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Assessment of plant biosecurity risks to Scotland from large-scale tree plantings for environmental benefits

PHC2019/06: Project Final Report

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Forest Research

Royal Botanic Garden Edinburgh

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Content

1 Executive Summary

This report centres on the assessment of tree and plant biosecurity risks to Scotland arising from large-scale tree planting schemes which aim to deliver environmental benefits. More specifically, it details a series of case studies and examines risks associated with these schemes, levels of awareness around pests and diseases, and how the decisions and actions of those involved can serve to reduce or exacerbate pest and disease related threats, and long-term tree health. By highlighting best practice and lessons learned, we hope to ensure that future planting schemes can be successful and, importantly, reduce the likelihood of pests and diseases being introduced and spread into the wider environment.

We feature five cases studies from across Scotland, each unique in respect of their combination of location, site conditions, ownership, management objectives, species choice, supply chains and management activities. Moreover, the schemes are diverse in terms of when the planting occurred, with some having been completed, others in progress and one yet to commence. However, all are – or will become – large-scale in terms of the number and expanse of trees, and the intention to deliver environmental benefits (sometimes alongside other benefits).

Data collection involved interviews with key stakeholders, selected on the basis of their role in decision-making and/or activities in the various phases along the supply chain. Additional sources, such as management plans and planning documents, were used to clarify, substantiate and augment the responses of interviewees. Audio recordings were transcribed verbatim and collated with the key documents to be analysed thematically using qualitative analysis software. The resultant coded text forms the basis of our findings.

Each case study is given context in the form of a summary of the site characteristics and the owner's objectives. We then outline several facets which may influence the likelihood of pest and disease related incidences, namely i) planting activities, ii) tree species featured, iii) size and complexity of the supply chain, and iv) the actors' considerations around tree health and biosecurity. For each, we detail the drivers and challenges underpinning decisions and actions. We conclude each case study with perspectives on the scheme's success and a series of reflections summarising the key points around biosecurity and tree health. Overall conclusions derived from the collective case studies are featured at the end of the report. In addition, we offer the following reflections:

Reflection 1: Those selecting nurseries and contractors to become involved in large-scale planting schemes should seek to partner businesses with the best biosecurity practices. In lieu of definitive guidance (Reflection 2), this may be achieved through the use of frameworks and scoring during a selection process. In the case of growers, participation in the Plant Healthy Certification Scheme signals a commitment to best biosecurity practice and could in future be favourably considered during scoring and selection decisions.

Reflection 2: There is a need for clear guidance about what constitutes best biosecurity practice, e.g. to allow those overseeing large-scale planting schemes to identify and select suitable nurseries. The Plant Health Management Standard underpinning the Plant Healthy Certification Scheme suggests this may be evidenced through a business' 'Plant Health Policy',

which includes a Pest Risk Analysis and by extension, controls and management systems for an appropriate level of protection against pests. However, specific details about what such precautions look like in practice are not well-defined. Thus, those wishing to partner with the most biosecure nursery make their selection somewhat subjectively. A flier/booklet describing key actions and procedures to look out for would allow for more informed and objective choices when selecting a supplier.

Reflection 3: Where it is necessary to rely on several nurseries to supply trees, it is prudent to ensure that a nursery with the best biosecurity practices handles those species most susceptible to pests and diseases.

Reflection 4: Measures should be taken to ensure trees are suited to the conditions of the planting site so as to reduce the likelihood of stress and susceptibility to pests and diseases. This may involve a specialist assessing the soil at a fine-scale and consideration of climate (including future conditions). Use of sterilised growing mediums matching local soil conditions can also reduce the risk of introducing pests, diseases and weeds, and the possibility of acid shock.

Reflection 5: The supplier and recipient should cooperate to manage logistics in order to prevent trees facing unnecessary stress prior to planting, e.g. prolonged periods without care.

Reflection 6: Where feasible, quarantining of received trees by the recipient should be considered before they are introduced to the wider environment. This should involve separation of batches from different suppliers and holding in a suitable area, i.e. where there is low risk for cross-contamination through puddling and rain-splash.

Reflection 7: Recipients of tree deliveries should confirm that they are consistent with the agreed specification. If possible, the recipient and supplier should check/confirm the specifics prior to shipping.

Reflection 8: A high level of tree species diversity should be sought so as to increase a scheme's resilience to existing and future pests and diseases i.e. 'don't put all of your eggs in one basket'. This is largely up to those planning a scheme, yet choices may be restricted by a funder's stipulations.

Reflection 9: Where it is feasible to substitute species susceptible to pests and diseases with alternatives without unduly compromising the management objectives, this should be considered.

Reflection 10: If susceptible tree species are to be used (e.g. in attempts to conserve threatened provenances or habitats), it is often advisable to locate them away from areas regularly frequented by site users, and to space batches of the species at considerable distance from one another, as well as existing populations.

Reflection 11: Where feasible, seeds should be collected and grown on site to reduce introductions of pests and diseases, and to help ensure trees are suited to the site conditions.

Reflection 12: Scottish nurseries and those planning large-scale planting and restocking should seek to participate in the forthcoming Nursery Notification Scheme so as to help address the familiar difficulty of sourcing and supplying adequate tree stock.

Reflection 13: Sites located in regions with existing pests and diseases and receiving many visitors face heightened risk. For these sites, precautions such as outreach, cleaning/disinfecting stations and information boards should be considered. However, it will often be more effective to try and segregate users from vulnerable species (Reflection 10).

Reflection 14: Management and monitoring plans should be put in place to help ensure any threats to tree establishment and long-term health can be quickly identified and addressed.

Reflection 15: A single individual should have responsibility for a scheme's biosecurity. They should have oversight and input into who is involved at each phase and consider collecting evidence of good knowledge and practice (prior to and during involvement). Provision of detailed written instructions and supervision of actors working on the site should be considered, even if time allows only for intermittent spot-checks.

Reflection 16: Those collating information on pests and diseases threatening UK treescapes should strive to (or continue to) produce and/or better signpost accessible guides to those involved in large-scale planting schemes. Information on emerging threats and likelihood of introduction and spread in future years is likely to be most influential in driving change in decisions and management actions.

Reflection 17: Those involved in large-scale planting schemes must find or be allowed time to keep abreast of information on existing and emerging pests and diseases threatening UK treescapes, as well as the biosecurity practices that serve to mitigate both known and unknown threats.

2 Introduction

Scotland's Forestry Strategy 2019-2029 outlines that over the last 100 years, forest and woodland cover in Scotland has increased from around 5% to 19% (to around 1.4 million hectares). While this percentage is high compared to other UK countries, it remains well below the European Union Member average of 38%. At the time of writing, the Scottish Government has pledged to grow the country's woodland creation each year from 12,000 hectares in 2020/21 to 18,000 hectares in 2030/31. Carbon sequestration to help mitigate climate change provides the main impetus for this enormous effort, yet there is also recognition among government and wider society of an opportunity to provide significant biodiversity, economic and social benefits. Indeed, some of Scotland's largest recent, current and planned woodland creation schemes centre on or integrate an ambition to provide environmental benefits. However, if such schemes are to be successful and contribute to government targets, it is imperative that many of the trees featured in such schemes are able to establish and remain in good health. Moreover, the biosecurity considerations for these schemes may have consequences for the wider environment if, for example, pests and diseases are introduced and spread across and beyond the scheme. Given the growing number of tree pests and diseases threatening UK treescapes as a result of increasing global trade and changes to species' natural ranges through processes such as climate change, biosecurity for tree health is of paramount importance to those involved in large-scale planting schemes. This includes stakeholders deciding which species to plant, who source and grow the trees, those transporting trees from place to place, and individuals, organisations and businesses involved in on-site activities such as ground preparation, planting and aftercare, as well as recreational visitors.

