A critical review of work undertaken to control invasive rhododendron in Scotland

A report commissioned by Forestry Commission Scotland and Scottish Natural Heritage

John Parrott and Neil MacKenzie

August 2013

CONTENTS

This report should be cited as:

> Parrott, J. and Mackenzie, N. 2013. *A critical review of work undertaken to control invasive rhododendron in Scotland*: a report commissioned by Forestry Commission Scotland and Scottish Natural Heritage. Coille Alba.

1 Introduction

Forestry Commission Scotland (FCS) and Scottish Natural Heritage (SNH) commissioned this report as a critical review of the experiences and outcomes of past and current rhododendron control programmes. The aim of this review is to help inform the development of a national strategy to promote a co-ordinated and cost-effective approach to managing invasive rhododendron in Scotland.

Rhododendron ponticum is the most damaging and most widespread non-native terrestrial plant in Britain. Left untreated, control costs are estimated to double every 20 years. Although control projects have been undertaken throughout Britain and Ireland, the cost of these has been very high and rhododendron continues to be a widespread problem which compromises biodiversity, forestry and other land management objectives.

Many rhododendron populations are still actively spreading, and it appears likely that a changing climate will favour further expansion. The threat of *Phytophthora*, to which rhododendron plays host, has made the need to control rhododendron at the national level all the more urgent.

2 Study methods and acknowledgements

The information for this review was obtained from a wide range of sources. It included the printed publications and internet. An internet search was made of relevant publications on rhododendron biology, origins, invasion history, impacts and control methods. Unpublished material was also consulted as well as information contained on the websites of relevant statutory agencies and NGOs (FC, SNH, Scottish Government, NNSS, SEPA, DEFRA, Snowdonia and Killarney National Parks).

We also corresponded by e-mail and talked with a number of FCS, SNH and NGO staff, private sector foresters, agents, land-managers, contractors, land-owners and grant recipients who have first-hand experience of aspects of rhododendron control (research, policy, funding, grant application, planning, commissioning and implementing field operations).

We would like to acknowledge the information and help provided by: Simon Amor, Sion Brackenbury, Ben Averis, Phil Baarda, Bob Black, Chris Bradley, Hugh Clayden, Tim Clifford, Ian Collier, Steve Connoly, Ken Cox, Ben Davies, Rob Dewar, Phil di Duca, Giles Drake-Brockman, Alasdair Eckersall, Colin Edwards, Anne Elliott, Bill Fisher, Gordon French, Julia Garritt, Dave Genney, Jeanette Hall, Syd House, Duncan Ireland, Elaine Jamieson, Donald Kennedy, Kenneth Knott, Zoe Laird, Colin Leslie, Donald Macleod, Babs MacRitchie, Stephen Mason, Ian McKee, Simon McKelvey, James Merryweather, Gilbert Milne, Rhys Owen, Julie Paton, Gordon Patterson, Angus Robertson, Jason Rumens, Manda Sansom, Lorraine Servant, Richard Thompson, Stan Whitaker, Malcolm Wield, Douglas Wright and Lenka Zaoralova.

3 Origins of rhododendron

Rhododendron ponticum is an evergreen shrub that is native to parts of the Iberian peninsula, eastern Europe and west Asia. It was first introduced to England in 1763 (Elton, 1958). Spain and Portugal are thought to be the source of most of the *Rhododendron ponticum* established in the UK (Milne & Abbott, 2000). Initially, plants were kept indoors as it was found not to be a particularly hardy plant. The species was subsequently crossed with frost-hardy *R. catawbiense* and *R. maximum* from the Appalachian mountains in the eastern USA and with the less hardy *R. macrophyllum* from western North America (Cullen, 2011; Dehnen-Schmutz and Williamson, 2006). A combination of hybrid vigour, natural and artificial selection and further cross-breeding helped the plants to adapt to colder temperatures. Together with its fecundity and its tolerance of shade, this has enabled it to thrive in our climate and out-compete native flora.

The rhododendron naturalised in Britain is commonly known as *R. ponticum*. It is a stable hybrid which acts as a distinct species and is only found in Britain and Ireland. Given its complex lineage, it has recently been proposed that it should be known as: *R. x superponticum* (Cullen, 2011).

A similar hybrid, possibly closely related to *R. x superponticum*, is also found as a naturalised invasive in Belgium, France and the Netherlands (Alien plants of Belgium; Esen *et al.*, 2006). The true *R. ponticum* from the Iberian Peninsula is neither vigorous nor invasive in its natural habitat (Cullen, 2011).

Rhododendron became popular in the policy woods around estate houses during the Victorian period. It was widely planted as a garden ornamental, as a shelterbelt and as cover for game. Rhododendron was often planted on old woodland sites for ornamental purposes, for example in the pinewoods at Achnacarry on Loch Arkaig (Smout *et al.*, 2005). It also became a popular root-stock for the many hybrid varieties of rhododendron. Cultivars which were grafted onto *ponticum* rootstock must be regularly pruned to prevent them reverting.

The first record for Scotland is unknown but is likely to have been sometime in the early 19th century as there is a record of a *ponticum* hybrid at the Royal Botanic Gardens in Edinburgh in 1814 (Brown, 2004). There were few recorded escapes from gardens in the 19th century (Welch *et al.*, 2001). The first record of a plant found in the wild was in 1894 in Lincolnshire (GBNNSS, 2011).

The decline in the management of policy woods and ornamental gardens, together with the expansion of plantation forestry and the overgrazing of semi-natural woods and moorland created suitable conditions for rhododendron expansion. Disturbance of the soil layer and displacement of the natural vegetation by grazers increases bryophyte establishment – the

perfect substrate of moisture, light and protection for rhododendron germination (Esen *et al.* 2006; Tabbush & Williamson, 1987).

In Wales and Ireland, however, high intensity grazing was found to suppress the establishment of dense rhododendron (Jackson, 2008; Cross, 1981).

The significant expansion of rhododendron into the wild during the 20th century can probably be attributed to a combination of several factors including lack of natural enemies, hybrid vigour, disturbance, climate, soils and changes in woodland management.

The naturalization and spread of this invasive shrub into semi-natural habitats has been particularly rapid and extensive in the west Highlands over the past 50 years. Welch *et al.* (2001) document an increase in the presence of *Rhododendron ponticum* in Scotland from 39 hectads in the 1950s to 55 hectads in 1988.

Today *Rhododendron ponticum* is the most damaging and most widespread alien plant in semi-natural terrestrial habitats in UK, with high control and restoration costs (Williamson, 2002). It is naturalised all over Britain and Ireland and to a lesser extent in France, Belgium, Netherlands and North West Germany (Esen *et al*., 2006; DAISIE, 2006).

The species was also introduced into New Zealand as a hardy garden plant. It has since become naturalized in the wild and has the potential to become a major problem. Consequently, the government listed *Rhododendron ponticum* in the 2008 National Pest Plant Accord and it is now banned from sale, propagation and distribution in New Zealand (New Zealand Government, 2012).

4 Impacts

Rhododendron has a severe impact on the biodiversity of native woodlands and open ground habitats. Once plants have become established, native tree seedlings, understorey plants and moorland and grassland vegetation are suppressed and further regeneration will fail to become established under the rhododendron canopy. Only holly, yew and ivy are able to survive under a dense canopy of rhododendron (Cross, 1981). However they cannot out-compete rhododendron which has extensive advantages, such as the ability to increase leaf area under shady conditions (Esen *et al.*, 2006; Niinemets *et al.*, 2003). There is also some evidence that phenolic compounds from decomposing rhododendron leaves can inhibit the growth of common grasses such as *Festuca ovina* (Rotherham & Read, 1988).

Rhododendron is particularly damaging to the rich oceanic bryophyte and lichen floras of the Atlantic oakwoods on Britain's western seaboard. Traditional methods of rhododendron control may also hinder the recovery of many lower plants (Long & Williams, 2007).

An ecological impact study by Dehnen-Schmutz *et al.* (2004) of 248 rhododendron sites (31,905 ha) reported that the main consequences of

rhododendron invasion were displacement of native species (45%), habitat change (45%) and hydrological damage (10%). Other impacts included visual effects, shading of watercourses, impeding access, concealing "muggers", damage to fencing, loss of grazing and poisoning of livestock.

Rhododendron is toxic to most herbivores, although small seedlings are grazed by sheep and deer (Jackson, 2008). Invasion of grazing land by rhododendron has repercussions for the farming industry as affected land is unproductive and therefore ineligible for agricultural subsidies (Jackson, 2008).

Along watercourses, overhanging bushes cast dense shade and damage the ecology of aquatic ecosystems by suppressing algal growth, providing poor quality litter, decomposing slowly and altering invertebrate abundance and assemblage structure (Stockan & Fielding, 2013).

Dense rhododendron stands can restrict access for recreation, angling and land management, with significant economic repercussions. Rhododendron can impact commercial forestry by preventing regeneration under continuous cover systems and impede surveying, harvesting and restocking operations. On moorland, rhododendron reduces the habitat available to commercial game management as well as restricting access to open ground.

Rhododendron plays host to the pathogenic fungus-like Oomycetes *Phytophthora ramorum* and *P. kernoviae*, which can have a serious impact on many tree species (see Section 9).

5 Biology

Rhododendron ponticum is extremely fecund. It begins flowering at around 10 years old, and a mature bush can produce up to 1 million seeds annually (Edwards, 2006). The re-growth from a felled stump can flower again after 2 years. Reasonably good light levels are required for flower production, and inflorescences are generally most plentiful in the open or on woodland edges.

Bees, hoverflies and butterflies pollinate the flowers, although bumblebees have been found to be the most successful pollinators (Stout, 2007). Seed dispersal is usually by wind and is generally not more than 100 m from the seed source, and usually considerably less in woodland with 500 m the likely limit by wind dispersed means (Edwards, 2006; Harris *et al*., 2011). The greatest dispersal distances came from plants over four metres in height and 50 years of age (Harris *et al*., 2009). Longer dispersal distances can occur but the dispersal vector is more likely to be via animal hair, vehicle tyres or other mechanical agent (Edwards, 2006).

Germination requires moist conditions such as those created by a thin layer of moss or litter. Seedling survival is considerably reduced if the moss layer is deep (Ninaber, 2009), except for certain sphagnum species that possess high water retention capacities (Cross, 1981). Logs, wind-blown

trees and stumps with a layer of moss are a favoured substrate (Stephenson *et al.* 2006). A felled woodland site is therefore highly susceptible to rhododendron colonisation. Seeds do not persist for long in the soil and are only viable up to about 160 days after release (Cross, 1981).

Unless there are drought conditions that prevent the roots from reaching deeper soil, growth is slow for the first few years. Growth rate increases with age (see graphics in Section 13).

Bushes can reach heights of up to 8 metres in height in sheltered locations, where they may use neighbouring trees for support. In exposed, open sites they are generally lower with round crowns. Once established, rhododendron can live to over 100 years. It does not produce suckers but bushes can spread laterally by layering.

Rhododendron has a competitive and toxic nature, rapid growth and ability to spread very effectively by layering. Despite an inefficient wind dispersal mechanism, the high seed output ensures successful spread and colonisation onto new ground. It is tolerant of deep shade and can thrive in woodland, out-competing nearly all native trees and shrubs. Once established, it casts a dense shade that eliminates all ground flora. It will also colonise open ground habitats and will spread onto moorland, rocky screes, cliffs and several types of bog and mire. It thrives in the riparian zone, and seed can be transported by water.

It is particularly prolific in the milder and wetter climate along the Atlantic seaboard where it thrives on acid and peaty soils. Although it also occurs throughout the eastern Highlands, it is usually less vigorous there. However, the possibility of warmer and wetter winters in the east as a result of climate change may alter this pattern, while increasing nitrogen deposition may also accelerate the invasive potential of rhododendron (Niinemets *et al*., 2003).

Rhododendron foliage is generally unpalatable to vertebrate herbivores, and few insects feed on the plant as the leaves and other tissues contain toxic chemicals, particularly ‘free’ phenols and diterpenes (GBNNSS, 2011).

6 Rhododendron in horticulture

Rhododendron ponticum has been widely planted in gardens and policy woodlands since Victorian times. It has also been widely used as rootstock for grafting.

Despite its well-known invasive nature, *Rhododendron ponticum* plants are still sold in a small number of horticultural nurseries, garden centres, non-specialist retail outlets and on Ebay. Plants can cost as little as £2.50. There is no mention of their invasive nature in most cases, although a few horticultural websites state that the plant “may become invasive”. Most of the larger nurseries and garden centres no longer sell *R. ponticum* but sell hybrids instead. These are thought to be less invasive. However, most

plants are given a vernacular or cultivar name with no details of the hybrid or rootstock if used.

In Scotland the larger specialist rhododendron nurseries have switched from using *R. ponticum* as rootstock to the hybrid *R. caucasicum* x white flowered *ponticum* known as "Cunningham's White". This hybrid is not considered to be invasive and does not revert to ponticum (K. Cox, *pers. comm.*).

A DEFRA consultation in 2009 included *Rhododendron ponticum* on a list of 15 alien species that were being considered for a ban on sale. The Horticultural Trade Association expressed concern that a ban would be difficult to implement and growers and retailers would be disproportionately affected. The Royal Horticultural Society accepts that invasive rhododendron is a big problem in the wild but objects to a ban listing hybrids of *Rhododendron ponticum*.

In New Zealand where it has also become naturalized in the wild, the government has banned it from sale, propagation and distribution.

The continued sale and planting of *Rhododendron ponticum* in UK clearly increases the risk of further spread to new locations.

As long as *Rhododendron ponticum* is still on the market, it will be difficult to build a sound case for eradicating it in the wild.

Recommendation:

- **initiate a positive dialogue with the horticultural community, with a view to withdrawing *Rhododendron ponticum* from sale.**
- **review knowledge of invasive and non-invasive qualities of *ponticum* hybrids.**

7 Historical perspective

The negative environmental and economic impacts of rhododendron have been recognised since at least the 1930s, when the earliest attempts were made to control rhododendron in the UK.

Efforts to remove rhododendron from Stapleford Wood in Lincolnshire, for example, started in 1930 (Dehnen-Schmutz & Williamson, 2006). Remarkably, they continue to this day. Accounts of other similarly long-lived, ongoing control programmes are not at all exceptional.

Despite considerable effort and resources, from the first efforts in the 1930s to the present day, eradication appears only to have been achieved for quite small populations, often under a single ownership. No control programme appears to have successfully achieved 100% eradication at a landscape scale.

These findings provide a salutary reminder that eradication can only be achieved if control operations are carried out diligently, coordinated at a population scale and maintained over a period of many years.

A fuller account of past control efforts appears in Appendix 1. Accounts of 4 more recent (and ongoing) control efforts are described as case studies in Appendix 2.

7.1 Policy and legislation

Over many years, a number of national (and European) policies have informed, supported and driven the ongoing development of a strategy to control invasive rhododendron in Scotland. In the last decade especially, attention has been increasingly focussed on invasive non-native species (INNS).

The policies which have helped shape priorities for action in Scotland and UK are described in Appendix 3.

The first piece of UK legislation to make mention of INNS was the Wildlife & Countryside Act (1981). Section 14 of the Act controlled the introduction of certain, named non-native species into the wild, these being listed in Schedule 9. The list was quite short and comprised both plants (mainly invasive aquatic and riparian species) and animals. It did not include rhododendron.

Over the years there have been several recommendations that rhododendron should be added to the list, most recently in a consultation by DEFRA (Gritten, 1987; DEFRA, 2007; Jackson, 2008), and it was finally added to Schedule 9 in 2010 as part of an extended listed within the the Wildlife and Countryside Act 1981 (Variation of Schedule 9) (England and Wales) Order 2010.

Schedule 9 was also updated in Scotland in 2005 (The Wildlife and Countryside Act 1981 (Variation of Schedule) (Scotland) Order 2005), but rhododendron was excluded from the list despite the addition of other less problematic invasives such as *Gaultheria shallon*.

However, the recent Wildlife & Natural Environment (Scotland) Act (2011) significantly amended the Wildlife and Countryside Act in Scotland. This simplified the issue of INNS in the wild and avoided the need for a list by making it an **offence to plant or cause <u>any</u> non-native plant species to grow in the wild** (or to release <u>any</u> non-native animal from captivity).

The amendments to the 1981 Act thus provide crucial legislative support for the control of INNS, including *Rhododendron ponticum*, at a landscape scale. The associated Code of Practice helps landholders to understand their legal responsibilities and underlines the importance of acting responsibly and exercising due diligence in relation to invasive non-native species. This would include, for example, failing to prevent rhododendron spreading from a garden into the wild.

