any alder that show interesting or severe symptoms that you would like to highlight, please complete an individual site survey form for the tree (please still include it in your woodland assessment).

Our priority is observations of the alder woodland as a whole. This factsheet gives an idea of the varying health conditions which are likely to be encountered when surveying alder.

Any signs of specific disease symptoms can also be recorded, such insect infestation or bleeds individual trees (e.g. bleeding on stems as in picture 8).

Example

I visit my local river, which I estimate has a group of 30 alder along the bank. I survey them for any of the signs and symptoms shown in the photo guide below. While there I record a central grid reference. I've noticed some symptoms, so I decide upon the healthiest alder, the one with the most symptoms (worst), and then one in the middle (intermediate) and take photos. I try to take a photo with most of the tree in.

With a broad estimate of the 30 trees, 15 look healthy (50%), 5 show the worst symptoms (~15%) and 10 have intermediate symptoms (~35%).

When back home I complete my site survey, entering the central grid reference, ticking number of trees and size observed, and ticking the symptoms I saw. In the extra symptoms information box I put in my number of trees; 30, along with my estimated percentages. I also note that most of the worst trees had bleeds, whereas the intermediate trees had mainly insect feeding damage. I then upload my three representative photos.

Thank you! This work is being led by Forest Research
and
Royal Botanic Gardens Edinburgh.

1. Completely healthy alders have dense dark green crowns

2. Trees which produce very sparse foliage on an intact crown

3. Trees with severely browned (often damaged) leaves

4. Trees with completely yellow leaves (sometimes smaller than usual)

5. Trees which are dropping their leaves early (sometimes discoloured)

6. Trees with recent dieback: large parts of crown leafless & branches dead

7. Trees with old dieback: twigs and small branches missing

8. Trees with tarry or rusty bleeds on their stems (usually at the base)

9. Rusty bleed

10. Bleeding example

11. Rust fungi on underside of leaf

12. Larvae with brown feeding damage

8 Appendix 2: Sample survey report from Observatree alder survey conducted in 2022.

Grid reference (centre of site surveyed):	NH664616
Name of wood:	Millbuie Forest (Forestry Commission) on the Black Isle
Site information:	An apparently planted block of alder (c.30 x 100m) by the Allt Dubhach burn at its intersection with a forest track (Kingsley Wood Way) – See Muilbuie Forest Plan and riparian ecological planting aims. The block of alder is situated in a wider area of mixed conifer planting, mainly Scot's pine and Sitka spruce and larch. There is also some willow and birch along the edge of burn and perimeter of alder block. Understorey largely grass/sedge/moss.
Date of survey:	13/06/2022
Surveyor:	-
Total Number of trees: (estimate)	500
Number Healthy (estimate of trees without symptoms):	80%
Number Unhealthy (estimate of trees with symptoms):	20%
Proportion of Healthiest Category (estimate) (Photo 1):	80%
Proportion of Intermediate Category (estimate) (Photo 2):	15%
Proportion Poorest Category (estimate) (Photo 3):	5%

<table>
<tr><td>General health of alder block:</td><td>Overall health:

Overall appearance was generally healthy: ca 80% trees with reasonably good leafy crowns

Some trees showing sparser foliage with smaller leaves and dieback in crown: ca 15%

No obvious severe browning or complete yellowing of leaves, nor any drooping of leaves.

Some trees with more significant and older dieback with twigs/small branches missing, or trees completely dead: ca. 5%</td></tr>
<tr><td colspan="2">Pests and diseases</td></tr>
<tr><td colspan="2">Bleeds on stems:

Some trees (ca 2%) showing rusty or blackish bleeds on lower trunk up to a height of 1m to 1.5m

(Photo 4: composite of bleeds seen on 8 different trees).

Trees with bleeds were either showing moderate dieback (intermediate category) or were dead or almost dead (worst category)</td></tr>
<tr><td colspan="2">Fungal infections:

Leaf symptoms (puckering, yellowing and browning with some surface whitening) of Taphrina observed on leaves on basal shoots of some trees (low incidence and low severity) and also on small saplings (<1m tall) in adjacent drainage ditch along forest track, typically only a few leaves per sapling.