Using a case study approach, the research detailed in this report attempts to provide an understanding of the biosecurity related risks associated with these schemes, and examines how the decisions and actions of those involved can serve to reduce or exacerbate pest and disease related threats. We feature five cases studies from across Scotland (Figure 1), each distinctive with respect to their combination of location, site conditions, ownership, management objectives, species choice, supply chains and management activities (spanning restoration planting of existing vulnerable habitats, new planting for habitat/native woodland creation, and commercial forests). Moreover, the schemes are diverse in terms of when the planting occurred, with some having been completed, others in progress and one yet to commence. However, all are – or will become – large-scale in terms of the number and expanse of trees, and the intention to deliver environmental benefits (sometimes alongside other benefits).

Data collection involved interviews with key stakeholders, selected on the basis of their role in decision-making and/or involvement in the various phases along the supply chain. Given the disparity in the size and complexity of the supply chains, the number of individuals differs from case study to case study. For more historic schemes/planting phases, it was not always possible to include all the key players. Those who did participate occasionally offered differing accounts of specific events and drivers. Additional sources such as management plans and planning documents were used to clarify, substantiate and augment the responses of interviewees (Table 1).

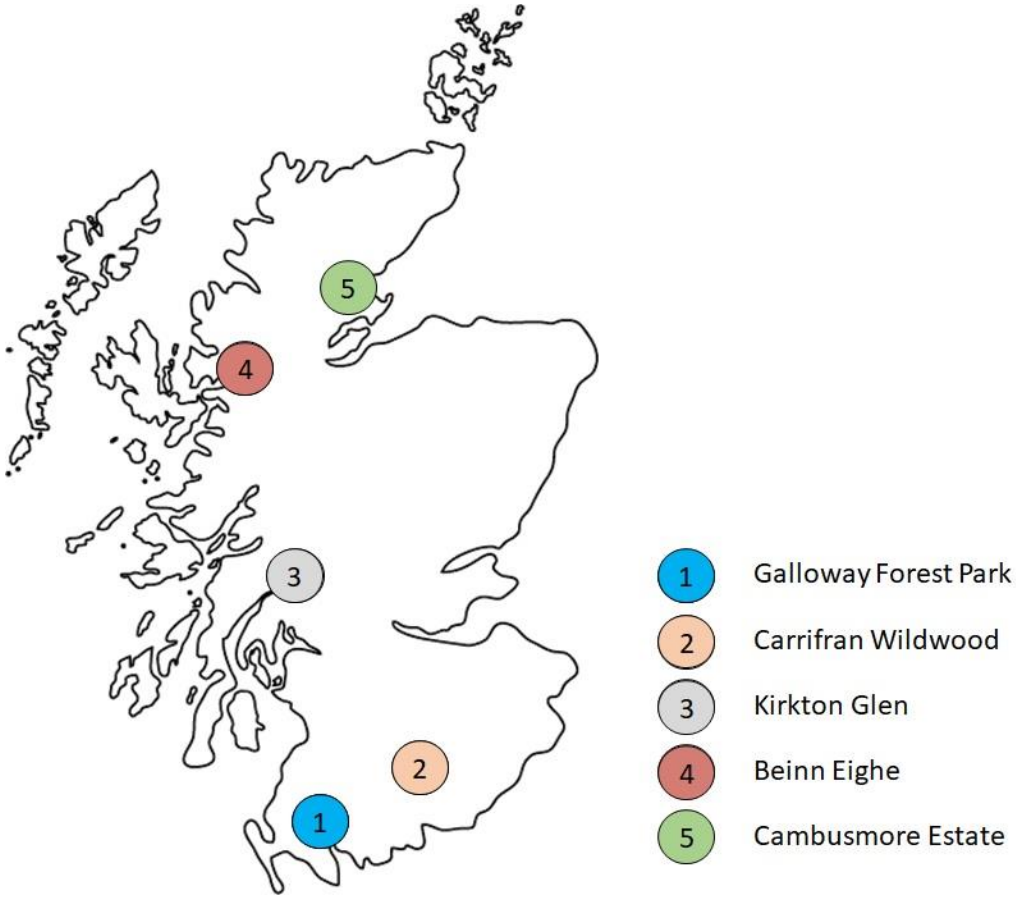

Figure 1 – Map of Large-Scale Planting Case Studies

Table 1 – Summary of Case Study Characteristics and Data Sources

Case Study Site	Key Characteristics	Planting Stage	Data
Galloway Forest Park	Habitat creation and connectivity over multiple Public Forest Estate sites, including one severely impacted by disease	Planting completed on featured sites, but more planting to occur with future rotations	5 interviews, Key documents
Carrifran Wildwood	Ecological restoration of upland farmland by a local charity	Large areas now planted, though additional planting and natural regeneration to follow	3 interviews, Key documents
Kirkton Glen	Diversification of a hill farm business by a land-based college	Planting completed, natural regeneration continuing	4 interviews, Key documents
Beinn Eighe	Ecological restoration and habitat creation on a National Nature Reserve, managed by an executive non-departmental public body	Planting of main areas completed. Approx. 3 years of more planting planned	2 interviews, 1 podcast, Key documents
Cambusmore Estate	Habitat creation on a private estate	Planting pending	4 interviews, Key documents

Audio recordings were transcribed verbatim and analysed thematically alongside the key documents using qualitative analysis software. The resultant coded text allowed us to reflect on where considerations and actions related to biosecurity and tree husbandry have been employed so as to minimise the introduction and spread of pests and diseases. We also consider where imperfect decisions were made and imperfect practices employed, and why this happened to be the case. In doing so, we are able to highlight good practice and lessons learned so as to inform those involved in future planting phases or on other planting schemes about how they can reduce the likelihood of experiencing and spreading tree pests and diseases. Moreover, by revealing overarching institutional and sectoral challenges and barriers, we offer government and other influential stakeholders' insights which can be used to shape policies and processes to improve biosecurity within large-scale planting schemes, and ultimately safeguard the wider landscape.

3 Case Study 1: Galloway Forest Park

3.1 Site Characteristics and Objectives

Galloway Forest Park was established in 1947, though many of its constituent blocks predate this designation. In all, the Park covers around 770 square kilometres, making it the largest forest in the UK. The site is overseen by Forestry and Land Scotland (FLS) whose remit involves managing and promoting Scotland's national forest estate: land, predominantly covered in forest, that is owned by the Scottish Government on behalf of the nation. This includes managing timber production, as well as conservation and biodiversity, recreation and tourism, renewable energy projects and working with communities.

The Galloway area has a wet maritime climate influenced by the Gulf Stream. Rainfall is relatively high ranging from 1200-2000 mm per annum while temperatures are relatively moderate and stable, providing ideal growing conditions for conifers. However, the area's deep peats and gley soils provide little support for tree roots. Combined with the strong Atlantic winds, these conditions leave trees at increased risk from exposure and windthrow. Nevertheless, Galloway Forest Park produces ~500,000 tons of timber in a typical year. In addition to timber production, tourism and community projects are emphasised in the Forest District's plans; the Forest Park welcomes ~800,000 visitors per annum for activities including hillwalking, wildlife viewing, salmon and trout fishing, climbing, mountain biking on the world-renowned 7stanes trails, and stargazing in the world's fourth official Dark Sky Park. Furthermore, there are plans to restore native habitats, including through the large-scale planting of appropriate sites. The focus herein is on two such schemes within the Forest Park, namely Loch Trool and Bennan Hill.