The amendments to the 1981 Act also introduced powers to require landowners to take action on non-native species. The lead agency must first offer the land manager a voluntary Species Control Agreement. Only if the land manager refuses to enter or fails to comply with an agreement can

the relevant agency proceed to make an enforceable Species Control Order. For example, these powers might be invoked if a landowner refuses to allow access to carry out a strategic eradication programme.

Supplementary guidance has also been drafted to help woodland managers abide by the Code and mitigate risks of spread of non-native species into semi-natural areas outside managed woodlands.

With the changes to the 1981 Act, Scotland has taken the lead in Europe with ground-breaking legislation in relation to the control of non-native species in the wild.

Plant health legislation also has a bearing on rhododendron control through powers to serve Statutory Plant Health Notices. See Section 9.

7.2 Funding

Forestry Commission Scotland has funded rhododendron control on NFE from their management budgets and through collaboration with other owners in projects funded by Objective 1 and LIFE, for example in Lochaber and in Argyll. Most NFE project work has been for initial control and follow-up treatments will still be required. In 2011, FCS made a commitment to eradicate rhododendron from the National Forest Estate within 15 years (FCS Press Release, 2011). The cost of this has been estimated at around £15 million. Control operations have now begun in all Forest Districts.

On private land, various financial incentives have been made available over the years to help private landowners to undertake rhododendron control. Some of these grants are deemed by users to have been better targeted, more cost-effective and more applicant-friendly than others.

These packages are outlined in Appendix 4, while the grant rates are given in Section 12. The most recent of these, Scottish Rural Development Programme (SRDP), is administered by FCS and SGRPID. It has been criticised for its complexity and competitive nature (see Section 17). In many cases, the existence of SRDP has prevented other potential funders from grant-aiding rhododendron control. SRDP is currently under review.

SNH have funded a number of surveys of rhododendron within SACs and SSSIs under the Species Action Framework (SAF). £33,125 was spent on surveys of 4,413 ha of rhododendron-infested land between 2011 and 2013 (Highland Rhododendron Project, 2013). SAF also funded a number of rhododendron control projects in designated sites, for example in Jura, the Loch Etive area and Mull.

8 Data on distribution and status

There is an abundance of survey data on *R. ponticum*. However, these have been collected over a period of many years in several different formats; many pre-date GIS. An attempt to collate data from diverse, often incompatible sources for the Highland Council area encountered a number of challenges (Parrott *et al.*, 2010).

Detailed surveys have been recently undertaken for Argyll and Bute (Edwards & Taylor, 2008a) and the Loch Lomond and Trossachs National Park (Chapman, 2007); rhododendron stands are mapped on GIS.

Survey data collected since 2010 indicate a total area of 35,709 gross hectares affected by rhododendron on the NFE. To date, control work has been undertaken on over 12,568 ha or 35% of this land.

The Native Woodland Survey of Scotland (NWSS) will provide an important national dataset from field surveys conducted between 2006 and 2012; the complete GIS dataset is expected to be made available in late 2013 (Grieve, 2011).

The survey covered private woodlands and NFE and included all woodland with a 40% or more native tree component as well as all PAWS sites. For each woodland polygon, invasive plants were recorded as a percentage of the mapped area. For rhododendron, an assessment was also made of stocking density and age class.

NWSS did not include gardens, non-native plantations, roadsides, open ground or native woodlands less than 0.5 ha or less than 20 metres wide. However, it is likely that in most cases rhododendron will have been picked up by the NWSS in adjacent woodland polygons.

The NWSS dataset should provide an accurate, up-to-date and reasonably comprehensive indication of rhododendron distribution within native woodland in Scotland. This would allow the mapping of discrete populations which will inform the development of a Scotland-wide rhododendron control strategy. Further surveys will be required to fill gaps in survey knowledge, particularly for open ground non-woodland sites, garden ground and narrow, linear strips along roadsides, railway lines and riverbanks.

Backed up by ground-sampling, the NWSS dataset might be used to make a reasonably accurate assessment of the overall cost of eradicating rhododendron in Scotland.

8.1 Gathering and sharing data

There would be many benefits to collating the available distribution data on rhododendron and presenting these to a wider audience, perhaps on a website. Web-mapping is being increasingly used to encourage the public to report invasive species.

Such citizen science initiatives are likely to assist stakeholder engagement in landscape-scale control programmes, and may encourage volunteers to participate in local projects. Volunteer help could be provided at all stages, but would be particularly valuable once most control operations have been completed. Volunteers could play a very useful role at this stage by monitoring and uprooting seedlings.

With distribution data on a web-map, these could be overlaid with information on proposed and ongoing control programmes to demonstrate progress.

Sharing the information we hold may promote a better understanding of 'the rhododendron problem'. Demonstrating the initiatives being taken to address it might help secure a greater buy-in from the public and prospective partners.

Recommendation:

- **collate and share data on rhododendron to promote wider engagement with stake-holders.**

9 Phytophthora

Rhododendron ponticum plays host to two key species of *Phytophthora* in Scotland: *P. ramorum* and *P. kernoviae*. Information in this section is correct at July 2013. For the current situation see http://www.forestry.gov.uk/forestry/INFD-8XLE56 (*P. ramorum*) or http://www.forestry.gov.uk/forestry/INFD-66JLGB (*P. kernoviae*).

These fungus-like pathogens also affect several other shrub and tree species. Japanese larch is the main commercial tree in the UK currently affected by *P. ramorum*, but adjacent infection, albeit in a non-sporulating form) of other species such as Douglas fir, Noble fir and Western hemlock can occur (Mabbett, 2011; Webber *et al*., 2010). *Phytophthora* also affects oak (although the US name 'Sudden Oak Death' is a misnomer in UK as our native oak trees have only very rarely been infected), beech, ash, birch and all larch species, especially in high rainfall areas.

Both of these *Phytophthora* species have also been found on *Vaccinium*, and on a range of garden shrubs such as *Viburnum*, Magnolia, *Camellia* and *Pieris*. At least 150 plant species are known to harbour *Phytophthora ramorum* (FC press release 2012).

Phytophthora has been identified at over 160 locations in Scotland mainly concentrated in the south west and in Argyll but with a recent discovery at Glen Dye in Aberdeenshire (FCS, 2013). A major outbreak of *P. ramorum* on larch occurred in west Galloway in 2012. This, together with some outbreaks in Northern Ireland, involved a new lineage of *ramorum* known as "EU 2"; all other outbreaks in the UK have been of the EU 1 lineage. Throughout Scotland, *P. ramorum* has been confirmed on larch at 137 sites, extending over a total area of some 420 ha (FCS, 2013).

Changes in the climate, particularly a rise in mean annual temperatures may promote an increase in the activity and range of *Phytophthora*, although this will be dependent on the availability of suitable hosts (Brazier, 1999). Recent climate modelling studies on *P. ramorum* in the United States suggest that there may be shifts in distribution rather than expansion in range as a result of predicted increases in heat stress (Venette, 2009). The same study suggested that climate change may also

act indirectly on the disease by causing tree stress and altering the susceptibility of trees to infection.

It is considered that damage from *Phytophthora* may have a severe economic impact on forestry and horticulture. Due to the statutory control measures in place within all infected EU countries plus Norway and Switzerland, direct economic impact is not quantifiable. However, the impact on nursery production and managed gardens when phytosanitary controls are taken into account is considered to be major (Sansford *et al*., 2008). There is a risk of serious damage to natural heritage interests and to timber production, as evidenced recently in south-west Scotland. This could become a major impact if *P. ramorum* adapts to new hosts or environments or becomes more widespread (Sansford *et al.*, 2008).

The widespread distribution of rhododendron across a range of woodland and heathland habitats, which are also favoured by *Phytophthora ramorum* presents a high risk that infection will spread. Rhododendron is now seen as a major threat to forestry and biodiversity interests throughout Scotland, not only because of its invasive nature but also because it acts as a reservoir host for these damaging pathogens (Purse *et al.*, 2012).

Distribution and spread

P. ramorum has been known in Europe since the 1990s. By 2003 it had been recorded in 11 countries, including UK (Webber, 2008), which it probably reached via the intra-EU plant trade (Mabbett, 2011). Initially identified in nurseries, it was found in woodland in southern England in 2003, but in Scotland it had not spread into the wider environment until about 2007 (Green & Webber, 2012) and has now been found at over 160 semi-natural locations.

P. kernoviae was first discovered on rhododendron plants and a beech tree in south-west England in 2003; in 2008 it was recorded in garden sites in Scotland (FC, 2013). Both species have overlapping ranges and can infect the same plant at the same time.

Phytophthora spores are spread via watercourses, moist winds and rain splash. They can also be transported by animals, people and vehicles. Infected plants (and spores) can be moved great distances through the horticultural trade (Webber, 2008). Trees affected by *Phytophthora* exhibit various symptoms including stem canker and foliar wilt. Asexual spores are produced from foliar infections. Any nearby trees with susceptible bark have a high risk of infection from *Phytophthora* (Sansford *et al.*, 2008).

Phytophthora chlamydospores can survive for at least 3 years. It is not yet known if these pathogens can survive in the soil following removal of the host plant, but rhododendron roots have been recently found to support asymptomatic infection of both *Phytophthora* species (Fichtner *et al.*, 2011 in Purse *et al.*, 2012).

In many ways, *Rhododendron ponticum* is an ideal host (Mabbett, 2011).

It is widespread and frequent in woodland understorey and, as an evergreen, it is able to produce spores over much of the year. However, larch when in leaf is also able to generate much higher levels of *P. ramorum* spores, particularly prior to needle senescence, high up in the canopy which are able to spread over a wide area (Webber *et al.*, 2010). *Vaccinium myrtillus* may become a significant sporulating host in heathland habitats (Purse *et al.*, 2012). The fact that rhododendron is often associated with both habitats may exacerbate *Phytophthora* transmission.

Control measures

There are no known chemical treatments that can kill *Phytophthora* in infected plants. Containment rather than eradication of the pathogen is now probably the only feasible course of action. DEFRA and the Forestry Commission consider that eradication and control of rhododendron is currently one of the most effective control measures to reduce the spread of the disease into new areas (Edwards, 2006; DEFRA, 2008; FCS website).

Forestry Commission Scotland's recent action plan for *P. ramorum* on larch recommends prophylactic removal of rhododendron in high risk areas (FCS, 2013). Following initial treatment, cleared sites must be monitored for at least five years as shoot re-growth and new seedlings can become re-infected with the *Phytophthora* pathogen (Edwards, 2006). Young shoots growing close to the ground appear to be particularly susceptible to infection.

Legislation

P. ramorum and *P. kernoviae* are notifiable plant pathogens subject to statutory control measures. It is a legal requirement to report any suspected infection to the relevant plant health authority.

Depending on the situation, responsibility for plant health falls to two bodies exercising statutory powers through either the Plant Health (Forestry) Order 2005 for both *P. ramorum* and *P. kernoviae* or the Plant Health (*Phytophthora ramorum*) (Scotland) Order 2004 for *P. ramorum*, and the Plant Health (Scotland) Order 2005 for *P. kernoviae*.

FCS assumes general tree health responsibility for forest trees. Its inspectors have significant powers to access private woodlands and the wider environment with or without permission, in order to check for pests and diseases. They do not have powers to enter private gardens without permission unless a court order to that effect has been issued. If a disease is found to be present the inspector will serve a Statutory Plant Health Notice (SPHN). The Notice prescribes the actions required; usually the felling and disposal of infected trees or shrubs, as well as biosecurity precautions to prevent further spread of the disease (FC, 2010).

In parks, gardens and the wider countryside the Scottish Government's Horticulture and Marketing Unit inspectors have the same powers under the Plant Health Orders to deal with suspected outbreaks of the disease but

also have the power to enter private gardens without permission.

Treatment procedures

Following a SPHN, best practice usually follows four stages for dealing with infected rhododendron (DEFRA, 2008):

- Cut all rhododendron stems and dispose of material by burning on site or transporting waste under secure covers to a separate disposal area.
- Apply herbicide to cut stump.
- Follow-up application of foliar herbicide on re-growth and seedlings.
- Monitor site for subsequent shoot re-growth or new seedlings for at least 5 years.

In addition, the SPHN requires contractors to undertake standard biosecurity measures such as cleaning (removal of soil and plant debris) and disinfecting all tools, machinery and boots before leaving the site. Wet weather working and muddy conditions should be avoided if possible as spores are more likely to be present and transported in wet soil.

Guidance is available for a site cleared under a SPHN if the site is to be replanted with trees or shrubs (Forestry Commission England, 2011; Webber, 2010).

Financial support

Infected rhododendron (and a 20m buffer if in woodland situations) which is served with a SPHN is not eligible for SRDP grant aid. However, SRDP funding is available for the clearance of adjacent uninfected rhododendron within woodland SPHN areas. Uninfected rhododendron growing as an understorey of larch served with a SPHN will also be eligible for funding.

In contrast to rhododendron, infected larch may be eligible for grant aid (through State Aid *de minimis* payments and hence subject to limitations) if the crop is immature or otherwise uneconomic to fell, or cannot be felled by the SPHN deadline. If the timber cannot be harvested and marketed, the support available is £1200 per net hectare; in most instances, this grant covers the cost of complying with the SPHN.

Monitoring changes in distribution

Inspections are regularly carried out on commercial premises handling susceptible plant material, parks, gardens and woodlands in order to monitor and assess the spread of *Phytophthora*. FCS currently conduct aerial surveys in early and late summer to search for new infections and sometimes to monitor SPHN compliance. Suspect stands are plotted on GIS, and these sites are subsequently ground-truthed by trained surveyors.

Infection of trees often needs to be confirmed by felling selected trees to test foliage and stem lesions. Any rhododendron associated with the larch is also surveyed for signs of *Phytophthora* damage. Samples of suspect plants/trees are collected and tested in the field using lateral flow devices

which will detect if a *Phytophthora* is present. If *P. ramorum/ kernoviae* is suspected, a Statutory Plant Health Notice (SPHN) can be served although laboratory analysis of samples is also often sought as a further check (and can also provide material for lineage assessment).

For larch a buffer of at least 100m is included around symptomatic trees although in some circumstances this can extend to 250m. Larch within that buffer zone also needs to be felled as part of the SPHN. Felling of non-sporulating potential tree hosts is not required although owners may elect to fell them for practical or financial reasons.

Although *Phytophthora* has been recorded in a number of plantations (mainly larch) in SW and west Scotland (and now one site in NE Scotland at Glen Dye), outbreaks in woodland rhododendron have been recorded mainly in the Kintyre peninsula, west Argyll and Mull. A total of 8 sites have been served with a SPHN covering over 5 ha in total and including private and FE land (H. Clayden *pers. comm.*).

In addition, there have been 36 records at nurseries and retail outlets, and 41 outbreaks covering 70 premises in gardens and the wider environment, mainly on *Rhododendron ponticum*. These are spread across Scotland, but are found primarily in the west and south-west of the country. All infected sites have been served with a SPHN which requires the owner to remove the infected plants plus susceptible hosts within a 2m buffer at their own expense. Scottish Government (SG) inspectors will impose bio-security measures on each site and will continue to monitor susceptible plants for *Phytophthora*. At some sites, owners have struggled to cope with the costs associated with removal due to the scale and extent of rhododendron cover (Jason Rumens *pers. comm.*). SPHNs are followed up by SG inspectors to ensure that the work required has been completed in a satisfactory manner. SG inspectors also undertake wider monitoring surveillance over a 1.5 km radius from the infected site.

Raising awareness

For a landowner or land-manager, it is not easy to understand the impact that *Phytophthora* might have on your holding and its management. Comprehensive, up to date information on *Phytophthora* is spread across the FC, FERA and Scottish Government websites, making it quite difficult to access.

Clear, comprehensive and up to date guidance on *Phytophthora* should be made more readily accessible, and downloadable as a pdf.

As with other tree diseases, it is hard to predict just how quickly *Phytophthora* may spread in Scotland, and the likely consequences.

The appearance of a new disease affecting tree health does however add a new dimension to the campaign to eradicate rhododendron in Scotland. It may help persuade some land-owners to take action. On the other hand, if it is not handled sensitively, there is a risk that it could have a negative

impact.

The current support arrangements for sites served with SPHNs appear inconsistent, in that FC offers grant to cover the net cost of felling infected larch or controlling uninfected rhododendron, but cannot cover the cost of removing infected rhododendron. It is estimated that, to date, the total cost to the handful of owners so affected has been in the order of £50,000.

The current system of regulation is not universally popular with owners, and it is likely that this rather odd inequity may give rise to further problems in future. Given that now, more than ever, we are looking to win hearts and minds in the campaign against rhododendron, it is important that we do not alienate owners.