(Photo 5: composite of symptoms)</td></tr>
<tr><td colspan="2">No rust observed on leaves</td></tr>
<tr><td colspan="2">No larvae or associated feeding damage observed on leaves</td></tr>
</table>

Photo 1: Healthiest tree (representative)

Photo 2: Intermediate tree (representative)

Photo 3: Worst tree (representative)

Photo 4: Bleeds on basal part of stems

Photo 5: Fungal leaf infections on leaves on basal shoots or saplings in drainage ditch at edge of site (Taphrina)

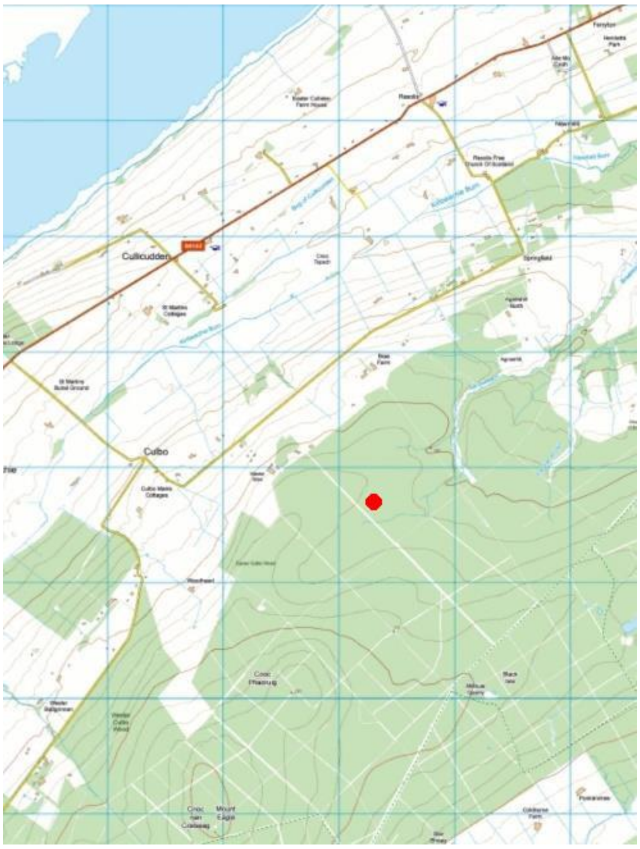
Site location map:

Millbuie Forest

Black Isle

NH664616

Riparian planting of alder block (c. 30m x 100m) near intersection of Kingsley Wood Way with Allt Dubhach burn within wider conifer plantation



9 Appendix 3: Future investigations

Potential locations for future investigations of *Phytophthora alni* / crown dieback and for conducting detailed studies of historic alder decline or additional sampling surveys based upon the reviews of historic data and site surveys carried out during the course of the current project.

Background

Information on the condition of alder and the distribution of the agents which are likely to affect its condition in Scotland remain fragmentary. Existing datasets from which to select a shortlist of areas where further investigations of the health of the species appear to be warranted are neither complete nor in all cases up-to-date. Therefore, rather than identifying specific sites at which past cases of disease have been recorded or surveys of tree condition have been carried out, the following recommendations relate to particular catchments where it is likely that sites which would be suitable for particular types of study can be identified.