Planting on the Loch Trool site, specifically that immediately south of the Loch has been prompted by widespread infection of larch (*Larix*) stands by *Phytophthora ramorum* which spread rapidly across Dumfries and Galloway having first been found in the area in 2011. The statutory removal of the larch has increased the susceptibility of neighbouring stands to windthrow, including those comprised chiefly of commercial species such as Sitka spruce. This predicament has expedited restocking decisions and activities, while forcing managers to reconsider the types of benefits the site should provide.

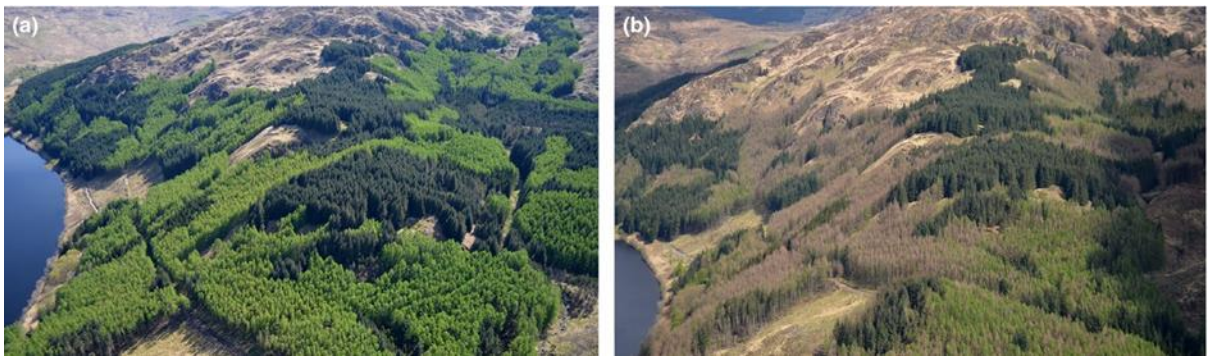

Figure 2– Loch Trool with (a) apparently healthy larch stands in May 2012 and (b) extensive dieback and mortality in May 2013. Source: Forestry Commission Scotland in King et al., 2015.

With the larch removed, the focus has shifted from commercial conifers to habitat expansion and connectivity, including linking of designated oak (*Quercus*) woods. While habitat and

ecological goals are the primary focus, it is acknowledged that some trees could serve a productive role in future years. There are also plans to maintain and improve existing visitor infrastructure across the site, for example by enhancing visual amenity, adding permanent open space, retaining mature trees, and creating a seasonal assortment of foliage colours.

The Bennan block lies South-east of New Galloway. Here the scheme in question involves the planting of 300 ha of new native woodland on Bennan Hill and the lower slopes of Benyellary. Inspired by Europe's Mountain areas, treeline woodland and montane scrub, the aim is to enhance the area's wildlife and landscape by replacing areas once closely packed with conifers with a more widely spaced and diverse range of native species. Planting will also serve to connect existing scattered semi natural ancient woodland SSSIs in the lower valleys and the slopes and hill summits. Planting density will vary to follow the natural landform and habitat type, while wet flushes and areas of peat remain unplanted so as to form a natural mosaic. Plans to enhance habitats for red squirrels (*Sciurus vulgaris*) and black grouse (*Tetrao tetrix*) also feature in the Land Management Plan, as does the enhancement of community access and enjoyment via improvements to path networks, increased open space and greater species diversity.

In both cases, the objectives have been set by the FLS Environment Team and the Delivery Forester, with consideration of overarching regional and national policies and objectives.

3.2 Planting Activities

On the Loch Trool site, planting of approximately 30,000 trees has occurred on the south side of the Loch using acorns collected from the adjacent oak woodlands in autumn 2016. By expanding the boundary of the planting beyond that previously occupied by the larch, it has been possible to increase the size of the restock site by several hectares. However, with the move from conifer to broadleaf species, it was acknowledged that the planting density would likely be substantially lower.

> *"In my experience we've not planted any commercial spacing broadleaf up in Loch Trool so I think most of the plans would have tied us down to something like about 1,200 stems per hectare, I think was a common broadleaf density. But equally in some areas, certainly over the years we had looked to get away with even lower densities and I'm thinking particularly at elevation where we're looking, or at that time we were looking for a phased gradual change in density from the upper elevation coops onto the serious amount of open ground that was up there."*

Mounding was carried out in areas where machines could gain access. Flat planting (as opposed to ploughing or mounding) occurred in those areas with steeper ground. This alternative is seen as complementary to FLS's wider objective of protecting and improving soil and water, which is particularly important in this catchment given the trout and salmon populations and the fishing they support.

> *"[We're] trying to minimise site and soil disturbance so you get that sort of environmental aspect, the more you do to a site the more you can tend to degrade*

the soil and site type. So obviously there's some element of trying to minimise that particularly in riparian zones where again a lot of our broadleaf are targeted."

The decision to flat plant was also deemed preferable to mounding from a landscape aesthetic perspective, providing a more desirable view for the many visitors using the trails extending from Glentrool visitor centre.

Figure 3 – Looking South across Loch Trool to the replanting area (image provided by research participant)

Recent planting on the montane Bennan site (post 2015) has sought to deliver a more widely spaced and diverse range of native species, replacing some areas of open ground once occupied by closely packed conifers. In total, the planting will create around 300 hectares of native woodland, at various elevations: downy willow (*Salix lapponum*) and juniper (*Juniperus*) have been planted on higher shallow soils around exposed rock; a roughly equal mix of aspen (*Populus tremula*), downy birch (*Betula pubescens*) and rowan (*Sorbus aucuparia*) have been planted in the treeline woodland with other native species of local origin such as sessile oak (*Q. petraea*), hazel (*Corylus avellana*), wych elm (*Ulmus glabra*), bird cherry (*Prunus padus*), hawthorn (*Crataegus monogyna*) and holly (*Ilex aquifolium*) on the lower slopes and richer soils, following the clearance of the conifer crops. Finally, eared and grey willows have started to naturally regenerate along the watercourses and are being diversified with a small number of less common creeping willow (*Salix repens*) and tea-leaved willow (*Salix phylicifolia*). The initial planting phase involved a total of 235,522 trees, with the aspen, downy birch and rowan mix in the treeline woodland accounting for around 78% of these.

Figure 4 – Typical montane habitat on the Bennan Hill site (image provided by research participant).

As with the Loch Trool site, difficult access and concerns around soil degradation limited the possibility of mechanical mounding. In fact, it is estimated that only around 5% of the trees have been planted with mounding, with the remainder being flat planted.

Both the Loch Trool and the Bennan sites were deer fenced in response to not only deer but also feral sheep and goats. However, tree guards and vole guards were not employed inside the fencing.

"You can't plant 60,000 [trees] on a site and expect anything to stay there if you don't put a fence around it."