Recommendations:

- **review arrangements for dealing with rhododendron infected with *Phytophthora*.**

10 Control techniques

A number of methods have been used over the years to kill rhododendron. Some of these have used chemicals which are now banned, such as imazapyr and ammonium sulphamate. Where chemical treatments are used, the herbicide usually specified is a formulation of glyphosate approved for forestry use (such as Roundup Pro Biactive 450). Glyphosate is readily translocated vertically (*e.g.* from leaves to roots), but not transversely (see Section 11). Triclopyr, although no longer in production, but still an approved herbicide, is more effective than glyphosate on cut stumps, and as a foliar application during wet weather (Edwards, *pers. comm.*) although a review by Tyler & Pullin (2004) found it to be less effective when used as a foliar spray.

There has been a lot of recent research on the use of bio-control against other invasive non-native plants, but this is not considered to be an option for rhododendron, because of the impact it would have on horticulture.

Only currently approved techniques used to kill rhododendron are described below. A few of these are producing promising results but have yet to be thoroughly trialled in a full range of sites and seasons.

10.1 Cutting

This is the most widely used method, often called "cut and burn", although cut material does not have to be burned, and is occasionally disposed of by other means, such as stacking, windrowing, chainsaw reduction or chipping. The disposal of cut material is necessary to permit access for follow-up treatments.

When undertaken by contractors, stems are usually cut using a chainsaw or clearing saw. However, bow-saws and loppers can be used, making this a method also suited to volunteers.

Cut material is usually dragged and burned. Green rhododendron burns well once a fire is started, but starting fires is often difficult, especially in wet weather.

It is not possible to kill rhododendron by cutting alone; this must be followed by treatments with a herbicide.

Pros and cons. This method has two principal advantages:

- it is a simple, well-tried technique which uses familiar tools and skills;
- it can be used to treat almost all types of established bush.

This method also appeals to practitioners for reasons more related to the process than the intended outcome (*i.e.* effective control of rhododendron).

Cut-and-burn is an energetic team activity which makes an immediate visual impact and leaves sites clear of debris. This provides job satisfaction to practitioners, and re-assurance to owners/clients that the job has been done (albeit no plants have been killed, and that it is often not necessary to clear a site, and not always desirable). Without doubt, the fire is central to the popularity of this technique with both contractors and volunteers, especially in wet or midgey weather.

However, the disadvantages are many:

- cutting bushes creates lots of bulky material which requires disposal; this makes this method very labour intensive, and therefore costly, especially for stands of large, mature bushes;
- cutting and dragging when seed-heads are ripe (typically February – April) may increase seed dispersal, both on site and further afield, on operators' clothing (C. Edwards *pers. comm.*);
- cut-and-burn creates a seed-bed for re-colonisation from adjacent untreated stands;
- even with careful stump treatment, many stools re-grow and require spraying, which may hinder restoration of native vegetation;
- the abundance of re-growth from cut and layered stems provides an ideal host material for *Phytophthora*; young shoots growing close to the ground are particularly susceptible to infection (Edwards, 2006);
- it opens sites up to future grazing, which may hinder the restoration of natural vegetation (see Section 15.4);
- cut material is usual burned, with significant environmental impacts and risks (see Section 11.1: A burning issue).

10.2 Stump treatment

Cut stumps are generally treated with herbicide (usually glyphosate), usually applied to the freshly-cut stump surface with a sprayer. The effectiveness of this treatment declines rapidly if this treatment is delayed more than a few minutes (Monsanto). Treatment is also less effective

during rain. Some operators drill holes and apply herbicide into the reservoirs so created. Other operators prefer not to treat cut stumps, but rely on spraying re-growth.

Stump treatment may not be effective in all months. June to September is the optimum period, but this control method has had mixed success in Snowdonia (Ninaber, 2009). In contrast stump treatment in Killarney National Park has achieved almost 100% success in all months (Higgins, 2008).

Trials have also been recently carried out by FCS on rhododendron with Ecoplugs. These plugs are placed into drilled holes and struck with a hammer to break the plastic seal and release glyphosate. Preliminary results indicate that Ecoplugs are effective but expensive.

Pros and cons. After cutting rhododendron, it is strongly recommended to treat stumps. Although not 100% effective, even when carried out correctly, it can significantly reduce the need to spray re-growth. Historically, stumps were often not treated immediately after cutting; this earned the treatment a reputation for being unreliable.

Ecoplugs have the advantage that the risk of herbicide leakage is very low. Given the cost of this treatment (both materials and labour), its use is likely to be confined to special situations (such as public access areas, or for roped access). Since Ecoplugs contain Glyphosate Max rather than Pro Biactive, they cannot be used within 20m of a watercourse. However, future production lines may include Pro Biactive.

10.3 Spraying

Small bushes and young re-growth, less than 1.3 metre in height, can be treated with a foliar application of glyphosate, usually from a knapsack sprayer. A maximum height of 1.3m is recommended for practical and safe working. A wetting agent or adjuvant such as Mixture B is used to aid uptake of herbicide. However, Mixture B is not approved for use near watercourses.

Pros and cons. Spraying is the usual treatment for re-growth from cut stumps. If undertaken with care, it is generally effective, but it is subject to a number of constraints:

- leaf area must be enough to take up herbicide, but below 1.3 metres in height; for re-growth, this may only offer a single season window for treatment;
- treatments are usually carried out when bushes are actively growing (from last spring frost to first autumn frost); however, it can also be effective in dry mild weather conditions in winter;
- spraying requires dry, still weather;
- all foliage must be sprayed to just before the point of run-off; any stems that are missed are likely to survive;

- extra care must be taken near watercourses; to conform with guidance on the use of adjuvants, operators would need to spray riparian buffer zones as a separate operation;
- there is always a risk of collateral damage to non-target vegetation;
- spraying will often result in exposed unvegetated soil conditions which offer the perfect seedbed for re-colonisation of rhododendron should seed bearing plants be nearby.

In practice, follow-up spraying is not always undertaken timeously, often due to a combination of above constraints.

10.4 Mechanical flailing

Where access and site conditions permit, rhododendron can be flailed using hydraulically-powered flail heads on tracked excavators or mulched using an excavator with an uprooting tool (Saunders, 2010a). As with cutting, these treatments must be followed up with herbicide applications on regrowth following mulching or on stumps after flailing.

In anticipation of a possible increase in the rate of spread of *Phytophthora*, DEFRA recently funded a study which trialled a range of mechanised methods in different site types around UK; results are not yet published.

Pros and cons. Mechanised control can be cost-effective on some sites. Flailing can hide stumps and make subsequent chemical treatments difficult while root fragments from mulching can root if on moist soil types (Edwards, *pers. comm.*). There is a risk of habitat damage when using large machines on sensitive sites. On bog and wet heath sites machine access should be restricted to existing vehicular tracks. Remote areas, steep slopes and rocky areas are generally unsuited to mechanised control. Due to the cost of transport, it is not cost-effective to use machines on small sites.

10.5 Uprooting

Rhododendron is a fairly shallow-rooted shrub. Small plants can be uprooted, especially if the roots are loosened before pulling. Care must be taken not to leave growing buds, and to remove layered stems.

A few years ago, this technique was developed to tackle larger bushes. Kennedy (2009) describes the experimental beginnings developed by Gordon French at Ardgour in 2002. A similar process had been employed by the Forestry Commission with some success in the early 1950s at Carradale and Benmore (Miller, 1954). The Lever and Mulch method uses a variety of manual techniques, including cutting with lightweight hand saws to break up bushes and physical levering of stems. The process aims to uproot all plants with their roots intact, but if this proves difficult, root-saws are used to sever roots. This material is laid over the site, acting as a mulch to hinder re-growth or seedling establishment. During follow-up treatments, any re-growth is killed by hammering growing shoots and

buds. Development of the lever-and-mulch is ongoing, with some practitioners trialling specialist tools. One such tool is the 'Extractigator' lever which is effective at removing medium sized stems up to 4m height (Saunders, 2010b).

Uprooting is much the best technique for killing seedlings. This is facilitated by loosening the soil using a masonry hammer or mattock.

Pros and cons. Lever-and-mulch requires no chemicals and only a small selection of inexpensive hand-tools. It is especially useful for smaller bushes, the locating and uprooting of which is very well-suited to volunteers.

Only those who developed the technique and a small number of other practitioners have used this method to tackle all stand types. The level of operator effort and skill required may limit the wider uptake of the lever-and-mulch method for larger plants. Use of the Extractigator requires minimal training but the tool is less effective on twisted stems and on stems that exceed the width of the gripping jaws (Saunders, 2010).

10.6 Stem treatment

Also known as "stem injection" or "drill-and-fill", this method is used to apply herbicide directly into the plant's woody tissues through a hatchet cut or drill-hole. With stem injection the procedure involves drilling into the cambial layer with a cordless drill and injecting 25% glyphosate into this reservoir (Edwards 2006). If a hatchet is used the herbicide is applied directly into a 2-3 cm cut (Ninaber, 2009).

As with other chemical methods, it is necessary to treat all stems to ensure herbicide is translocated throughout the plant. The "drill & fill" method is particularly well-suited to large mature bushes and the hatchet cut method works well with smaller stems. Treated bushes are left *in situ*, or can be cut once dead. When plantations are harvested mechanically, dead stems can be broken up or used as brash mats by the harvester.

This technique has been used in Scotland since 2004 but only on a small number of sites, mainly under NTS ownership (Inverewe, Torridon, Brodie). It is used more widely elsewhere; it accounts for 40-50% of all rhododendron control operations in Snowdonia (D. R. Owen *pers. comm.*). Anecdotal reports suggest that a high kill can be achieved throughout the year, but that it may be most effective in winter.

Pros and cons. Given that stem injection has been found to be a highly cost-effective technique, especially on large mature bushes which would otherwise take a lot of effort to cut and burn, it is unfortunate that it has not been more widely trialled.

There are several possible reasons for this. The most significant is probably the perceived risk associated with any unfamiliar treatment. Neither land-owners nor contractors may be willing to invest in new equipment and training when there is a tried and tested alternative in cut-and-burn.

There is also a long delay between treatment and any visible effect, i.e. signs of the rhododendron bushes dying. Owners may be reluctant to pay contractors who have made little noise, no smoke and left only rather subtle signs of their passing.

However, drill-and-fill has many advantages:

- it can be very effective, with reports of 99% kill from a single treatment;
- the investment in tools and training is lower than for any other method;
- for many mature stands, the cost of control (labour and materials) is lower than for any other method;
- it is the easiest technique to use during roped access, as the equipment is lightweight
- the operation is less likely to exacerbate seed dispersal, because the canopy is left intact;
- ground disturbance is minimal, so it does not create a seed-bed; in the early stages, a treated site is mulched by rhododendron leaves;
- little follow-up required, as most bushes are killed in a single treatment;
- minimal damage to non-target plant species;
- low risk to animals which might be sensitive to disturbance such as otters, badgers, amphibians;
- more gradual change in light and humidity may benefit habitat recovery.

Following leaf loss, it is necessary to check for surviving stems. These may have been missed, and are often layered stems.

The dead stems can be left standing *in situ*, or they can be cut and stacked. Alternatively, they may used to build dead-hedges to protect regeneration (see Section 15) or removed for firewood.

10.7 Combining techniques

It will be evident from the descriptions above that practitioners have a wide range of control methods at their disposal, and that some are better suited to certain sites and bush types than others.

It is important to note that techniques such as stem injection and lever-and-mulch require operators to observe bushes closely. This has the advantage that they are more likely to identify and treat layered stems, which are not infrequently overlooked by other methods. The discipline of careful observation is also vital when working in sensitive areas such as the riparian zone and exposed rock outcrops.

The 'tool-box' of control techniques is better-stocked than in the past. On many sites, practitioners who are willing to select treatments, almost on a bush-by-bush basis, may be able to deliver more cost-effective and less environmentally-damaging control.

Funding mechanisms need to recognise the benefit of this flexible, adaptive approach - at present it is necessary to produce a complete work plan as part of an application.

11 Minimising environmental impact

All of the techniques used to control rhododendron have the potential to damage the environment. Two of these are considered below, together with measures which might reduce their impacts.

11.1 A burning issue

When rhododendron is cut, the arising brash must be removed to allow access for the treatment of stumps and subsequent re-growth. Burning is the usual method of disposal during control operations, the bulky cut material being dragged, stacked and burned. If plants are infected with *Phytophthora*, cut material must be disposed of by burning as this minimises the risk of disease spread.

However, burning rhododendron presents a number of risks:

Health and property. Burning any vegetation presents potential risks to health and property, but special care is required when burning rhododendron. Stems and leaves contain phenolic compounds which are readily flammable even when freshly cut. Particular precautions must be taken under power-lines, near roads and houses and on peat (Esen *et al.*, 2006). Setting fires under powerlines is especially hazardous due to the risk of electrocution as carbon particles in smoke can act as a conductor. Burning is best avoided in windy conditions, and especially during dry weather.

Burning rhododendron is regulated under the Waste Management Licensing Regulation (1994) and SEPA are required to be informed in advance (Edwards, 2006). Application for a Paragraph 30 exemption for the burning of plant tissue waste can be made to SEPA provided that the total quantity burned does not exceed 10 tonnes in any 24 hour period (SEPA registration). In Ireland new waste disposal legislation has made the burning of rhododendron brash illegal, except for *Phytophthora* infected material (Higgins, 2008). This appears not to have hindered control programmes as alternative methods have been found to dispose of cut material.

Rhododendron also contains a neurotoxin. While this is not fatal to humans in normal doses, the effects of long-term exposure to rhododendron smoke inhalation are unknown (Wong *et al.*, 2002).

Wildlife and soils. Fire can disturb wildlife, permanently change soil and vegetation on burn sites, damage native vegetation and soil structure and cause localised enrichment which may encourage weed species (Pryor *et al.*, 2002). To avoid damage to peat and prevent soil enrichment at Roudsea Moss NNR, rhododendron brash was burnt on iron sheets and the

ash removed (Singleton & Rawlins 1999).

Rock outcrops are often used as burn locations because they provide some draw. Unfortunately these also provide some of the best woodland habitat for bryophytes (D. Genney *pers. comm.*).

Atmospheric pollution. Carbon dioxide emissions from the burning of rhododendron are estimated at 160 tonnes per hectare (S. Brackenbury *pers. comm.*). It takes a commercial tree crop about 30 years to sequester this amount of carbon.

What are the alternatives to burning?

Burning can be avoided in various ways:

Stem injection. If rhododendron is killed by stem injection, it can be left as standing dead wood. Some of this material can be cut and used as 'dead hedging' to protect regenerating vegetation from grazing.

Chipping or stacking of cut deadwood. Where access allows, cut material can be chipped and used for surfacing paths or as a mulch. Elsewhere, when the cut material is not too bulky, it can be stacked or windrowed. Higgins (2008) found no evidence of re-growth from mulched or stacked material but it is important that untreated cut stumps are not covered up with brash.

Harvesting fuelwood. Rhododendron has a very high calorific value (21.85 kJ g^{-1} - higher than beech and oak) and makes excellent firewood; one hectare of mature rhododendron yields 170 tonnes of dry phytomass (Wong *et al.*, 2002).

Producing charcoal and Biochar. Rhododendron makes high grade charcoal with high calorific value (Wong *et al.*, 2002). As well as fuel, it is used as a soil improver. It is manufactured in a mobile pyrolysis kiln which oxidizes harmful emissions before venting to the atmosphere (soil fertility project; Nature, 2009). Biochar production may also offer a suitable solution for the safe disposal of rhododendron infected with *Phytophthora* (Forestry Commission, 2013).

11.2 Glyphosate

Glyphosate is a broad-spectrum systemic herbicide. It can be absorbed through leaves, soft stalk tissue or injected directly into stem tissue. The herbicide is translocated through the plant tissues. It inhibits certain plant enzymes which assist amino acid metabolism, so killing the plant over a period of weeks or months. These enzymes are not present in mammals, birds or fish.

Glyphosate is applied to foliage or the cut surface of stumps or by stem injection. Effectiveness is reduced if plants are under stress due to hot weather, frost or water-logging. It is often mixed with an adjuvant or surfactant (such as Mixture B) which helps the herbicide penetrate waxy leaf cuticles. Many adjuvants are toxic, particularly to aquatic organisms

(Haller & Stocker, 2003). For use in forestry, Roundup Pro Biactive is usually recommended. The surfactant it contains carries no COSSH hazard rating and can be safely used near water.