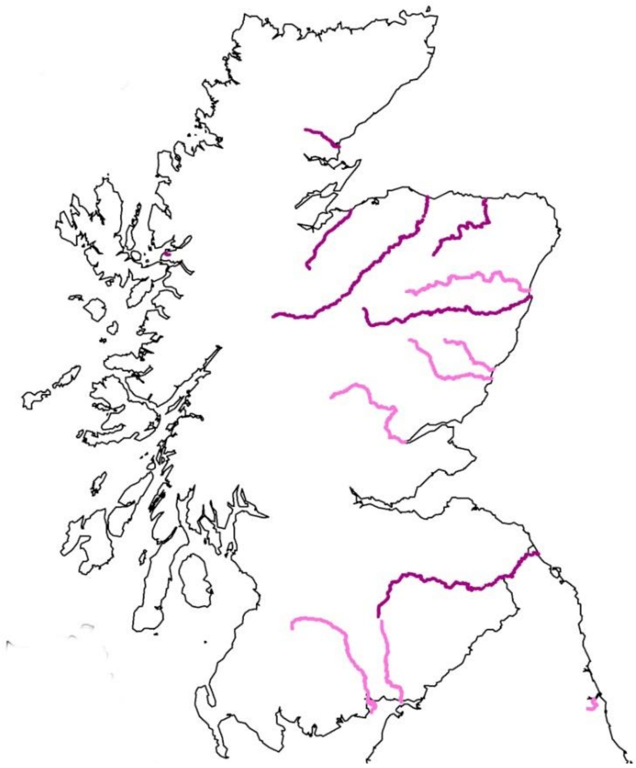
Catchments of interest

Alder Phytophthora

Since 1998, confirmed cases of *P. alni* infection have been recorded from the following catchment areas: upper Tweed, middle and lower Dee, middle and lower Deveron, middle Spey and tributaries, river Duirinis, lower Fleet, middle Nairn.

As noted in Webber et al. (2004), these are almost exclusively east coast river systems. Other east coast catchments where the presence / absence of *P. alni* is unknown but which would be worthy of investigation include the middle and upper Tay, North & South Esks, middle & lower Don. West coast rivers where *P. alni* might reasonably be sought include the Annan and Nith.

***Figure 1**. Catchments from which Phytophthora alni has been confirmed (dark purple) and catchments particularly worthy of investigation for presence of the pathogen (light purple).*



Crown dieback sensu Gregory et al. (1996)

Cases of crown dieback in isolated trees or scattered small groups have been noted in many locations in the north / northwest of Scotland but cases affecting large groups of trees or several smaller groups have been noted particularly from the following catchment areas:

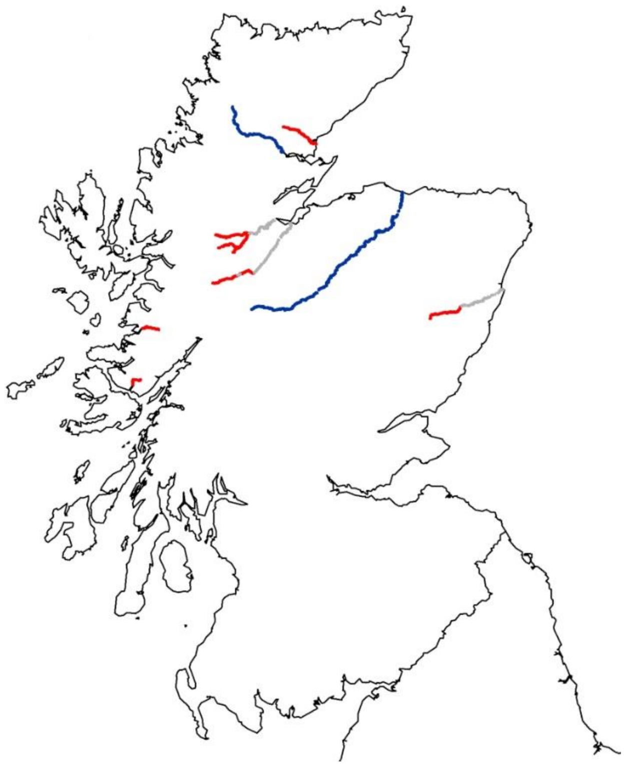
Rivers Fleet, Cannich, Glass, Moriston, Ailort, Water of Feugh and Abhainn a Ghlinne Ghil.

Partial dieback of larger trees (abiotic cause or cause not confirmed)

Populations of older trees with partial crown dieback have been observed in the following catchment areas:

lower Fleet, middle Spey, lower Oykel / Kyle of Sutherland

***Figure 2**. Catchments in which large groups of alders suffering from crown dieback have been observed (red) and catchments where partial dieback of larger trees has been noted (blue).*



Herbivore impacts on regeneration

A review of the Native Woodland Survey of Scotland (2006-2013) dataset, where recent herbivore impacts on the tree population as well as the proportion of visible and established tree regeneration were recorded, would be worthy of consideration. Although the definition of woodland employed in the NWSS precluded the inclusion of narrow riparian strips, wet woodland constituted 14% of the native woodland area surveyed. Follow-up surveys to determine the longer-term fate of the recent and established regeneration recorded during the NWSS might also be considered.

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