"If you're putting your trees in over 300 hectares, that's a lot of vole guards. It's a lot of plastic. Again, the decision was taken over the cost of putting vole guards in, the cost of taking it away, the rubbish that it creates, and because the site wasn't a productive site so we didn't need to achieve stocking densities of 1,200 or 1,600 per hectare, we would be willing to accept losses"

3.3 Species Choice

Species selection for FLS sites involves deliberation by FLS's Environment Team, the Planning Forester and Delivery Forester (in this case, an individual with an ecological background). Their decisions are informed by walking the site and digging soil pits as well as through the use of the Ecological Site Classification decision support tool. In addition, consultation with internal and external stakeholders over a 12-month period is not uncommon for FLS sites. Ultimately, approval of the planting plans - including species choice - must be obtained from the regulating agency, Scottish Forestry.

On the Loch Trool site, larch had served as a deciduous conifer within the landscape providing an aesthetically pleasing contrast with the darker sitka spruce (*Picea sitchensis*) plantations. While the larch had occupied some of the area's most favourable sites for growing trees, an existing management agreement for the control of *Phytophthora ramorum* states that sanitation fellings (as with the larch) can only be replaced with an agreed list of species. Notably, restocking with Sitka spruce is not permitted. While any restocking decisions required careful consideration of the trade-offs and benefits, ultimately it was decided that the Loch Trool site would be planted as oak woodland. This would serve to connect existing oak woods designated as SSSI sites, while also providing the same contrast and landscape value previously provided by the larch. The acorns used in this scheme were collected exclusively from the area's designated sites. While the longer-term plan is to create a more diverse broadleaf woodland, the priority in the early years of planting has been to ensure the establishment of oak.

"Let's get the oak in and then we'll worry about minor species once the oaks get established."

"It's not that difficult, just stand and plant trees. If there's bracken, plant oak [...] and where there isn't bracken and your feet are squelching, don't plant the oak. That was about as rigorous as the specification was really."

Although parts of the Bennan site had featured commercial conifers at one point in time, the lack of access for harvesting has long since led to the conclusion that the site is unsuitable for

restocking with productive species. Instead, decision makers have opted to undertake a native woodland creation project to recreate a natural landscape which is deemed to be missing from the area. The species featured have been dictated by botanical surveys of the fragments of mountainside woodland in Galloway. These surveys established that there are fewer than 300 wild individuals of downy willow, 300 juniper and no more than 60 aspen surviving in Galloway Forest Park. By using the seeds and cuttings from the small remaining local populations of these species it is hoped that these local provenances can be conserved within the new woodland, along with other native broadleaf species.

3.4 Supply Chain

Sourcing planting stock for both the Loch Trool and the Bennan Hill sites involved collection of local seeds and cuttings which were then propagated by nurseries before being returned to the site for planting. The collection process was greatly assisted by the Cree Valley Community Woodlands Trust (CVCWT); a partnership between Dumfries and Galloway Council, Forestry Commission Scotland, Scottish Natural Heritage, Scottish Environment Protection Agency, Freshfield Foundation, Galloway Estates, Royal Society for the Protection of Birds, Community Councils and private landowners, with its base in Newton Stewart, at the southern edge of Galloway Forest Park.

Having identified that the area's oaks were set to produce a bumper acorn crop in autumn 2016, FLS worked with the CVCWT to collect over one million acorns which would go on to provide around 600,000 saplings for replanting on the two FLS sites. FLS also worked with specialists to collect seeds and cuttings of other local species, including the locally rare downy willow, juniper and aspen destined for the Bennan site.

Seeds and cuttings were sent to various nurseries and propagators including an FLS nursery in England, specialist tree nurseries in south Scotland and the CVCWT's own community nursery. The use of several nurseries was largely a result of their limited capacity (or desire) to handle large volumes of seeds and cuttings. To ensure best practice and just use of financial resources, FLS employs a rigorous procurement process when selecting contractors to supply trees or work on the public forest estate (Boxes 3.1 and 3.2). As one forester highlighted, the growing requirement to engage with this process will restrict or remove the possibility of partnering with some organisations.

> *"We're not really supposed to go to any local nurseries to get anything, even if it's a small number of trees. Only when [the nursery] who won the last contract come back and say we can't do it, can we then do that, which is frustrating […] Initially when we first started this project you could use the framework or not, it's up to you, but procurement changed, and now if there's a framework in place, that's where you must go."*

It was acknowledged that the level of satisfaction with each nursery varied with respect to agreed protocols being followed, number and quality of saplings which resulted, and cost. In the case of juniper – which of all the species being planted is considered to be that most at risk from pests and diseases - it was decided that a nursery with demonstrable biosecurity practices be given the responsibility of raising healthy specimens.

As with the tree supply, on-site activities such as planting and weeding in FLS's large-scale schemes such as Loch Trool and Bennan Hill often relies on contractors. Both representatives of FLS and the contractors who worked on the sites remarked on the need to have some degree of flexibility within the planting process. For example, those on the ground at the Loch Trool and Bennan Hill sites were permitted to make small-scale planting decisions based on their own observations and existing knowledge and experience.

"You're putting a lot of effort into your procurement because you don't want just forestry tree planters. You want planters that kind of get it and understand it and can look at the land and go 'oh, that's fine' … 'I'll take these trees … 'that's too wet, but maybe these trees will go there'. You can't mark sites like these out conventionally, it's got to be slightly organic. […] It's not as easy as marking it out; we sometimes just have to go in the ground with a spade and go that's too wet, put your sod back and walk off and go somewhere else."

"Normally the client would already have a good idea as to what they want [but] if I felt that what the client was suggesting was wrong, I would definitely say something and explain why it wouldn't be quite appropriate for that site. It would then be a discussion and we'd come to a solution that everybody was happy with."

Box 3.1 – Contracted works on the public forest estate

Contracts for supplying work on the public forest estate are awarded through the Dynamic Purchasing System. There are two types of 'lot' which registered contractors may express interest in:

Lot 1 refers to traditional woodland creation lots, whereby a contractor is tasked with delivering to a land management plan over a 5-year period. The contractor must outline how they will arrive at the agreed endpoint and takes responsibility for the entire establishment i.e. ground preparation, plant supply, planting, beating up, maintenance and protection such fencing and shooting. Generally, this will involve the use of local subcontractors to deliver elements of the work.

Lot 2 is aimed at delivering projects where the behaviour of the site is uncertain (such as restoration of remedial sites), and outcomes over the 5-year period are subject to reassessment. In these instances, FLS acts as the Forest Works Manager outlining how and when works such as planting and weeding should be undertaken, but also monitoring the development of the site and renegotiating works accordingly, typically on an annual basis. Given the unpredictable nature of Lot 2 sites, the activities of contractors is inherently more fluid than on Lot 1 sites.

Awarding of contracts is administered through a tendering process whereby interested parties outline their proposals for a specific site, before being scored by a national level panel. There are many criteria including evidence of addressing FLS's Key Performance Indicators, compliance with UKFS and UKWAS, pesticide minimisation requirements, deer management requirements and biosecurity (see Box 3.2). A list of the delivery team must also be included (including contractors), along with details of their respective skills and experience. During the scoring process, each criterion within a proposal is rated from 0-4 (non-compliant through to excellent) with a minimum requirement of 2 (acceptable) in each category.

The winning contractor must inform FLS who is going to be on site, when this will occur, and have all of the correct documentation (e.g. certificates for spraying and operation of machinery).

In previous iterations, the application to enlist on the Dynamic Purchasing System proved to be a relatively long and laborious, albeit free, process. As a result, only three contractors were registered to tender for Lot 1 schemes. In recent years, enrolment has been made more inclusive, with prospective contractors simply needing to demonstrate that they have the ability to establish a woodland. While this is allowing a greater number of contractors (including smaller businesses) to submit proposals, the minimum score threshold for each criterion must still be met in order for a tender to be awarded.