In forestry, glyphosate has a good safety record for operators and the environment. It is reported that glyphosate becomes inactive in the soil as it binds with soil particles and is then subsequently degraded by microbial activity. However, there is evidence that it may have a deleterious impact on amphibians and soils. As with any pesticide, its use should be minimised and careful consideration should be given to the method of application.

Rhododendron requires higher doses of glyphosate than many other woody weeds because of its thick waxy leaves and its poor translocation. When applied to foliage, it is necessary to spray the whole bush to 'just before' the point of run-off (Edwards, 2006).

When stem injected, glyphosate is translocated throughout the vascular system of each treated stem. The herbicide is stored in the root system over winter and re-translocated in the spring, causing the death of new growth (Franz *et al*., 1997). At this point, most of the herbicide is concentrated in the leaves. When the leaves fall and decay, the microbial action also degrades the glyphosate. Although it may take several months for both leaves and herbicide to completely decay the glyphosate is contained within the leaf until it rots (M. Sansom, Monsanto UK *pers. comm.*).

Compared to other methods, stem injection of glyphosate is very targeted. The herbicide is 'locked' into the plant, so ensuring minimal damage to the environment.

12 Control costs

The cost of controlling rhododendron varies greatly according to bush density, size and type, site conditions and the methods used. These parameters can vary significantly even within a single stand. Even for experienced contractors, it can be difficult to accurately gauge control costs. Dense stands are not easy to survey and not infrequently conceal crags and other hazards which will incur additional, unanticipated costs.

Table 1 overleaf shows control costs using different methods; this has been compiled from a number of sources. Grant rates are also included in this table.

Unless specified otherwise, most of these figures refer to initial treatments, and do not generally take account of costs in the later stages of a control project. Even when plant density is very low, sites must be searched to locate stragglers. Although the cost of uprooting small plants is low, searching alone can be time-consuming, especially in difficult, broken terrain, and where vegetation such as bracken conceals plants.

Note that:

- all costs are given in £ per hectare;
- some costs may be partly based on grant rates rather than actual costs;
- where a range is given, this is usually based on bush density and/or difficulty of terrain;
- SRDP manual/mechanised cut includes herbicide treatment;
- for the Grants section, in some cases only a percentage of these rates was paid as grant;
- follow up work per ha every year or two for 5 years then every 5 years until clear – say twice more; minimum 10 years.

Machine cut			Manual cut/clear/ treat			Lever & Mulch	Uproot seedlings	Foliar spray	Stem inject	Follow-up (ha/yr)	Source
Light	**Medium**	**Dense**	**Light**	**Medium**	**Dense/diff.**						
COSTS											
1100	1100	1100		2391	2391			233			Robertson, 1999
			1800	2500	5500		15 - 400	18 - 500	13000 (roped)		Wong et al., 2002
755		3125	2005		7625		100 - 7000	85 - 375		85 - 375	Willoughby et al., 2004
			3500	5000	7000			1000	2500	50	Jackson, 2008
			500 - 1500	3000 - 9000	3500 - 12000	3500 - 4500				75 - 125	Kennedy, 2008
200 (flat)			420 (flat) 503 (slight) 719 (severe)	3402 (flat) 3718 (slight) 13032 (severe)	4009 (flat) 4386 (slight) 15019 (severe)						Edwards & Taylor, 2008b
			3710 (flat) 4081 (slight) 11995 (severe)	4360 (flat) 4760 (slight) 13644 (severe)	5121 (flat) 5523 (slight) 15306 (severe)			698 (flat) 829 (slight) 981 (severe)	789 (flat) 1198 (slight) 2661 (severe)		Edwards, 2009
						3071					Ireland, 2009
			2571							175	Thompson, 2013
			1553							175	Thompson, 2013
			5000						3000		D. R. Owen (pers. comm) (2013)
GRANTS											
550	1300	2100	2800	3100	4100			-	-	-	FCS – SFGS (rate 60% - 90%) (2003)
2400	2400	2400	3000	4000	5000 (severe) 6000 (severe with large bushes)			400	1500 (flat) 2000 (severe)	-	FC England E.WGS - regional grant 80% of costs (2011)
1,800	2,400	2,900	4,500	6,100	9,500			1500	1500	-	FCS SRDP (2012)

Table 1 Rhododendron control costs and grant rates using a range of methods

12.1 The significance of gradient

Rhododendron frequently invades steep ground. Control is more difficult on slopes, and is consequently more expensive. In addition, grants are calculated by the hectare from a plan, not as measured on the ground. In recognition of these factors, steeper ground attracts higher rates for cut-and-burn under SRDP, as shown in Table 2.

Operation	*Description*	*£/hectare*
Light infestation/easy access	Bushes are less than 1.5 metres high and on a flat site with a slope of less than 15 degrees.	£ 4,500
Medium infestation/access	• Bushes are less than 1.5 metres high and on a site with a slight slope (greater than 15 degrees) or • Bushes are greater than 1.5 metres high and on a flat site (less than 15 degrees) or • Bushes are greater than 1.5 metres high and on a site with a slight slope (greater than 15 degrees).	£ 6,100
Difficult access	• Bushes are less than 1.5 metres high and on a steep site (with a slope greater than 30 degrees) or • Bushes are higher than 1.5 metres and on a site with a steep slope (greater than 30 degrees).	£ 9,500

Table 2 Grant rates payable for manual eradication (cut-and-burn) under SRDP

However, under SRDP, a **flat rate** applies to other methods (such as stem injection and lever-and-mulch) **regardless of gradient**. Grant rates for these alternative methods are anyway significantly lower than for cut-and-burn, and this discrepancy renders these methods even less attractive.

Control on very steep sites and rock-faces necessitates the use of roped access. Control costs on such sites are inevitably high, and are normally quoted on a site-by-site basis; per hectare rates are meaningless. They have normally been grant-aided on an Actual Cost basis.

13 Planning and implementing control projects

A carefully-considered plan is crucial to successful control of any invasive species, whether this is used to guide work at a single site or over a wider geographical area. Such a plan must take account of all the factors which will govern its successful implementation. When planning a control programme, it is important to set realistic objectives based on an assessment of risk and the resources available.

For many mobile species such as rhododendron, the ideal objective is **eradication** of an entire population. This minimises the need for future monitoring and allows the affected habitats to be restored.

Where this has not been achievable, programmes have been forced to pursue other options. Typically this has been to implement **control** on a holding-by-holding basis. Attempts have also made at **containment**, using a barrier such as a dense plantation of spruce to help reduce spread outside a defined area (Willoughby *et al*., 2004). Outside this, a buffer zone or 'cordon sanitaire' is monitored for incursions. Both of these options demand ongoing management, and have generally proved ineffective.

13.1 Working at a population scale

Much of the rhododendron control work to date has focussed on designated sites, ancient woodland and land owned by NGOs. In many cases, control has not been undertaken on adjacent sites. Predictably, cleared areas have been re-colonised and efforts at ongoing control have dwindled.

Failure to implement control on all affected holdings in a population is probably the commonest cause of project failure. It is quite clear that, as for other invasive species, results are achieved most cost-effectively when a population of rhododendron is tackled as a whole rather than piecemeal.

This requires a survey to be undertaken of the **whole population**, regardless of ownership boundaries. This exercise should identify and map likely dispersal pathways, possible receptor sites, constraints, access and ownership boundaries.

Needless to say, such a 'population-scale' approach typically requires negotiation with many land-holders. This will lead to a coordinated control programme over multiple holdings.

13.2 Selecting control methods

When deciding on control methods, practitioners are usually aiming to achieve maximum kill for the lowest cost and the least environmental impact, although the relative weighting of these 3 parameters may vary between sites. On a particularly sensitive site, for instance, it may be appropriate to adopt a combination of stem injection and lever-and-mulch, and so avoid spraying.

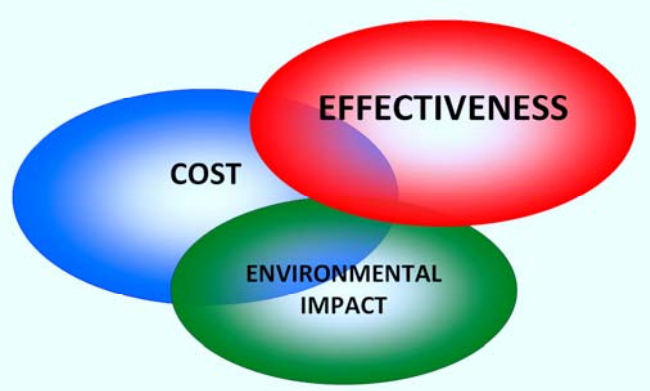


Figure 1. The relationship between cost, effectiveness and environmental impact varies between control methods

The choice of methods may be influenced by a number of site-specific factors.

Post-control management objectives, such as restoration of native woodland, timber harvesting, restocking, amenity and public access.

Constraints, such as watercourses, designated sites, sensitive habitats and species (Atlantic bryophytes, otters etc.)

Bush type. The age and structure of rhododendron stands varies greatly. Some control methods are better suited to certain bush types than others. For instance, large mature bushes with few thick stems may be treated very cost-effectively by stem injection, and follow-up costs are minimal. By contrast, cutting and disposing of these large bushes is slow and labour-intensive. Spindly, multi-stemmed bushes may be best treated using lever-and-mulch, or by cutting with a clearing saw, and the cut surfaces sprayed.

Overall, the best strategy is to select the most appropriate control methods on a site-by-site and bush-by-basis basis.

The grants system, however, makes it difficult to adopt a flexible approach towards control methods on two counts. Firstly, it requires applicants to specify methods for each compartment in their application. Secondly, certain control methods are much more generously funded than others.

13.3 Ongoing control and monitoring

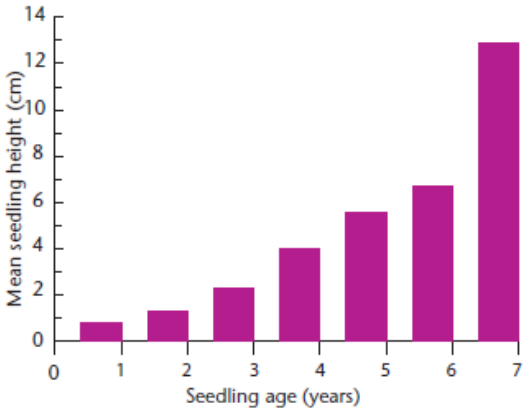
The eradication of rhododendron is a long-term undertaking. Even where control is effectively implemented across a whole population, eradication is unlikely to be achieved in less than 10 years.

There are several reasons for this:

- most methods require 2 or more treatments, spaced at least a year apart;
- whatever control methods are used, none will kill every treated plant without fail;
- in any given treatment, operators inevitably overlook a small percentage of plants.

The difficulty of locating all plants is exacerbated by the slow growth of seedlings in the early stages of development (see Fig. 2). The mean height of a 7-year old seedling is less than 15cm; many may be smaller. Depending on the vegetation and season, such a plant may not be easily spotted unless the operator is within 2-3 metres.

There is also anecdotal evidence that seedling development may be slowed down by the presence of grazing animals, either through browsing or trampling. If this is the case, the consequence of this is that monitoring may have to be maintained for an even longer period.



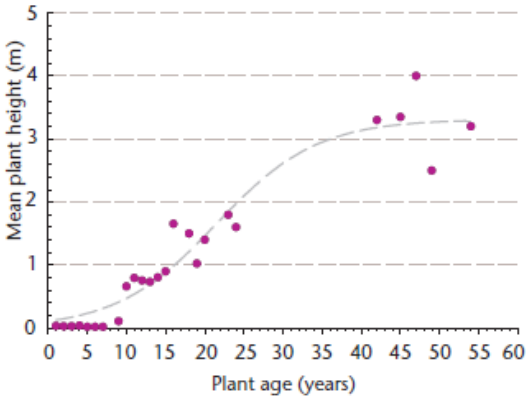


Figure 2. Early rhododendron seedling growth **Figure 3.** Increasing height with age (both from Edwards 2006)

The most cost-effective strategy for the later stages of an eradication programme may be to establish a 4 - 5 years monitoring cycle. This will ensure seedlings are spotted and removed before they flower (see Figs. 3 and 4).

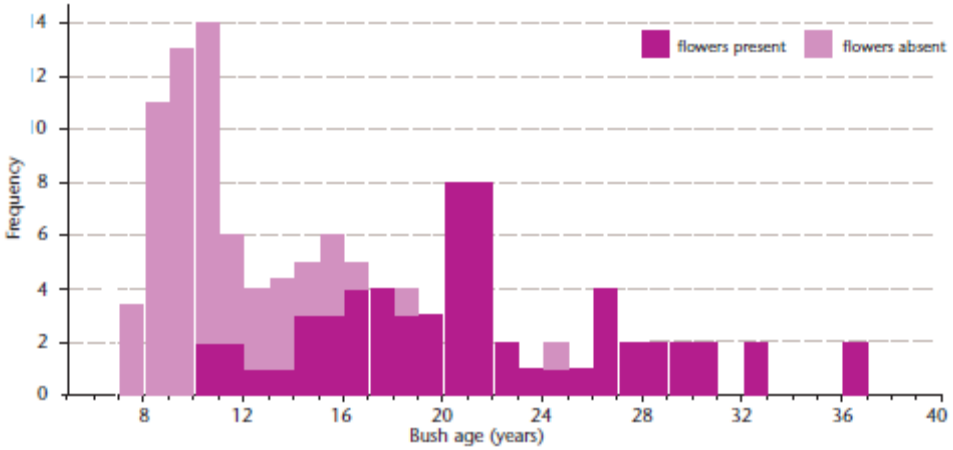


Figure 4. Flowering age of rhododendron bushes (from Edwards 2006)

It is imperative to programme and allocate resources for all control operations well in advance, and to keep careful records. Forest Enterprise now uses a software module known as Tactical Planner to systematically plan and track rhododendron control efforts (Fletcher, 2013).

Past grants systems have not catered for the need for monitoring for a period of 10 years or more after the initial treatments have been completed.

13.4 Bio-security

A mature rhododendron bush can produce a million seeds every year. Typically seeds are dispersed by wind between February and April, but timing is dependent on weather and location.

Despite the tremendous potential for management interventions to assist seed dispersal, little research appears to have been carried out on the bio-security risks associated with rhododendron control operations.

It is known that cutting bushes when seed-heads are ripe (February to April) will increase seed dispersal. Any control operations may lead to seed being carried considerable distances, especially in windy conditions. It is likely that seed may be dispersed over much greater distances on clothing and vehicles. It has also been suggested that the updraft from fires may disperse seed.

These risks should be taken into consideration when deciding on the timing of operations and the techniques used. Care should be taken to minimise spread on tools, clothing and vehicles.

Measures to minimise the risk of spreading *Phytophthora* are described in Section 9.

14 Developing a tool-kit

It should be possible to significantly increase the cost-effectiveness of rhododendron control by continuing to develop our understanding of the theory and practice of rhododendron control through demonstrations, workshops and written guidance.

Control methods. In recent years, researchers and practitioners have been working to refine traditional methods and trial alternative, innovative control techniques. Despite the progress made with these methods, the great majority of rhododendron control in Scotland is still undertaken by cut-and-burn.

There is a pressing need to demonstrate the effectiveness of other, less costly and more environment-friendly alternatives, such as stem injection and lever-and-mulch in a range of sites and stand types.

These demonstrations and training workshops might be facilitated by experienced contractors on accessible NFE sites. These sites could be used to compare the long-term cost-effectiveness of different methods, and the practicalities of extracting firewood, as well as the sites' recovery.

Updated guidance. A comprehensive guidance manual was published in 2006 by Forestry Commission "Managing and controlling invasive rhododendron" (Edwards, 2006). It would be useful to update this guidance in the light of the growing body of information on control methods and strategies.

This might include a decision-making tool to help practitioners adopt the most appropriate and cost-effective method for every stand.

Recommendations:

- **use demonstration sites to develop and exchange skills with practitioners;**
- **update guidance manual on rhododendron control.**

15 Site recovery

One of the principal objectives of rhododendron clearance on most sites is the restoration of natural vegetation. This is particularly important in ancient woodlands and on designated sites where there is a need to secure favourable conservation status.

Following rhododendron removal, vegetation recovery on many sites has been disappointing. Robertson (1999), for instance, found that some sites in Ardtornish supported only a few mosses and a handful of spruce trees, even 12 years after treatment.

It has been suggested that phenolic exudates from rhododendron leaves and roots may be toxic to other plants (Esen *et al.*, 2006; Jackson, 2008). The growth of *Festuca ovina* may be inhibited by decomposing rhododendron (Rotherham & Read, 1988). Soils below dense rhododendron thickets can also become depleted of nutrients (Esen *et al.*, 2006), while Mitchell *et al.* (1997) observed an increase in sodium which can negatively affect plant growth and recovery.