Box 3.2 – Tree supply and biosecurity on the public forest estate

At times, FLS has insufficient trees within its own nurseries to supply new or replacement planting on the public forest estate. In such cases, registered suppliers are invited to bid for a supply contract in order to make up the shortfall. To be eligible to fulfil this role a supplier must demonstrate that their nursery systems meet the following Industry Best Practice in the processing, storage and transportation of plants to site:

1. Safe use of Pesticides PA1, PA12
2. Guide to the Use and Specification of Cell Grown Trees and Shrubs (HTA Forestry Group 1995)
3. British Standard 3936 `Nursery Stock'. Specification for Trees and Shrubs.
4. HTA National Plant Specification (REV. 1995)

Suppliers must also comply with the principal Legislation governing the supply of transplants from within Great Britain to FLS, notably:

1. The Forest Reproductive Material (Great Britain) Regulations 2002
2. Plant Protection Products (Sustainable Use) Regulations 2012
3. Control of Substances Hazardous to Health Regulations 2002
4. The Plant Health (Forestry Order) 2005
5. The Plant Health (Scotland) Order 2005

In addition, all trees provided to FLS must have been sown and grown within the United Kingdom. If UK plant shortages occurred, FLS will accept stock originating from outside of the UK where satisfactory biosecurity checks have been completed at the UK nursery which receives and grows this stock. These checks are carried out in the form of an inspection by the SASA Horticultural Marketing Unit (or in England, DEFRA) with the resultant 'licence to market' signalling that the nursery's stock is free of diseases. Due to the risk of hybridisation of dothistroma needle blight (DNB), current FLS policy is to only use Pine species which are sown and grown in Scotland.

Plant deliveries made by contracted nurseries to FLS sites require that; vehicles carry pollution control kits and biosecurity equipment (bucket, water container with water, brush for boots, clothing and vehicle wheels, and an approved disinfectant). Wash down procedures are to be undertaken before and after visiting the site and when travelling between forests and infected sites.

3.5 Tree Health

At the national level, much of FLS's tree health activities relate to the impacts of the oomycete *Phytophthora ramorum* on larch, and the fungi *Hymenoscyphus fraxineus* on ash (*Fraxinus excelsior*), and *Dothistroma septosporum* (dothistroma needle blight or DNB) on pine (*Pinus spp.*). However, numerous interviewees expressed concern that the onset of climate change would increase the number and prevalence of pest and disease related risks (as well as tree-site suitability challenges) in ways which were difficult to predict or plan for. To date, all three

of the aforementioned threats have been found in the Galloway area, yet it is *P. ramorum* – which led to widespread sanitation felling of the area's larch – and other *Phytophthora* species that are perceived to be the greatest tree health threat among those working on the ground. As with DNB, spread of *Phytophthora spp*. can occur through movement of infected plant material including that attached to footwear, clothing and machinery. Since moisture facilitates dispersal, moist winds and mists are also posited as a pathway for spread over longer distances. In many cases, *P. ramorum* is initially spread to larch trees from the invasive, non-native species *Rhododendron ponticum*. While areas around Loch Trool have a small yet persistent rhododendron population perpetuated by escapees from private grounds including a house at Loch Trool, some suspect that *P. ramorum* is likely to have arrived via wind, having been carried from some distance away.

> *"There's much more chance of [*P. ramorum*] spreading in mud and earth than in air but [...] I'm pretty sure that it's spreading a fair amount in wind, as well as in some mud and debris and bark and mountain bikes and dogs and so on. There are larch that are a long way and quite remote from other areas of larch, with very little public access and so my reason is that, how else could it have got there? [...] the highest likelihood is the wind has taken it three miles, four miles, five miles from somewhere else."*

On many parts of the public forest estate, FLS's are opting not to restock with species prone to established and prevalent pest and diseases, e.g. Corsican pine and Ash. In the case of *Phytophthora* spp. capable of impacting a range of species to varying degrees, there is guidance to assist these decisions, including suggested use of a fallow period to reduce the presence of viable spores, and details of the level of risk associated with replacement species (Webber, 2010). While FLS's stance of not planting larch is clear, some feel that decisions around what and when to plant instead remain too complex for any guidance to fully reflect.

> *"It's not a perfect world [and] we do need to take risks as active land managers, otherwise you would end up not doing anything. If we follow [the] guidance document, we would really need to wait three years to try and let the spore load reduce, but if you wait three years for your next rotation to be planted, you're then delaying the adjacent crop because you can't fell the adjacent crop until the newly planted crop is established at two metres. So in cases like that, I would take the risk, plant sooner, to allow that to get to two metres, then allow the felling of the next adjacent crop [...] it might be quite a large coup and that might be worth a lot of money and so we want to get that felled before it blows down and we lose money."*

> *"I know there's a lot of debate as to whether we should be planting any kind of juniper at the moment because of* Phytophthora. *I'm firmly in the camp that we should be, because if all the stuff that's there dies, then we're knackered aren't we."*

While planting at the Loch Trool and the Bennan Hill sites have included species at some degree of risk from *Phytophthora* spp. (most notably oak and juniper), a number of precautions have been taken to reduce the likelihood of future outbreaks. Firstly, every

attempt has been made to source plant material from the local area so as to limit the arrival of new pests, diseases and strains. In the case of juniper, which is considered to be the most at risk species being planted, saplings were grown at a Forestry Commission nursery in northern England - a default supplier with a reputation for high biosecurity standards. Once the juniper was received back from the nursery they were stored outside for a year before being planted in order to ensure the trees were disease free. Subsequently, the juniper has been situated and spaced so as to reduce the likelihood of all the trees being impacted should an outbreak occur. All personnel across both sites were instructed to follow biosecurity protocols by the contract manager e.g. disinfecting equipment and vehicles. Relatedly, there have been efforts to engage and educate local communities and visitors whose use of the forests can heighten the risk of spread. Despite such precautions, interviewees highlighted several areas where tree health related risks could be lessened e.g. tree supply, enforcement of best practice guidelines for FLS staff and contractors and reducing apathy among forest users.

> *"The guys that are winning the frameworks with us are ahead of the game [with biosecurity], but there is still that issue when we're asking for Scottish hazel and the nearest Scottish provenance hazel is somewhere down the south of England at some obscure nursery. You don't really know what's coming do you? Or where that's been before it's got back to that nursery."*

> *"Coming from Galloway where we've been going through the* Phytophthora *stuff for so long, there was nobody forcing you to clean your van before you went to another district on a visit. We were doing it because that was the sensible thing to do and we should be, but nobody was enforcing it."*

> *"We make sure that none of the juniper was planted anywhere near the Merrick path. They're well back. So, you would have to be going out of your way to look for juniper. Unfortunately, every now and again they like to run a hill race that goes up over the site."*

> *"The problem that we've always seen is that mountain bikers don't care, hauliers aren't cleaning their trucks between forests, so actually, what's the point with us going absolutely mad with [biosecurity]."*

In addition to the aforementioned pests and diseases, factors such as exposure, herbivory, competition from weeds and poor care of saplings were all highlighted as threats to tree establishment and tree health. In the case of Galloway's planting schemes, stunting at high elevations is being tolerated more so than would be the case with commercial crops. Herbivory from deer and feral sheep and goats has largely been removed through the erection of fences (shooting is infeasible due to the slope angle and public access). However, this is not always the case on the public forest estate due to factors such as cost and impacts on other species such as black grouse. Even where deer fences are erected, as in Galloway, damage by smaller species such as voles and mountain hare persist. Tackling weeds which deprive newly planted trees of light and nutrients has traditionally relied on the use of herbicides but where site managers opt against this practice because of the wider environmental impacts, establishment becomes more challenging. One contractor in Galloway remarked that this was particularly

true on screefs where other vegetation is capable of establishing quickly. Finally, it was noted that one of the yards used to receive deliveries of trees offered no means of watering. As a result, some batches were thought to be at severe risk of drought stress prior to planting.

3.6 Scheme Success

At this time, it is too early to judge whether the planting schemes in Galloway can be considered a success. However, it is clear that there has been careful consideration of how the selected tree species relate to site objectives whether for habitat connectivity, aesthetic appeal, water quality improvements or conservation of locally rare tree provenances.

> *"The local provenance plants that were involved with the [Bennan Hill] scheme had got to such low numbers that they could have faded away forever and this was a case of recognising that, having these species propagated, planted back in the ground and saving that local provenance. I think that was very important and it's very important that it's been recognised."*

While the desire to conserve rare provenances is admirable it is known that propagation from cuttings results in a very narrow genetic base, which renders planted populations vulnerable to a pathogen. In addition, supplementary planting of any existing vulnerable population comes with a risk, even if plants raised from local seed are planted.

Despite acknowledgement of lessons learned and trade-offs made over the course of the process, to date no substantial tree health related issues have been encountered. In fact, the most notable challenges the trees have faced post-planting are as a result of the site's physical conditions (elevation and exposure) and browsing by mountain hare (*Lepus timidus*) and the occasional ungulate breaching the deer fence. In comparison to FLS's commercial conifer stands, the newly planted broadleaves are of low density, while the importance ascribed to rates of establishment is low. Thus, it may be some time before the full extent of the desired benefits are realised.

> *"There was a bit of 'plant these trees and see what happens'. So we planted in the soils that would be okay, but what we weren't necessarily taking into account when we're planting is how sheltered and protected trees were from wind and weather, and so it will make a nice sort of natural looking thing in a hundred years' time, but it's not what foresters like to do is it?"*

> *"In Loch Trool, because you were planting out trees where we could, as high as we could, some of them aren't going to grow great because they're a bit on the high side probably. And some will grow away, some will fail. None of this is the end of the world, for me."*

Going forward, monitoring of success at a granular level is unlikely, not only as a result of competing demands on people's time but also because of the absence of any precise planting records.

> *"I probably left the contractors a bit too much freedom and said, 'plant where's*

right and don't plant where's not'. And they did. I think they did a fantastic job with that. What I should have done though is said 'can you mark where you planted everything?' and mapped all the areas that are planted, which I didn't do. And now, it's so hard to tell if it's planted and failed or whether it was never planted in the first place."

3.7 Reflections

- Those involved in the Galloway sites are aware of extensive guidance on a range of pests and diseases, their means of spread and the species they impact. Although various measures have been taken to reduce the possibility of pests and diseases arriving on stock and being spread across sites by users, the presence of windborne pathogens such as fungi and oomycetes is difficult, if not impossible, to prevent.
- In addition, it is feared that the onset of climate change may lead to additional types and occurrences of pests and diseases in Scotland.
- In this multi-objective forest, both Dothistroma needle blight and ash dieback have been experienced. In these cases, it has largely been possible to substitute impacted trees with similar species, minimising implications for management objectives and benefits. In contrast, the presence of *Phytophthora* has led to restocking with dissimilar species, and relatedly reconsideration of management objectives and benefits delivered.
- There is specific guidance to aid decisions around species selection and timing of planting on *Phytophthora* impacted sites. Despite this, land managers may be required to account for wider considerations, deviate from the guidance and accept some level of risk. i.e. to access and fell adjacent stands at risk of windthrow.
- The Ecological Site Classification (ESC) tool together with onsite inspection (including soil pits) can assist in determining which species are suitable for specific planting sites, helping to ensure successful establishment and long-term tree health. Allowing experienced and knowledgeable contractors to suggest or enact alternative planting decisions at the micro-scale can allow for more appropriate matching of species to site.
- In some cases (such as when planting batches of juniper), locating trees in remote areas and attempting to space batches at considerable distance from one another can reduce the likelihood of pests and disease related incidences.
- Producing trees from locally sourced seeds and cuttings can appear an effective way of minimising the risk of new pests, diseases and strains being introduced to a planting site. However, the risk will not be meaningfully reduced if relying on an unsuitable nursery, e.g. one far from the planting site with poor biosecurity and/or large volumes of imported stock that are not adequately separated.
- Where a particular species provenance is absent from the site, it may be necessary to source trees from far beyond the local area. Uncertainty around where such trees have been and the conditions they have been subjected to prior to arriving at the planting site are a cause for concern for some practitioners.
- It is recognised that there is some disparity in nurseries' biosecurity standards. However, since any nursery has a finite capacity to propagate, it is often necessary to rely on nurseries with imperfect practices to some degree. Where this is the case, it is prudent to ensure that a nursery with high biosecurity standards handles those species

most susceptible to pests and diseases. This may be achieved with the aid of frameworks designed to score and record potential suppliers (see below).

- FLS's continual refinement of frameworks to select suppliers of trees and operational works on the public forest estate is helping to address pest and disease issues by ensuring those winning tenders can demonstrate and articulate how they meet Best Industry Practice, including minimum biosecurity standards. While there is no fixed list of biosecurity practices that must be demonstrated or described to become approved, a contractor must be adjudged to meet a threshold score. A number of the nurseries included on FLS's tree supply framework are aligning with the Plant Healthy Certification Scheme. Although FLS's own nursery is not yet pursuing this certification, the measures and improvements encouraged through the scheme are well-regarded by those involved in scoring and approving potential suppliers for the public forest estate.
- The challenge of sourcing trees for large-scale planting schemes may come to be addressed by The Forestry Commission's recently announced plan to introduce a Nursery Notification Scheme (NNS). The scheme aims to inform UK seed suppliers and tree growers of forthcoming woodland creation and restocking projects, thus allowing them to prepare tree stock accordingly.
- Storage of received trees prior to planting (e.g. in a yard) can double as a quarantining process, helping to ensure trees are free from pests and diseases before being introduced to the wider environment. Different supplier's plants should be stored separately to lower the risk of pests and diseases spreading between batches. Storage conditions must also be suitable (e.g. away or raised off ground susceptibly to puddling). It is also important to ensure trees can be cared for where they are received or stored (e.g. presence of watering facilities/infrastructure).
- Forestry practitioners recognise that disinfecting clothing, equipment and vehicles is of paramount importance when working on or visiting forest sites, particularly those impacted or susceptible to *Phytophthora* outbreaks. Despite this, monitoring and enforcement does not always occur.
- For the public forest estate, where visitors are often encouraged, the risk of pests and diseases being introduced and spread is heightened. Users may need educating on tree health issues, yet even then, apathy can prevent the appropriate behaviours from being adopted.
- In addition to pest and disease related threats, exposure, browsing and competition with weeds can threaten tree establishment and long-term health. Issues such as cost of shelters and fencing, public safety, aims to conserve rare bird and mammal species, and reluctance to use particular products (plastics and herbicides) can complicate these challenges.