Allelopathy and nutrient status may account for slow recovery on some sites, but the control operations themselves are generally considered to have a more significant impact on soils and vegetation. The impact of different control methods on vegetation recovery, particularly epiphytic bryophytes, is currently being researched as a PhD hosted by Aberdeen University and the James Hutton Institute (D. Genney *pers. comm.*).

15.1 Soil compaction and disturbance

Mechanical control using heavy machinery will disturb and compact the soil, and increase the risk of soil erosion. It may also damage any remaining ground vegetation. There are also concerns about losses of soil nutrients, disruption of nutrient retention mechanisms and long-term site productivity following mechanised control, especially if areas are poor in nutrients (Esen *et al.*, 2006; Willoughby *et al.*, 2004).

Some soil disturbance may assist the establishment of natural vegetation (Higgins, 2008; Robertson 1999). However, where a rhododendron seed source is still present nearby, disturbance also creates a seedbed for re-invasion (Jackson, 2008; Edwards, 2006).

15.2 Management of brash

The cutting or uprooting of rhododendron generates a considerable bulk of brash. Whether stacked, burned, chipped or used as a mulch, it will influence subsequent site recovery by casting shade, affecting nutrient

balance and influencing vegetation composition (Thompson *et al.*, 2003). Most commonly, cut material is burned. This leaves sites free of debris, but can have a major impact on soils and vegetation (see Section 11).

15.3 Herbicide damage

Foliar application of herbicide and stump treatments rarely avoids some spray drift or surplus run-off. Herbicide applications are typically repeated 2-3 times on any given site, and almost inevitably cause some damage to native plants (Ninaber, 2009), even where special precautions are taken (Higgins, 2008; Jackson, 2008).

Post-treatment vegetation damage has been described frequently. Jackson (2008) noted in Snowdonia that *Vaccinium* took several years to recover following spraying. Kennedy (2008) reported successful eradication of rhododendron at sites in Ardnamurchan, but only at the expense of all other natural vegetation, including tree seedlings. Edwards (2008) recommends alternative control methods where sensitive species such as bryophytes are present, as recovery for some species can be exceedingly slow (Long & Williams, 2007). The use of glyphosate is discussed in Section 11.

15.4 Grazing

The restoration of any semi-natural habitat and the successful re-establishment of native trees depends on herbivore numbers. Recovery of some sites cleared of rhododendron has been hindered by high grazing pressure.

Stock removal, culling and fencing are the usual prescriptions in these instances, but managers in Killarney devised an innovative solution by using dead stems left by stem injection to build ‘dead hedges’. These have proved an effective barrier against deer for up to 10 years (Higgins, 2008).

15.5 Optimising site recovery

The use of the stem injection procedure on standing rhododendron avoids many of the disadvantages described above (Ninaber, 2009). Disturbance to soil and native vegetation is minimal (Edwards *et al.*, 2000; Edwards, 2006; Jackson, 2008).

Retaining a dense tangle of stems may also provide a barrier to browsing deer and livestock, which will help to aid the regeneration of native trees and shrubs. This function can be enhanced by 'dead-hedging', as described above. Although the standing stems may take 5-10 years to decompose (Higgins, 2008), the increased light levels following leaf fall will permit rapid re-vegetation of bare soil.

Complete clearance using mechanical or manual methods results in heavy collateral damage to the field layer and to bryophytes, lichens and fungi in particular (Long & Williams, 2007). Lower plant communities and other

shade tolerant sensitive flora, associated with ancient woodland sites for example, are likely to benefit from the more gradual change in light levels, humidity and shelter as the rhododendron canopy dies following stem injection (B. Averis *pers. comm.;* Long & Williams, 2007; Thompson *et al.*, 2003). This principle is paralleled by the guidance provided for the restoration of ancient woodlands on PAWS sites (*e.g.* Woodland Trust, 2005).

The choice of treatment used to control rhododendron must balance cost and efficiency against the need to minimize soil and vegetation disturbance and limit the use of pesticides in order to best promote site recovery (UK Woodland Assurance Standard; Willoughby *et al.*, 2004).

Recommendation:

- **research the relationship between control methods and site recovery (PhD in progress – see above)**

16 Uptake of grant

Since the introduction of SFGS in 2004, grants totalling over £ 3.6 million have been approved and/or paid for rhododendron control on private land. As shown in Figure 5, uptake has varied from year to year. The marked reduction in spend after 2006 coincides with the hiatus between SFGS and SRDP.

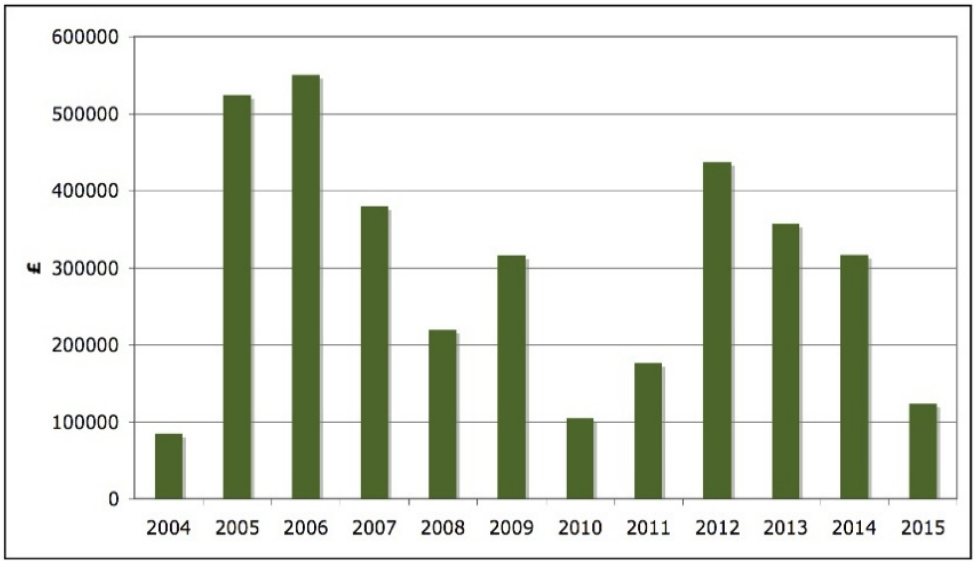


Figure 5. Annual combined SFGS, SRDP WIG (approved) and Rural Priorities – control of non-native invasive species (paid) for rhododendron control since 2004. *(Data on RP approved not available for individual years).*

The proportion of forestry grants spent on rhododendron control work has never exceeded 3% of the annual expenditure (Figure 6).

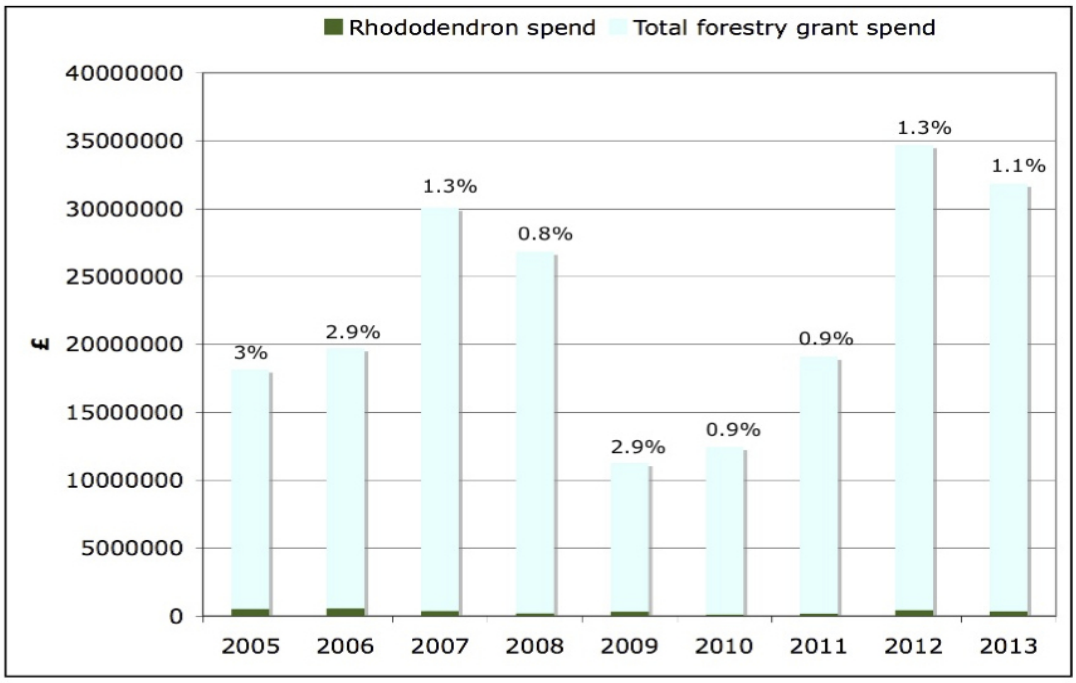


Figure 6. Total forestry grant spend and total annual spend on rhododendron control, 2005-2013; % are the proportion of rhododendron expenditure as % of total grant spend

Most grant payments were made for the manual eradication of rhododendron (cut-and-burn). See Figure 7.

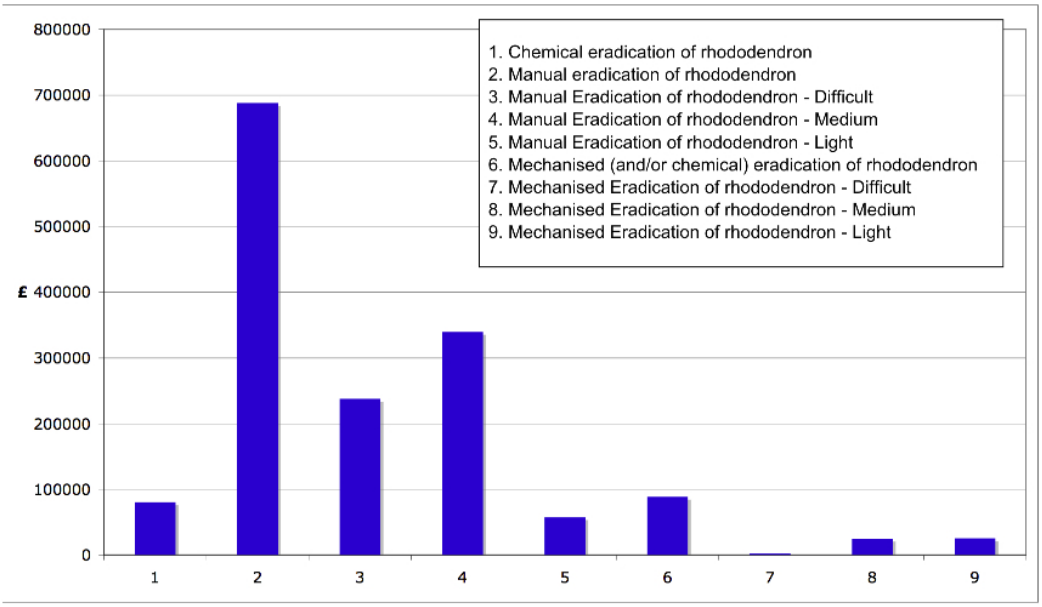


Figure 7. Approved expenditure under RP/SRDP –WIG for different methods of rhododendron control.

Overall, a minimum total of £3.6 million has been spent on rhododendron control in the private sector since 2004. In addition, a further £1.5 million has been approved funds under Rural Priorities, but not yet claimed (Table 3). These grants covered a total rhododendron control area of 2,143 ha. Most of the work has been carried out in Highland and to a lesser extent in the Clyde Valley area.

Grant type for rhododendron control	*Years*	*Area (ha)*	*Approved*	*Paid*	*Total forestry grant spend*
SFGS	2004 – 2010	541	£2.1 million	£2.1 million	£119.36 million
SRDP - WIG	2011 – 2017	106	£572,685	£60,654	£92 million
RP – Control of non-native invasive species	2009 - 2015	1496*	£2.5 million	£967,953	N/A
TOTAL	2004 - 2017	2143	£5.2 million	£3.1 million	

* Area approved for rhododendron control; current grant paid area is 260 ha.

Table 3. Summary of grant types and expenditure on rhododendron.

Note that we were unable to compare annual expenditure between grant packages due to differences in data presentation.

17 Why has grant uptake been low?

There have been radical changes in the forestry grants system in recent years. These started in 2006 when SFGS closed without advance notice. There followed a period of 3 years when no grants were available.

SRDP, the system which succeeded SFGS, opened in 2008. It made a shaky start and was beset by technical problems. Applications can only be made online, the process is complex and navigating the website is difficult. Many heart-felt criticisms have been levelled at SRDP. It was recently described as "… tortuous, counter intuitive, reliant on technology, unfit for purpose and in attempting to be all things to everyone, has been nothing to anybody" (Page, 2013).

Despite some minor improvements, applying for SRDP remains a heavily bureaucratic, arcane process, and most owners resort to paying an agent to help them through the process. In comparison with earlier schemes, grant claims are processed very slowly, so exacerbating problems of cashflow.

From 2008, applications for funding rhododendron came under the 'Control of Invasive Species' option. Applications had to be submitted to RPAC, making the application process rather lengthy. It was also competitive, so giving no guarantee of a successful outcome. In 2010, it became possible to apply for funding for rhododendron control under the forestry grants system.

When grant rates were increased in July 2011, many owners were prompted to start preparing applications. However, only 14 months later, in October 2012, again without prior notice, SRDP funding for rhododendron control was withdrawn (except where associated with a SPHN). As a result, a number of partially-prepared applications stalled, and owners and agents incurred a financial loss.

Uptake of grant for rhododendron control has been low under all schemes, but declined further under SRDP. There are many disincentives which affect owners or agents, or both, some of which have already been touched on. They include:

- the SRDP application procedure is complex and time-consuming;
- there is no guarantee that an application will be successful, either because the process is competitive or because a grant scheme may close without warning;
- there is no funding available for the early stages of a control project (such as survey, planning, grant application, seeking quotes etc...), despite the fact that these costs are considerable;
- because of the high costs, applicants are required to demonstrate that they will be able to re-pay grants in the event that they are unable to deliver the contracted outputs;
- grant claims can only be made retrospectively, once work is completed, and take many months to process. As a consequence, cash-flows are at times typically over £50,000 in deficit;
- SRDP requires owners to eradicate rhododendron within 5 years; on all but small isolated sites, this is unlikely to be achievable, as outlined in FC's own guidance (Edwards, 2006);
- penalties for failure to meet grant conditions are severe.

In addition to these disincentives, the uptake of grant for rhododendron control may have been influenced by outside factors, such as attractive rates of grant for new planting. There is also finite capacity in the industry, and many of the contractors most experienced in rhododendron control have been occupied working on NFE.

Regrettably, with SRDP being seen as the first (and only) port of call for funding to control rhododendron, access to other sources of funding has been blocked (Boulton *et al.* 2012).

18 Can a voluntary scheme eradicate rhododendron?

Whilst it may be possible to tailor a voluntary grant scheme to deliver better outputs, this will still not guarantee engagement with a great many landowners whose holdings are affected by rhododendron.

These broadly fall into 4 categories:

- land-holders who are interested in principle, but are unwilling or unable to apply for grants
- land-holders who are not interested in rhododendron control
- land-holdings which are ineligible for SRDP funding
- rhododendron stands growing on land whose ownership is unknown or disputed.

Many owners of affected land may be **interested in principle**, but

- they are unwilling to embark on control because it is present on neighbouring land;
- they are offered insufficient assistance to assess the likely costs, implications and viability of a control programme;
- they have only a small area of rhododendron, and the cost of applying to SRDP (relative to the control costs) would make an application financially impractical;
- they are unable to bankroll the cost of applying for grant (survey, planning, grant application) or implementing control operations;
- they are deterred by exacting contract conditions, and the possible penalties if they fail a site inspection;
- they are unwilling or unable to enter into a long-term commitment which may run well beyond the 5 year contract period;
- there is doubt that further funding may be made available for follow-up control and monitoring, since owners will have already been paid for eradication;
- they are unable to find agents and contractors who are able or interested in carrying out the work;
- they are concerned about the impacts and risks associated with control operations, especially fires and chemicals;
- they do not wish to engage with government agencies, and their perceived 'big brother' attitude and inflexibility;
- the affected land is on common grazings, and the crofters will not apply to SRDP (because they are unable to agree on this course of action and/ or bankroll the work);
- the affected land forms part of an agricultural tenancy, so the land-owner is not eligible for SRDP; and the tenant is unwilling to apply.