4 Case Study 2: Carrifran Wildwood

4.1 Site Characteristics and Objectives

Carrifran Wildwood constitutes a 1600 ha area in the Moffat Hills in the South of Scotland and is mainly a community-based project. It includes valleys and upland areas between 200m - 600m elevation. The Borders Forest Trust bought Carrifran Wildwood in 2000, without the use of any public money, raised from private individuals and Charitable Trusts. It is still owned by the Borders Forest Trust.

Previous land use at Carrifran involved sheep farming. The site just had a few lone trees that were surviving in protected areas where browsing activities from goats and sheep were low. When planting started the site was fenced to exclude goat and sheep and roe deer is controlled by stalking.

Substantial funding for the restoration work in the valley came from a variety of public and private sector organisations, including The Millennium Forest for Scotland Trust, Scottish Natural Heritage, The Forestry Commission, The David Stevenson Trust, Scottish Power, and The World Wide Fund for Nature.

The aim of the project was to restore the Wildwood that would have existed there six thousand years ago. The goal is to provide the building blocks to recreate an extensive tract of wild and largely wooded land. The intention is to gradually reduce the level of human intervention, to allow natural rewilding, and for the Wildwood to ultimately become a functioning natural ecosystem. The hope is that with time, Carrifran will increasingly provide a biodiversity rich area of native Scottish plants and animals.

> *"We want to create the building blocks of what would become a woodland ecosystem but that will just do its own thing. We don't want to be managing it forever, we want to be setting it off and then letting it go."*

4.2 Planting Activities

Planting started in 2000 and has continued ever since. Planting took place in the main valley floor itself and up the side but not on the hill tops, including montane scrubs. Juniper has also been planted at high elevations, though they have not done particularly well compared to willows, which seem to be better suited at higher elevations(see Table 4.1).

Woodland establishment was ensured by managing deer, currently there is a zero-tolerance policy for deer. Furthermore, appropriate protection has been put in place to avoid vole damage and to enable the trees to grow through the bracken (*Pteridium aquilinum*). This has meant putting in tubes and vole guards and then later removing them so that it looks more natural.

The project is now at a stage where natural regeneration might be enough to ensure woodland growth. While some natural regeneration has been observed it is not sufficiently frequent and particularly limited for birch. Direct seeding with acorns and hazelnuts is currently being trialled. To help natural regeneration through seed, there was the idea of introducing pigs to

turn up the ground but due to complexities around obtaining necessary permissions this has not happened.

To help initial tree growth, glyphosate has been used to spot spray areas before planting, mainly to kill off grasses. To get away from using chemicals, trials are currently underway to explore the effectiveness of manual screef (clearing a space using a shovel to expose mineral soil in order to plant) and other natural methods compared to using chemicals.

All planting has been done by hand because of limited site access for vehicles and the steep terrain.

Table 4.2 - Woodland restoration data table (2012)

Woodland Type	Code	Compartment	Area ha	% of total site
Birch-alder woodland	W4	1b	0.86	
		1e	6.88	
		2a	3.66	
		4b part	8.1 estimate	
		4d	13.57	
		Subtotal W4	**33.07**	**11**
Upland broadleaved woodland	W7/W9	1c	14.75	
		1f	1.82	
		1g	11.50	
		7 (Todcastles)	8.0 nominal	
		Paddock	5.0 nominal	
		Subtotal W7/W9	**41.07**	**14**
Upland oak-birch woodland	W11	1a	3.95	
		1d	11.53	
		2b	35.31	
		2c	35.07	
		2d part	2.02 estimate	
		3b	10.45	
		4c	11.66	
		Subtotal W11	**109.99**	**37**
Upland oak-birch woodland	W17	2d part	1.01 estimate	
		3a	7.1	
		3c	4.75	
		4a	43.15	
		4b part	30.0 estimate	
		WC3b/3c	10.40	
		Subtotal W17	**96.41**	**32**
Treeline juniper woodland	W19	6 (Rispie Lairs)	4.5	
		5 (Firth Hope)	15.0 nominal	
		Subtotal W19	**19.5**	**6**
AREA OF WOODLAND		**TOTAL**	**~300**	
NUMBER OF TREES & SHRUBS		**TOTAL**	**>500,000**	

[1]**Note:** Woodland areas include a variable amount of planned open ground within compartments (average 20%). This is additional to unplanted areas outside compartments and shown on the Carrifran map. Grant-supported planting was initially at 1600 stems/ha, with varying amounts of mortality, beating up and subsequent enrichment planting. Areas labelled 'estimate' are partitioned between woodland types within a compartment. Areas specified as 'nominal' relate to compartments that were not grant-aided and planting density was lower. In spite of these complications, the rounded totals of area and tree numbers are essentially correct. Several thousand more shrubs and trees are being planted each year, mainly in treeline woodland areas.

4.3 Species Choice

A lot of planning and research went into working out what kind of species would have grown at Carrifran in the past. This involved looking at a pollen profile and peat cores which were taken from the top of the site where a lot of peat is present.

Even though Scots pine (*Pinus sylvestris*) is not considered to grow naturally at Carrifran, pollen grains were found in the cores indicating that it was found there in the past. Therefore, an effort was made to find local provenances of Scots pine to plant at Carrifran.

As it was not possible to get hold of all species that were anticipated to have grown in the Wildwood six thousand years ago, additional species have been used to increase diversity. These supplemented trees were planted as they became available.

> *"A lot of the seed has been gathered by volunteers from what are considered to be very appropriate provenances with the locality of the area and so at the time of initial planting, there might not have been the range of a number of species that we would have anticipated being in the Wildwood that would have been there six thousand years ago, so a lot of effort has gone into you know, diversity, additional diversity planting beyond the sort of WGS stage."*

4.4 Supply Chain

Until recently, there was a close relationship with a large Scottish nursery, from which about 90% of trees came from. As the focus of the nursery has changed to a different production style their ability to deal with smaller batches of seeds (as was needed for Carrifran) is no longer possible and other nurseries will now be used.

Trees generally arrive ready for planting as polythene wrapped, cell grown plants which increases the ease of planting and lowers the risk to root drying. Upon arrival, trees were unpacked, put into a pound (for deer protection) and kept off the ground to protect from small rodents. They are planted over that same season. The main protection after planting was voleguards.

Decision making about which nursery to use was mainly down to traceability, all the way from seeds to grown trees. Efficiency and stock availability of a large range of species is also an important factor and can influence decisions as to whether to use a big nursery compared to smaller community-based nurseries. While biosecurity did not seem to be a main factor for the choice of nursery, it was assumed that standards would be very high and that best practice was used. The assumption was made due to the good reputation of the nursery.

Apart from the main nursery supplier, trees were also bought from Cree Valley Community Woodland Trust because they use local provenances, and another south Scotland nursery.

A lot of seeds have been collected by volunteers, using local provenances. Where no local populations were available the next best suited provenances were used. Source populations were identified, checked for viability, landowner's permission obtained and then seeds were collected and sent to nurseries to be grown on. When seeds weren't available for some species,

e.g. aspen, cuttings from local trees have been used which were also grown on by nurseries.

"We've worked very closely with [Nursery X] over the seed growing, so they've been very good in terms of their traceability of us giving them seeds then sending them off and getting them prepared ready for sowing and growing on for us and then giving us them back. […] Unfortunately, their ability to deal with smaller batches of seeds with us anymore, is no longer possible, which is a real shame."