In many cases, owners may not wish to undertake rhododendron control for a variety of other reasons, including:

- they wish to retain bushes for their flowers, as a screen, shelter, game cover, a fixture in a historic landscape;
- they are concerned that the aftermath of control will be unsightly;
- they are averse to change;
- they consider rhododendron control to be squandering public money, especially in an economic recession;
- they do not perceive rhododendron as a problem.

The following are **ineligible** for SRDP funding:

- gardens and parks;
- rhododendron stands on which *Phytophthora* has been detected, and where owners have been served with a Statutory Plant Health Notice (SPHN);
- owners who may have defaulted on previous grant schemes (not necessarily relating to rhododendron control).

Lastly, it may be difficult to determine the ownership of a rhododendron stand, or to contact the owner.

18.1 How grants work

The Forestry Commission has been offering financial incentives to private forest-owners through a succession of grant schemes for many decades. These grants have helped deliver a range of national and regional policies usually relating to timber production, biodiversity and recreation.

The practice of using incentives to deliver public benefits from private woodlands is well-established in UK forestry. Invariably, owners also derive some private benefit. The establishment of new native woodland, for instance, may have amenity and landscape benefits, and add value to their land-holding.

The balance between private and public benefit will vary between operations. Those that generate the most private benefit will require the lowest incentives; they may also be competitive. Conversely, those which provide relatively little benefit to the owner may require to be more heavily subsidised through grants.

18.2 The challenge of landscape-scale management

The mobility of many natural resources means they are best managed at a landscape scale. Deer, for instance, range over many land-holdings. Similarly, the life-cycle of migratory fish depends on a whole river system.

The need to manage resources and problems (such as diffuse pollution) at a population or catchment scale has given rise to organisations such as

deer management groups, fishery boards and catchment management groups which help to agree and coordinate actions over multiple holdings.

Where the management of these resources generates private benefits (such as income from fishing), it may be self-financing. Where there are few perceived benefits for individual owners, management is more likely to require public funding and facilitation.

Whilst many owners might be prepared to allow a third party to remove rhododendron from their property, it is generally only a minority who are willing to be proactive and apply for grant.

For most populations of rhododendron, it is unlikely that eradication will be achieved under a voluntary scheme.

A recent evaluation of landscape-scale management initiatives (Bolton *et al.* 2012) found that:

> "the level of public versus private benefit in a landscape-scale project is a major determinant of the type of approach that is required."
>
> "Evidence suggests that, in the majority of cases, landscape-scale projects are only likely to take place where third party facilitation is used. A 'reactive' approach ... – setting up a scheme and waiting for applications - does not lend itself to the delivery of landscape-scale public benefits."
>
> "Attempts at SRDP funded landscape-scale control of invasive non-native species ... have generally been unsuccessful. Achieving 100% coverage of INNS in target areas will be highly unlikely under the current circumstances."

19 Securing public support

Despite efforts by many agencies and NGOs, efforts to control rhododendron are not universally understood and supported by land-owners, local communities and the general public.

Rhododendron remains a popular plant among horticulturalists and the general public, particularly when in bloom. A UK-wide questionnaire on control efforts reported in Dehnen-Schutz *et al*. (2004) revealed that only 2% of respondents did not wish to eradicate *Rhododendron ponticum* on their land. The main reasons given were the benefits in terms of aesthetic appeal, recreational amenity and tourism during the flowering period. Enhanced revenues was implied by land holders but could not be quantified. Fear of a public outcry about rhododendron control was a major theme of the 1987 Snowdonia Rhododendron Conference (Gritten, 1987). Since then, more effort has been made to disseminate information about rhododendron and the problems that it causes.

Many organisations have produced information leaflets that set out the benefits to biodiversity of controlling rhododendron (e.g. Highland Biodiversity Forum). There have been numerous stories in the media, including video diaries, about native habitats being restored following the clearance of rhododendron (e.g. Discover Bute). The GB Non-native

Species Secretariat website contains extensive information as well as species fact sheets on the dangers of non-native invasive species. All of these media have helped inform the public of the need to control rhododendron in the countryside.

Organisations such as the National Trust (and National Trust Scotland), RSPB, Woodland Trust and John Muir Trust have organised volunteer work parties for many years to help clear rhododendron on their properties.

The announcement in 2012 by FCS that they would control rhododendron on NFE and eradicate the plant within 15 years sent a powerful message to land-owners and land-managers throughout Scotland. Some of these owners have in the past refrained from embarking on rhododendron control because their efforts would be thwarted by re-invasion from NFE.

The EU Commission is also supporting efforts to raise awareness of INNS. “Raising awareness of invasive species is an important part of the battle”. The Commission recently held a public consultation, which attracted 880 replies, three-quarters of them from individuals. The survey revealed "widespread backing for action at EU level. Some 91% of respondents agreed on the urgent need to bring in new measures to prevent the spread of INNS. Nine out of ten wanted an EU-wide early warning system, and 86% thought that Member States should be legally obliged to take action. Most respondents (90%) saw a lack of public awareness as a barrier, and felt it was important to raise the profile of the issue (77%). The EU is using these results in developing its policy” (quote from EU 2009 Invasive alien species factsheet).

However, much more needs to be done to help raise awareness of the issue and the mounting cost of inaction, and to engender a stronger sense of shared responsibility across key stakeholders, land managers and the general public to address the problem.

The presentation of stories relating to rhododendron control is also important. The focus must be on the native woodland restored, rather than the rhododendron killed.

Efforts must be made to more fully engage local communities and volunteers in control projects. The raising of awareness will play a vital role in the early stages of a population-scale control project. Securing the willing participation of **all** land-holders is an important objective, and will reduce the need to invoke the new powers under the Wildlife and Countryside Act, which should be seen as a last resort.

It is not helpful to any awareness campaign or any national eradication strategy that *Rhododendron ponticum* is still available for sale.

If *Phytophthora* continues to spread in Scotland, it may change many land-owners' perception of rhododendron as a relatively benign component of their woodlands.

Recommendations:

- **raise awareness of the negative impacts of rhododendron among land-holders, forest managers and general public through a variety of media.**
- **raise awareness of the positive value of restoring woodland habitats and improving biodiversity.**

20 Facilitating rhododendron control

In the long-term, the most cost-effective strategy for rhododendron control is to aim for eradication at a population scale. This requires a proactive approach. A reactive, voluntary system is unlikely to secure the 100% sign-up required to achieve eradication.

Most eradication projects will require the following:

- a third party to plan, coordinate, facilitate and implement control;
- a population scale approach: encompassing all rhododendron plus a buffer zone (500m-1km);
- a carefully targeted awareness-raising campaign;
- all affected land-holdings must consent to control;
- careful and thorough planning and implementation;
- a long-term commitment to resource control operations and monitoring until objectives are achieved.

They will also benefit from:

- good work-force continuity using experienced contractors;
- a mix of control techniques and approaches, according to stand type, site characteristics and local opportunities (such as involving volunteers, employing local residents...).

The current reactive grants system used to fund rhododendron control on private land has demonstrably failed to deliver the required outputs. It is necessary to shift the onus for rhododendron control from land-owners to a third party.

Planning and implementing operations at a population scale and working across ownership boundaries could offer significant opportunities to increase efficiency and reduce costs.

Recommendation:

- **explore alternative funding mechanisms for funding and coordinating rhododendron control.**

21 Recommendations

The principal recommendations appear in the relevant sections of this report. They are as follows:

- initiate a positive dialogue with the horticultural community, with a view to withdrawing *Rhododendron ponticum* from sale
- review knowledge of invasive and non-invasive qualities of ponticum hybrids
- collate and share data on rhododendron to promote wider engagement with stake-holders
- review arrangements for dealing with rhododendron infected with *Phytophthora*
- use demonstration sites to develop and exchange skills with practitioners
- update guidance manual on rhododendron control
- research the relationship between control methods and site recovery
- raise awareness of the negative impacts of rhododendron among land-holders, forest managers and general public through a variety of media
- raise awareness of the positive value of restoring woodland habitats and improving biodiversity
- explore alternative funding mechanisms for funding rhododendron control.

22 REFERENCES

Argyll Woodlanders (2012) Glen Creran – Review of *Rhododendron ponticum* on private property. Unpublished report for Forestry Commission Scotland.

Baarda, P. (2006) Woodland habitat restoration: core sites for a forest habitat network. Caledonian Partnership, Munlochy.

Baptie, M., McFarlane, N. and Thompson, R. (2011) *Rhododendron Control Strategy for the National Forest Estate in Scotland.* Forest Enterprise Scotland.

Barron, C. (undated) The control of rhododendrons in native woodlands. Native woodland scheme information note 3. Forest Service/Woodlands of Ireland.

Boulton, A., Lockett, R. & Seymour, A. (2012) A review and evaluation of collaborative landscape-scale management initiatives. Commissioned report. Scottish Natural Heritage, Stirling.

Brazier, C. (1999) Phytophthora pathogens of trees: their rising profile in Europe. Information Note 30. Forestry Commission, Edinburgh.

Brown, J. (2004) Tales of the Rose Tree - Ravishing Rhododendrons and their Travels Around the World. Harper Collins, London.

Brown, J.M.B., 1953. The Rhododendron problem in the woodlands of southern England. Quarterly Journal of Forestry 47, 239–253.

Burton, D. & Carpenter, P. (1999) Life after rhododendron. Enact 7, 11-14.

Chapman, P. (2007) Audit and management recommendations for invasive plants in the Loch Lomond and The Trossachs National Park. Final Report for Loch Lomond and Trossachs National Park. SAC, Inverurie.

Clifford, T. (2002) Restoration of Atlantic Oakwoods, 1997-2001. Final project report to the EU (Project no B4- 3200/97/234). Caledonian Partnership/ Highland Birchwoods, Munlochy.

Cross, J.R. (1981) The establishment of *Rhododendron ponticum* in the Killarney oakwoods, S.W. Ireland. Journal of Ecology 69, 807- 824.

Cullen, J. (2011) Naturalised rhododendrons widespread in Great Britain and Ireland. Hanburyana 5, 11-29.

DAISIE (2006) *Rhododendron ponticum* factsheet. Delivering Alien Invasive Species Inventories for Europe. (www.europe-aliens.org).

DEFRA (2007) Consultation on: 1. The review of Schedule 9 to the Wildlife and Countryside Act 1981; and 1. The ban on sale of certain non-native species. DEFRA, London.

DEFRA (2008) *Phytophthora ramorum*. A practical guide for established parks & gardens, amenity landscape and woodland areas. DEFRA.

Dehnen-Schmutz, K., Perrings, C. & Williamson, M. (2004) Controlling *Rhododendron ponticum* in the British Isles: an economic analysis. Journal of Environmental Management 70, 323–332.

Dehnen-Schmutz, K. & Williamson, M. (2006) *Rhododendron ponticum* in Britain and Ireland: Social, Economic and Ecological Factors in its Successful Invasion.

Environment and History 12, 325-350.

Edwards, C. (2006) Managing and controlling invasive rhododendron. FC Practice guide, Forestry Commission, Edinburgh.

Edwards, C. (2009) Rhododendron ponticum: strategies for control and management in woodland landscapes. (extended abstract). Forest Research, Roslin.

Edwards, C. and Taylor, S. L. (2008a) *A survey and strategic appraisal of Rhododendron invasion and control in woodland areas in Argyll and Bute.* Contract report for Perth Conservancy, Forestry Commission Scotland.

Edwards, C. & Taylor, S. (2008b) Rhododendron survey: control costs and priority. Technical seminar, 11 June 2008, Inveraray, Argyll. Forest Research, Forestry Commission, Edinburgh.

Elton, C.S. (1958) The ecology of invasions by animals and plants. Chapman & Hall, London.

EnviroCentre (2006) Highland LBAP Review: Highland Biodiversity Action Plan. EnviroCentre, Glasgow.

Esen, D., Nilsen, E.T. & Yildiz, O. (2006) Ecology, competitive advantages, and integrated control of rhododendron: an old ornamental yet emerging invasive weed around the globe. In: Floriculture, ornamental and plant biotechnology Volume III. Global science books. pp 407-421.

European Commission (2009) Invasive alien species. European Commission, Luxembourg.

European Communities (2006) LIFE and European forests. European Commission, Luxembourg.

European Union (2011) EU biodiversity strategy to 2020: towards implementation – Council conclusions. Council of the European Union, Brussels.

Fletcher, J. (2013) Description of rhododendron control statistics on the national forest estate Scotland. Unpublished progress report. Forest Enterprise, Inverness.

Forestry Commission (2010) Guidance to Forestry Commission staff carrying out plant health inspections. FC, Edinburgh.

Forestry Commission England (2011) Supplementary guidance for sites felled due to *Phytophthora*. Operations Note 024. Forestry Commission England.

Forestry Commission Scotland (2012) FCS Briefing Note – Rural Priorities. Issue 6. Forestry Commission, Edinburgh.

Forestry Commission Scotland (2013) Action plan for ramorum on larch in Scotland (2013/14). Forestry Commission Scotland, Edinburgh.

Franz, J.E., Mao, M.K. & Sikorski, J.A. (1997) Glyphosate: A Unique Global Herbicide. In: American Chemical Society Monograph 189. pp. 65-97.

GB Non-native Species Secretariat (GBNNSS) (2008) The invasive non-native species framework strategy for Great Britain. DEFRA.

GB Non-native Species Secretariat (GBNNSS) (2011) Rhododendron,

Rhododendron ponticum factsheet. GBNNSS.

Green, S. & Webber, J.F. (2012) The emerging threat from Phytophthora to trees in Scotland. Scottish Forestry 66, 8-16.

Grieve, Y. (2011) The native woodland survey of Scotland database: what you get and how you get it! Scottish Forestry 65, 5-9.

Gritten, R.H., 1987. The spread of Rhododendron ponticum - a national problem. In: Gritten, R.H., (Ed.), Report of a conference, Snowdonia National Park, Plas Tan-y-Bwlch, North Wales.

Haller, W.T. & Stocker, R.K. (2003) Toxicity of 19 adjuvants to juvenile *Lepomis macrochirus* (bluegill sunfish). Environmental Toxicology and Chemistry 22, 615-619.

Higgins, G.T. (2008) Rhododendron ponticum: A guide to management on nature conservation sites. Irish Wildlife Manuals, No. 33. National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Dublin, Ireland.

Highland Rhododendron Project (2012) Highland *Rhododendron ponticum* control strategy 2011 – 2013. Highland Birchwoods, Munlochy.

Highland Rhododendron Project (2012) Sunart SSSI/SAC update – April 2012. Highland Birchwoods, Munlochy.

Highland Rhododendron Project (2013) Draft final report 2010-13 . Highland Birchwoods, Munlochy.

Holmes, G.D. 1957. 'Experiments on the chemical control of Rhododendron ponticum'. *Forestry Commission: Forest Record* 34: 1–7.

Ireland, D. (2009) Rhododendron control: manual lever and mulch. Internal project information note 27/08. Technical development, Forest Research, Forestry Commission.

Jackson, P. (2008) Rhododendron in Snowdonia and a strategy for its control. Snowdonia National Park Authority.

Jones, W.I., 1974. A rhododendron eradication trial, Rep. No. Information Paper No 1, Nature Conservancy Council, UK.

Kennedy, D. (2008) A survey of *Rhododendron ponticum* in the Sunart oakwoods initiative area. A report for Forestry Commission Scotland, Dingwall.

Kennedy, D. (2009) A brief history of *Rhododendron ponticum* at Doire Donn Wildlife Reserve, Conaglen Estate, Ardgour – and the Lever & Mulch method of eradicating it. Native Woodland Discussion Group field visit report.

Long, D. & Williams, J. (2007) Rhododendron ponticum: impact on lower plants and fungi communities on the west coast of Scotland. Plantlife Scotland, Stirling.

Mabbett, T. (2011) The ramorum conundrum. Forestry Journal 1/11, 13-15.

Miller, A.D., 1954. Eradication of Rhododendrons. Journal of the Forestry Commission 23, 52–55.

Milne, R.I. & Abbott, R.J. (2000) Origin and evolution of invasive naturalized material of *Rhododendron ponticum* L. in the British Isles. Molecular Ecology 9,

541-556.

Mitchell, R.J., Marrs, R.H., Le Duc, M.G. & Auld, M.H.D. (1997) A study of succession on lowland heaths in Dorset, Southern England: changes in vegetation and soil chemical properties. Journal of Applied Ecology 34, 1426-1444.

New Zealand Government (2012) National pest plant accord 2012. New Zealand Government.

Ninaber, D. (2009) Improved control of *Rhododendron ponticum* for environmental management. Unpublished PhD, University of Wales, Bangor.

Niinemets, U., Valladares, F. & Ceulemans, R. (2003) Leaf-level phenotypic variability and plasticity of invasive *Rhododendron ponticum* and non-invasive *Ilex aquifolium* co-occurring at two contrasting European sites. Plant, Cell & Environment 26, 941-956.

Page, M. (2013) Lessons from the SRDP. Reforesting Scotland 47, p.42.

Parrott, J., MacKenzie, N. & Clifford, T. (2010) Mapping invasive species in Highland. A report for Highland LBAP Invasives Sub-group. Scottish Native Woods, Aberfeldy.

Pryor, S.N., Curtis, T.A. & Peterken, G.F. (2002) Restoring plantations on ancient woodland sites. Woodland Trust.

Purse, B.V., Graeser, P., Searle, K., Edwards, C. & Harris, C. (2012) Challenges in predicting invasive reservoir hosts of emerging pathogens: mapping *Rhododendron ponticum* as a foliar host for *Phytophthora ramorum* and *Phytophthora kernoviae* in the UK. Biological Invasions Online edition.

Robertson, A. (1999) Ardtornish Estate rhododendron report. Unpublished report. Ardtornish Estate.

Rotherham, I.D. & Read, D.J. (1988) Aspects of the ecology of *Rhododendron ponticum* with reference to its competitive and invasive properties. Aspects of Applied Biology 16, 327-335.

Sansford, C.E., Inman, A.J., Baker, R., Brasier, C., Frankel, S., de Gruyter, J., Husson, C., Kehlenbeck, H., Kessel, G., Moralejo, E., Steeghs, M., Webber, J. & Werres, S. (2008) Report on the risk of entry, establishment, spread and socio-economic loss and environmental impact and the appropriate level of management for *Phytophthora ramorum* for the EU. Deliverable Report 28. EU Sixth Framework Project RAPRA.

Saunders, C.J. (2010a) Rhododendron control – mechanical methods treatment. Technical Development report FCPR002. Forest Research, Dumfries.

Saunders, C.J. (2010b) Rhododendron control – lever and manual pull methods. Technical Development report FCPR012. Forest Research, Dumfries.

Scottish Executive (2004) Scotland's biodiversity – It's in you hands. Scottish Executive, Edinburgh.

Scottish Executive (2006) The Scottish Forestry Strategy. Forestry Commission Scotland, Edinburgh.

Searle, S., 1999. Controlling Rhododendron at Windsor. Enact 7, 15–16.

Singleton, P., Rawlins, M., 1999. From pest to peat. How rhododendron has been managed at Roudsea Moss NNR. Enact 7, 17–18.

Smout, T.C., MacDonald, A.R. & Watson, F. (2005) A history of the native woodlands of Scotland, 1500-1920. Edinburgh University Press, Edinburgh.

Stephenson, C.M., MacKenzie, M.L., Edwards, C. & Travis, J.M.J. (2006) Modelling establishment probabilities of an exotic plant, *Rhododendron ponticum*, invading a heterogeneous, woodland landscape using logistic regression with spatial autocorrelation. Ecological Modelling 193, 747-758.

Stockan, J.A. & Fielding, D. (2013) Review of the impact of riparian invasive non-native plant species on freshwater habitats and species. CREW report CD 2013/xx.

Stout, J.C. (2007) Pollination of invasive *Rhododendron ponticum* (Ericaceae) in Ireland. Apidologie 38, 198-206.

Tabbush, P.M. & Williamson, D.R. (1987) *Rhododendron ponticum* as a forest weed. Forestry Commission Bulletin 73. HMSO, London.

Thompson, R. (2013) Neighbouring populations of Rhododendron – implications for successful eradication on the NFE. Unpublished draft report. Forestry Commission Scotland.

Thompson, R. (2013) Carradale site visit 19 October 2012. Unpublished draft report. Forestry Commission Scotland.

Thompson, R., Humphrey, J., Harmer, R. & Ferris, R. (2003) Restoration of native woodland on ancient woodland sites. Practice Guide. Forestry Commission, Edinburgh.

Turner, J.S. & Watt, A.S. (1939) The oakwoods (*Quercetum sessiliflorae*) of Killarney, Ireland. Journal of Ecology 27, 202-233.

UK Biodiversity Action Plan (1994) Biodiversity: the UK action plan. HMSO.

Venette, R.C. (2009) Implication of global climate change on the distribution and activity of *Phytophthora ramorum*. USDA Research Forum on Invasive Species.

Webber, J. (2008) Update on *Phytophthora ramorum* and *P. kernoviae*. Technical seminar 11 June 2008. Inveraray, Forest Research.

Webber, J. (2010) Advice on replanting sites affected by *Phytophthora ramorum*. Forestry Commission, Edinburgh.

Webber, J.F., Mullett, M. & Brasier, C.M. (2010) Dieback and mortality of plantation Japanese larch (*Larix kaempferi*) associated with infection by *Phytophthora ramorum*. New Disease Reports 22, p. 19.

Welch, D., Carss, D.N., Gornall, J., Manchester, S.J., Marquiss, M., Preston, C.D., Telfer, M.G., Arnold, H. & Holbrook, J. (2001) An audit of alien species in Scotland. Review No. 139. Scottish Natural Heritage, Battleby.

Wester Ross Biodiversity Group (2004) The Wester Ross biodiversity action plan. Highland Biodiversity Project.

Williamson (2002) Alien plants in the British Isles. In: Pimental, D. (Ed.) Biological invasions. Economic and environmental costs of alien plant, animal and microbe

species. CRC Press. pp. 91-112.

Willoughby, I. & 13 others (2004) Reducing pesticide use in forestry. FC Practice guide. Forestry Commission, Edinburgh.

Wong, J., Youde, E., Dickenson, B. & Hale, M. (2002) Report of the rhododendron feasibility study. Prepared for the Beddgelert Rhododendron Management Group by the School of Agricultural and Forest Sciences, University of Wales, Bangor.

Woodland Trust (2005) The conservation and restoration of plantations on ancient woodland sites. Woodland Trust.

23 Appendix 1. History of rhododendron control

The earliest description of the ecological damage caused by rhododendron was in an account of the Killarney oakwoods of Ireland in 1939 (Turner and Watt, 1939). A 1930 report on Stapleford Wood, an ancient woodland site in Lincolnshire, also notes the negative effects of rhododendron in relation to access for shooting and describes costly control measures needed to maintain rides (Dehnen-Schmutz and Williamson, 2006). Efforts to remove rhododendron from Stapleford Wood continue to this day (Forestry Commission England press release 2011).

The Forestry Commission became concerned about the impact of dense rhododendron on restocking of commercial plantations and on restricting access for thinning and were already aware of the high cost of clearance by 1930 (Miller, 1954). In Glen Garry between 1930 and 1936, FC attempted to reduce costs by cutting 30 foot wide strips and leaving 20 foot wide rhododendron hedges upon which were piled the cut material. Costs were also saved by not needing to burn the cut material (see Journal of Forestry Commission 21, 1950).

The first chemical trials were undertaken at Bramshill Forest, Hampshire in 1949. A range of herbicide treatments were tested on seedlings, large and small bushes, cut stumps, re-growth and basal bark (Holmes, 1957). Ammonium sulphamate was the only chemical to provide effective control on seedlings, re-growth, cut stumps and small bushes. Spraying large standing bushes and basal bark spraying proved to be either impractical or ineffective. Further experiments in the best control techniques took place at Hempsted Forest and other locations in Kent between 1950 and 1952 (Brown, 1953; Miller, 1954). Here they tested the efficacy of mechanical clearance (bulldozers, grubbers, rotavators, winches) and the use of herbicides. They quickly found that mechanical treatment resulted in re-growth from buried fragments and that the use of bulldozers to clear the debris resulted in the loss of a significant part of the humus layer with consequent effects on future tree growth. Chemicals were found to be very costly and best utilised by targeting cut stumps or spraying small bushes.

On a smaller scale, at Benmore and Carradale in Argyll, Miller (1954) reported that “maiden plants of considerable size were totally eradicated by pulling them out by hand”.

The FC also considered controlling rhododendron using evergreen shade trees (especially *Tsuga*, *Abies grandis, Thuja plicata, Pinus radiata* and Douglas fir) although it was known this could never be a complete substitute for other treatments. However, following the strip cutting at Glen Garry, Douglas Fir was planted in 1930-36 and by 1954 the shade became so dense that all rhododendron re-growth had been suppressed and some of the narrower uncut strips had been killed (Miller, 1954).

By the 1950s, some private estates were also interested in control measures; for example, Argyll Estates in 1950 and the Windsor Estate (Dehnen-Schmutz and Williamson, 2006; Searle, 1974). Reasons for controlling rhododendron included ecological impacts and the suppression of native species, reducing access for harvesting and planting, impairing the growth of commercial trees, creating a fire risk and harbouring anti-social activities.

Early pioneering work on sensitive conservation sites included rhododendron control in National Nature Reserves in Snowdonia in the early 1970s (Jackson, 2008) and the clearing of rhododendron from Roudsea Wood and Mosses NNR (Singleton & Rawlin, 1999). At Roudsea, dense rhododendron stands had invaded fragile raised bogs which had dried out as a result of past drainage work. The rhododendron had smothered the native vegetation and damaged the natural hydrological cycles of the bog. Work began in 1981 and continues through to the present day and involved cutting, burning and spraying re-growth in order to remove all woody material and restore the peat bog vegetation.

In Snowdonia National Park action has been taken against rhododendron for over 30 years and yet much still needs to be done. There is now a Park-wide strategy for rhododendron control (see Appendix 2).

Many of the early control schemes were piecemeal. On conservation sites, volunteers were often used.

The Nature Conservancy Council attempted to control rhododendron in Coedydd Maentwrog National Nature Reserve (Wales) in 1971 by experimenting with chemicals (Jones, 1974) and at Beinn Eighe and the Loch Maree area in the 1980s (T. Clifford, *pers. comm.*).

There was a significant increase in the scale of rhododendron clearance from the mid 1990s when targeted funds became available through the EU LIFE Nature Programme, EU Objective 1/ERDF, SFGS/SRDP and SNH discretionary funds. The principal LIFE project was aimed at the restoration of the Atlantic oakwoods; this included extensive operations to control rhododendron at several Natura and other sites in Wales, England and Scotland. Two of the Scottish sites were Sunart and Loch Maree; these involved a 6 year control programme. An account of the work at Sunart is given in Appendix 2.

During the past 80 years efforts have been made to control rhododendron at numerous locations and by private landowners, local authorities, forestry commission and conservation NGOs. Volunteers are often used by charities to assist with control work on nature reserves. For example, the Groundwork volunteer teams in the Killarney oakwoods in Ireland have cleared 40% of the infestation (Barron, undated). Although successful in some cases volunteer effort has not been found to be the most effective means of increasing control but may be the only option when funds are scarce (Dehnen-Schmutz et al, 2004).

24 Appendix 2. Case studies

24.1 CASE STUDY 1: Rhododendron control on Ardtornish Estate

This project aimed to eradicate *Rhododendron ponticum* from 2000 ha of affected land within the 14,000 ha privately-owned Ardtornish Estate in Lochaber. Funding of £140,000 was obtained via SNH and ERDF Objective 1 programme for the Highlands & Islands. This funding paid for all labour, machinery, equipment and training, while the estate was responsible for project design, implementation, management and administration. The total project cost between 1995 and 1999 was about £149,000 (Robertson, 1999).

Between 1995 and 1999, all rhododendron was treated and re-growth sprayed 1-3 times. Control operations began in the core areas of seed-producing plants to minimise re-colonisation of peripheral areas. Most of the treatment was undertaken by cutting, either by chainsaw or teams of casual unskilled employees working irregular hours using hand tools. Plants under 1 metre in height and re-growth were sprayed with glyphosate. Some rhododendron was treated using a mechanical flail mounted on a tracked excavator; this was efficient only on gentle terrain.

77% of the grant funding was allocated to paying 17 local employees over a period of four years.

Some cut stump treatment was tried in less accessible areas where it would be difficult to return with a sprayer. However, **stump treatment was found to be costly and impractical** because the stump had to be treated immediately after cutting and could not be applied in rainy weather.

Brash was either burnt on site, mechanically flailed (in areas accessible to the excavator) or cut for firewood (if accessible). **Disposal of cut material by stacking and burning required much more labour than the cutting**.

Site recovery after control was variable. Some sites have some moss regeneration and a few spruce seedlings but little else. On more fertile ground, particularly where the soil had been disturbed by the mechanical flail, and on fire-scars, regeneration of grasses and native trees was common.

The estate has maintained its long-term commitment to control rhododendron by monitoring on a 4-cycle cycle. Every year, an estate employee hand-pulls seedlings over 25% of the estate. **Even after 15 years of zero seed production, seedlings are still being found up to 1 km from untreated stands on neighbouring ground.**

Sources as cited and *pers. comm.* Angus Robertson.

24.2 CASE STUDY 2: Rhododendron control in Glen Creran

The rhododendron in this small glen in north Argyll is largely isolated from nearby populations. As a consequence, eradication may be more readily achievable in Glen Creran than for many other populations.

Over 200 hectares in the glen support some rhododendron. The affected land-holdings include 187 gross hectares on the National Forest Estate (NFE), 30 – 40 hectares on private holdings (mainly gardens) and a privately-owned estate with a significant affected area.

The glen's native woodlands are of prime conservation importance and include a number of designations (SSSI, SAC, NNR). Rhododendron removal is consequently a high priority.

Some owners have undertaken control work over the past 10-15 years. A few years ago, Forestry Commission Scotland initiated a major control programme on the NFE. To date, they have carried out initial treatments on the densest stands (about 34 ha), and aim to eradicate rhododendron on their holdings in the glen. However, much of the NFE abuts gardens and other private land with rhododendron. Without the cooperation of neighbours, rhododendron will re-invade NFE.

In 2011, a meeting was convened with residents and land-owners in an endeavour to secure agreement with all affected holdings. In 2012, a contractor was appointed by FCS to make informal contact with owners and assess their views on participating in a collaborative control project throughout the glen.

The contractor's report (Argyll Woodlanders, 2012) concluded that there was an overwhelming consensus in favour of eradication, and that most owners were prepared to enter into a collaborative control programme. However, there were concerns about the complexity, conditions and cash-flow problems attached to SRDP. At least one landowner was not prepared to pursue a grant application unless there were significant changes in the new funding arrangements.

In addition, a different form of funding would be required for gardens that were ineligible for SRDP. The costs of this were estimated at £22,000. Some funds might also be required to supply alternative shrubs in some gardens to replace the rhododendron removed.

A project to eradicate rhododendron from the whole glen will require careful coordination. Some funds have already been obtained to tackle the gardens, and FCS is also keen to engage volunteers and involve the local community, for example in helping to report and monitor re-growth. Such a project may be offer training opportunities and serve as a demonstration of best practice for a landscape scale control programme.

Sources as cited in text, and *pers. comm*.: Bob Black, Elaine Jamieson, Ian McKee, Richard Thompson.

24.3 CASE STUDY 3: Rhododendron control in Snowdonia

It is estimated that 2075 ha of land are affected by *Rhododendron ponticum* in Snowdonia National Park (SNP) in North Wales. Of this, 21% is NFE, 15% is owned by NGOs and the remainder is privately owned (26% woodland; 37% farmland). Less than 1% is in gardens.

Rhododendron poses a major threat to the Park's Atlantic oakwoods, while its economic impact is felt in agriculture (loss of grazing and associated subsidies), in forestry (increased costs of establishment, spread of *Phytophthora*) and recreation (access).

Attempts at controlling rhododendron in SNP began in the early 1970s. In 1986, a comprehensive survey was undertaken, and the Snowdonia Rhododendron Group was set up to plan and coordinate a control programme. This is led by the Park Authority (SNPA), who commissioned the preparation of a control strategy (Jackson 2008).

A substantial amount has been spent on rhododendron control; this has been largely funded by EU Objective 1, SNPA core funds and Countryside Council for Wales capital grants (claimed and administered by SNPA). The SNPA continues to seek match funding.

The blooms have been a popular tourist attraction for many years, but public attitudes are changing, with a growing awareness of the negative impacts on landscape and environment. In a survey of 100 landowners, over 95% were sympathetic in principle to controlling rhododendron.

Some owners of large gardens have expressed concern that the removal of rhododendron will result in a loss of privacy, but all accept the rationale for control. SNPA is exploring the possibility of providing other shrubs to garden owners to replace cleared rhododendron. Control on farmland has been assisted by concern that farm payments might be in jeopardy from cross-compliance regulations.

The Park has trialled and refined a number of control methods over the years. Stem injection now accounts for 40-50% of control operations. For many stands this method has been found to be the most cost-effective. The typical cost per hectare is £3,000, compared to £5,000 for cutting. However, it was found that stands with a very high stem density are unsuited to stem injection.

The Park's experiences with rhododendron control particularly highlight the importance of observing two guiding principles:

- eliminate seed sources near cleared sites
- ensure timely follow-up and maintenance.

Where these criteria have been neglected, subsequent control costs have escalated. Until these critical conditions can be guaranteed, it is considered prudent to delay treatment.

Sources as cited and *pers. comm*. D. Rhys Owen

24.4 CASE STUDY 4: Rhododendron control in Sunart

Rhododendron ponticum affects over 1135 ha of land scattered over a very extensive area around Loch Sunart in Lochaber. Of this, over 30% is within the Sunart SAC which contains the richest complex of Atlantic bryophyte-rich old sessile oak woods in the UK. The landscape-scale project that has been operating in Sunart for almost 20 years has undoubtedly been the most ambitious rhododendron control programme in Scotland.

The earliest major control work was initiated on private land in the mid 1990s, as part of the EU LIFE Atlantic oakwoods restoration project (LIFE 2), and subsequently by the Core Forest Site project (LIFE 3) (Clifford, 2002; Baarda, 2006). LIFE funding was used to fund operations in the Sunart SAC that were ineligible for forestry grants. After LIFE, 53 ha (at a cost of £110,292) of rhododendron control were funded by SFGS and only one 62 ha control scheme has been funded through SRDP.

Between 1999 and the present, FC tackled rhododendron on NFE within the SAC and the wider Sunart area. Substantial areas of very dense rhododendron have been cleared, seedlings have been removed and extensive follow-up treatment has been undertaken across a gross area of 1135 ha in the Sunart area at a cost of £254,512 (this sum also includes some training and survey work). Follow up work continues, but nowhere has full eradication yet been achieved.

In 2008, FCS funded a survey of rhododendron through the Sunart Oakwoods Initiative (Kennedy, 2008). This found that follow-up on treated sites had been undertaken with varying degrees of commitment and success. Small owner-managed sites with easy access were generally the most successful. It also recorded the willingness of owners to undertake rhododendron control. The Highland Rhododendron Project digitised Kennedy's maps and maintained contact with owners, allowing information of land-holder engagement data to be updated, and further developing the landscape management approach to rhododendron control.

Implementation of this landscape-scale rhododendron control project has faced a number of challenges. The greatest of these is the complexity of land ownership, tenure and management systems. Affected land-holdings include NFE, SNH, conservation NGOs, large private estates, crofts and common grazings, community-owned land, Council land, private gardens and islands. Over 100 land-holdings lie just within or adjacent to the boundaries of the SAC. Control operations have also had to contend with difficult terrain including offshore islands, rocky shorelines and gorges.

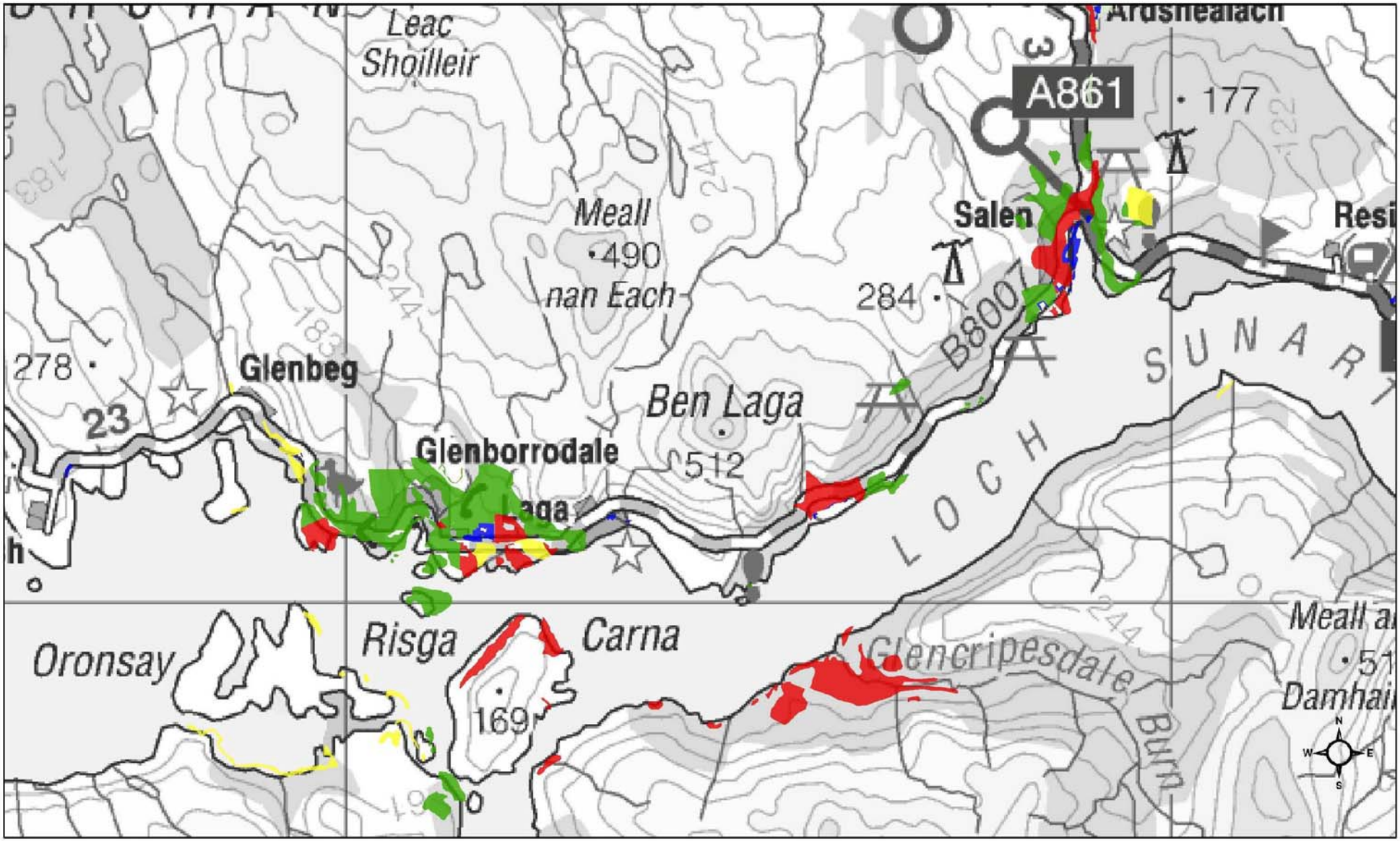
Despite the employment of a community project officer, an education / interpretation officer, public events, awareness-raising, personal contacts, and 100% funding over a number of years, over 30% of owners do not wish to participate in the project. These include absentee owners who could not be contacted or did not respond, and building plots of unknown ownership. 10% of owners are sympathetic and had considered control but

did not wish to apply for SRDP, while 4% were small parcels of land ineligible for SRDP (Highland Rhododendron Project, 2012). Regrettably, the land-holdings who would not (or could not) participate in the project are scattered throughout the Sunart area, often adjacent to treated sites (see map below). This has hindered attempts to pursue a landscape scale eradication programme, and buffer zones with regular monitoring are required at most control sites.

Although a considerable sum has been spent clearing rhododendron on private and NFE land, re-growth and re-invasion are continuing apace on private land. Follow-up operations will continue to be required for many years and, where untreated seed sources remain, for the foreseeable future (Thompson, 2013).

Sources as cited in text, and *pers. comm.*: Phil Baarda, Ian Collier, Donald Kennedy, Kenneth Knott, Lorraine Servant, Richard Thompson, Malcolm Wield.

Note that the map covers only part of the Sunart area; it was digitised by the Highland Rhododendron Project from data presented in Kennedy (2008).



Highland Rhododendron Project-
Sunart Uptake April 2012

0 1.5 3 Kilometers

- Owner not interested / can't be contacted / no resolution reached
- Owner interested / considering control
- Under active management / framework agreement / SRDP approved
- Small land parcels < 1ha / mulitple owners

HIGHLAND BIRCHWOODS
Coille Beithe na Gàidhealtachd

25 Appendix 3. Policies affecting rhododendron

Convention on Biological Diversity (1992). Article 8h requires signatories to control, eradicate and prevent the introduction of alien species that threaten ecosystems, habitats and species. As a signatory, the UK committed to halt the loss of biodiversity, and specifically where caused by invasive non-native species. The UK subsequently published its Biodiversity Action Plan (UK BAP, 1994). The Convention underpinned subsequent legislation such as the EU Habitats Directive 1992 which also requires member states to control the introduction and spread of non-native species.

Natura 2000. This European designation under the Habitats Directive required the UK to bring a network of statutory designated sites into favourable condition by 2010. This generated a number of control schemes aimed at eradicating rhododendron within these sites.

The **Scottish Biodiversity Strategy (Scottish Executive, 2004)** stressed the need to improve legislation to minimise the detrimental impacts of non-native species. Greater awareness and knowledge of these species was also necessary.

Local Biodiversity Actions (LBAPs) aimed to deliver key objectives of the Strategy through targeted action for species and habitats. For example, the Wester Ross LBAP identifies rhododendron as causing damage to native flora; it specifies control areas such as Loch Maree, Talladale and Torridon, and proposes partnerships between FCS, NTS, SNH, HC and land managers (Wester Ross Biodiversity Group, 2004). The last review of the Highland LBAP further emphasised the need to continue with action against non-native species and considered that "the single biggest non-native species threat to terrestrial Priority species present in Highland is posed by *Rhododendron ponticum*. Therefore, to strengthen links with the UK and Scottish BAPs, it is considered that Rhododendron should be the first invasive non- native species tackled" (EnviroCentre, 2006).

One of the key themes of the **Scottish Forestry Strategy (Scottish Executive, 2006)** is to halt the loss of biodiversity in native woodlands by targeted action on invasive species such as *Rhododendron ponticum.*

The SFS Implementation plan (2012–15) and Progress report (2011-12) reports that FCS has continued to develop the programme of work to control rhododendron on the national forest estate, and are working with neighbours to identify areas for collaborative effort. FCS has developed a co-ordinated approach to managing non-native species, through both new regulatory powers under the Wildlife and Countryside Act 1981 and more accessible advice and promotion (FCS, SNH, SEPA, NGOs). For 2012-13 the Implementation Plan proposed a national strategy for the control of rhododendron.

SNH's Species Action Framework (2007 - 2012) specifically identified rhododendron as an invasive species that damaged biodiversity interests and that targeted action over the five year framework period would improve species and habitat diversity.

The **Invasive Non-Native Species Framework Strategy for Great Britain (GBNNSS, 2008)** provides a framework for a more co-ordinated and structured approach to dealing with non-native species. It advocates contingency planning and improved capacity to act decisively which will enable rapid responses with a view to eradicating newly arrived invasive species. There would be more targeted and efficient control, mitigation and, where both necessary and feasible, eradication of established invasive non-native species. It identifies the need for greater public awareness, more strategic research and proposals for an improved legislative framework. The success of the strategy would involve a partnership approach among all land holders, and include monitoring of control programmes and a government mechanism to operate the scheme.

The **EU 2020 Biodiversity Strategy** states that "Invasive alien species (IAS) pose a significant threat to biodiversity in the EU, and this threat is likely to increase in the future unless robust action is taken at all levels to control the introduction and establishment of these species and address those already introduced. IAS cause some €12.5 billion worth of damage each year in the EU. Although the challenges posed by IAS are common to many Member States, with the exception of legislation concerning the use of alien species in aquaculture there is currently no dedicated, comprehensive EU policy to address them. This strategy proposes filling this gap with a dedicated EU legislative instrument which could tackle outstanding challenges relating inter alia to IAS pathways, early detection and response and containment and management of IAS." The EU has recognised the increasingly serious problem of invasive alien species in Europe and is currently working on a dedicated legislative instrument on Invasive Alien Species which is due to be adopted in 2013. Target 5 is one of six key objectives that the Commission adopted in its Biodiversity Strategy of 2011 (EU, 2011).

> *Target 5: "By 2020, Invasive Alien Species and their pathways are identified and prioritised, priority species are controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS."*

26 Appendix 4. Funding control on private land

Over the years, various financial incentives have been made available to help private landowners to undertake rhododendron control. Some grants are deemed by users to have been better targeted, more cost-effective and more applicant-friendly than others. These packages are briefly described, and their relative merits and demerits.

Woodland Grant Scheme. WGS 1 operated between 1988 and 1991, and WGS 2 from 1991 to 1994. WGS 3 (1994- 2003) offered Woodland Improvement Grants (WIG) for rhododendron control based on up to 50% of net costs. Uptake for rhododendron control under this scheme was limited.

LIFE. Since 1992 the LIFE-Nature Programme, alongside other EU financial instruments, has funded projects aiming to restore, preserve or halt the decline of forest biodiversity in Europe in the context of the Community-wide Natura 2000 network of Special Conservation Areas.

In Britain, the principal LIFE project was the restoration of the Atlantic oakwoods which involved extensive control operations to eradicate rhododendron at several Natura and other sites in Wales, England and Scotland. Two of the Scottish sites were Sunart and Loch Maree, each involving a 6 year control programme. This was followed by a 10-year management plan in 2001 to monitor the sites (EC, 2006). A follow-up ex-post study of the project was carried out in April 2006 by the LIFE external monitoring team. The study focused on Scotland, in particular the Sunart SAC area, where an extensive post project conservation programme was initiated. LIFE funding variations included costs to fund ongoing work beyond the 6 year LIFE programme (Burton & Carpenter, 1999).

Objective 1 European Development Fund for Highlands and Islands. Operating from 1994 to 1999, funds were only applicable to the Highlands and Islands Objective 1 area. Project funds were based on actual cost estimate. Rhododendron control was funded at Ardtornish and Glengarry.

SFGS opened in 2003. A stewardship grant for the care and improvement of existing woodlands would help fund the removal of invasive species, including rhododendron. Grants payable were based on 60% of standard costs, except on Natura sites, National Scenic Areas and certain local authority designations where 90% of costs were paid. There was a significant uptake of this grant by private landholders for the control of rhododendron. SFGS was closed without advance notice in 2006.

Scottish Natural Heritage has funded rhododendron control on a number of designated sites through Management Agreements; agreed programmes of work are usually negotiated with owners on a year-by-year basis.

SNH's Species Action Framework (2007–2011) funded rhododendron control work in SSSIs and SACs, but only if there was no other available source of funding and the work had to be carried out urgently to prevent

habitat decline. It did fill a funding gap between the end of the SFGS and the beginning of the SRDP in 2008-09. Rhododendron control on three SSSI / SAC woodland sites in Jura, Loch Etive and Mull were funded under SAF.

The **Scottish Rural Development Programme (SRDP)** opened to applicants in 2008. At the outset, rhododendron control was only funded under **SRDP-Rural Priorities – Control of non-native species**. This Option funded targeted control of five invasive non-native species including *Rhododendron ponticum* in specified areas. The aim was to help protect designated sites, Biodiversity Action Plan priority species and habitats, and assist rural land managers that needed to control one of the named invasive non-native species as part of another SRDP management option. At the end of Year 5 there must be no Rhododendron present on the treated area.

Grants are provided under Rural Development Contracts – Rural Priorities, which opened to applicants in 2008. RDC sources funding from the European Agricultural Fund with match funding from the Scottish Government. SRDP included three main Options for rhododendron control.

SRDP-Rural Priorities-WIG-Woodland Habitats and species requires a rhododendron management plan demonstrating a long term strategy to eradicate and control invasive rhododendron, ideally in collaboration with neighbours (if applicable). After 5 years, contracts require there to be no rhododendron on the site. No minimum area.

SRDP-Rural Priorities-WIG-Non-woodland habitats aimed at restoring habitats or species that are a priority under the UK BAP. It applies to non-woodland and associated open ground provided this is integral to the woodland (*i.e.* either surrounded by woodland or comprising the tree-line/moorland fringe), but not more than 20% of total area. There is no minimum area. It includes rhododendron removal at the same rates as SRDP woodland.

In October 2012, SRDP forestry grant applications were either modified or restricted to avoid overspend on forestry options (FCS Briefing Note 6, 2012). Applications for WIGS (Woodland habitats and species and Non-woodland habitats) were closed except for rhododendron removal where this was associated with a Statutory Plant Health Notice, for example for *Phytophthora* spp. (FCS, 2012). See Section 9.