"…stick to the local provenance as best we can but where there's not that tree available, we have looked further afield because we actually feel that you're better to have the species rather than eliminating that species because it's been wiped out from other places locally, when it's something that you know would have existed there."

About two thirds of the site has been planted by contractors and a third planted by volunteers.

4.5 Tree Health

Ash dieback has been detected on the site. Testing was done to see whether *Phytophthora* was present and none was found.

To prevent pests and diseases, plants are secured from nurseries with presumed high biosecurity standards. When buying juniper in from nurseries, they had to be quarantined before planting. The main contractor was well organised and informed around biosecurity and keeping risks low of spreading disease. For example, all tools and boots are sprayed before moving to a new area. Biosecurity awareness is high, particularly when working in areas that may have *Phytophthora*. Moreover, the main tree supplier has reputable biosecurity measures in place. Every lorry that comes in has to go over a wheel wash. Plants are not brought back to the nursery once they have left (e.g. in case of a mis-order) and they try not to buy in stock from other nurseries. When they do these plants will be placed in a quarantine area and visually inspected. To reduce the risk of spread of *Phytophthora* the supplier tries to reduce the amount of surface water on site.

"We've been working with [Nursery X]. They've always had a really good clean bill of health and, you know. Based on that, we believe they must be doing things right if they've not had any infections themselves."

"Trying to secure plants from a disease-free place is a priority and consideration is given to that, from gathering the seeds and then the nursery that's been growing them on."

There is a recognition that more and more people are visiting the site. There is no incentive to have an extensive network of paths because the idea is to keep it as a wildwood without too much human disruption, although there are still many visiting groups and hill walkers accessing the site. No biosecurity management is in place for people coming in.

Apart from general vegetation surveys conducted over 15 years to monitor vegetation change over time, no specific longer-term health monitoring is conducted. This is because the project

has reached a stage where woodlands in the valley are established and self-sustaining. Monitoring is still done for the montane scrubs to see how well they establish, as this will direct future planting activities.

In terms of pests, vole and deer were perceived as the greatest threat to planting success. A contracted deer stalker works all year, with a night licence over the winter, shooting 25-30 deer per year.

> *"It's a case of managing the deer, putting in the appropriate protection to avoid vole damage and enabling the trees to get up through the bracken."*

4.6 Scheme Success

Scheme success for this project can be monitored in comparison to neighbouring sites that have not been planted, and thus are able to serve as controls. Overall, Carrifran consists of various establishing woodlands and wildlife is returning, e.g. twelve woodland bird species are now present that hadn't previously been sighted, and red squirrel are also present. This landscape change and increase in species diversity is notably different to the bare, open neighbouring hills.

> *"We have been monitoring the plant changes so…I think there's ten or fifteen years, one of the two, studies of vegetation from when we first bought the site and we're also able to look at our neighbouring valley where there's no trees whatsoever, which is what Carrifran used to look like. So, we were able to use that as a control to see what had changed there and then what had changed on our site and it was all very positive."*

> *"I think a lot of lessons have been learned, as you do in anything that's new, but I would say that, you know, we're well on the way to having large established wild wood there, which is a fantastic thing to say… […] …particularly when you drive up and down the valleys around that area and you either have big, bare open hill or you have blanket conifers and you just don't have woodland like that and it's great to actually see it establishing back on the hill again."*

At the time of the initial planting, ash dieback was not known as a threat. Planted ash was subsequently impacted and more recent planting phases have omitted ash saplings due to its susceptibility. However, for the site as a whole, the observed variability of tree growth is likely due to environmental differences rather than a direct impact of pests or pathogens. In better soils, at lower altitudes, the trees are growing well and forming woodland. Areas that were planted a few years later but on higher, north facing slopes, and on thinner soils remain small. However, this stunted bushy growth is likely a result of the growing conditions and is accepted as the aim is ecological restoration rather than commercially productive forestry.

Figure 5 – Landscape change on the Carrifran Site (images provided by research participant)

4.7 Reflections

- Good use has been made of local provenances, either by seed collected directly from local areas, wild populations or by buying from nurseries that grow stock from local provenances.
- Using local provenances is important from an ecological viewpoint as the trees are adapted to local conditions and can to some degree help biosecurity by not importing plants. It is important to note though that local provenancing does not directly address or mitigate biosecurity risks.
- A lot of dependencies lie on the nurseries and their ability and willingness to process small, less lucrative seed batches which are often needed for environmental projects and manager will have limited supplier choice This may lead to nurseries with lower biosecurity standards to be chosen for restoration projects, not because of lack of awareness but rather due to lack supplier choice.
- Voles and deer are perceived as the largest pest threat. Apart from ash dieback no major disease outbreaks have been noted.
- A large number of people, mainly volunteers, have been involved in the project. This offers a range of expertise to the project but does also carry risks if responsibility is given to personnel without key training or experience in plant health. Nonetheless, the community buy-in and volunteers at Carrifran have played a large role in the success of the scheme.

- The scheme has been successful overall despite relatively little direct management for biosecurity likely due to the local approach and working with trusted nurseries and contractors.

5 Case Study 3: Kirkton Glen

5.1 Site Characteristics and Objectives

Kirkton and Auchtertyre Farms constitute a 2200 ha Highland estate near Crianlarich in the west Highlands of Scotland, within the Loch Lomond and Trossachs National Park. The farms are owned by the Scottish government, although SRUC has served as a tenant since 1969. The land itself ranges from high quality and productive grazing to high altitude (over 1000 metres above sea level) semi-natural habitats of high conservation value. However, the site is also host to SRUC's Hill and Mountain Research Centre, from where The Hill Sheep and Native Woodland Project was conceived in 1998 as a response to the economic challenges facing upland sheep farms. This experimental project was intended as a new approach to land management in the uplands, with the aim of improving the sustainability of upland farming through the integration of an innovative sheep husbandry system, fostered through establishment of native woodland on the same block of land. Inspired by agroforestry projects elsewhere, the project's proponents hoped that once the trees matured, they would provide sheep with shelter, shade and fodder (lowering business costs), while reducing frost and contributing to nutrient cycling with their leaf litter. It was also hoped that the removal of grazing pressure from areas which would remain fenced would lead to biodiversity benefits. Secondary to these objectives, there was interest in growing the farm tourism business so as to capitalise on the thousands of hillwalkers passing through the site to scale peaks such as Ben Challum. It was hoped that additional trees would improve the aesthetics of the landscape for visitors and, in later years, provide a source of saleable firewood to those wishing to extend their stay by renting one of nearly 30 log cabins located at one of the farms.

5.2 Planting Activities

The project was financially supported by SOAEFD, Forestry Commission Scotland, Scottish Natural Heritage, Countryside Council for Wales, Rural Stirling LEADER II Programme, Upland Tayside LEADER II Programme, and the Meat and Livestock Commission.

Two adjoining glens were used in the project; Caol Gleann (590 ha, rising from 230-818m) which served as a control, and Gleann a'Chlachain (848 ha, rising from 230-1025m) where planting occurred in three blocks over two phases:

- Phase 1 comprised a 43 ha block of native woodland enclosed within a stock-proof fence along the Allt Gleann a'Chlachain gorge (220-380m). The main purpose of this woodland was to act as a wildlife corridor linking an area of existing semi-natural downy birch, rowan and aspen woodland in the lower part of the gorge with the second phase of planting in the upper bowl of Gleann a'Chlachain.

- Phase 2 comprised a 36 ha block on the north-west facing flank of Ben Challum (360-610m) attached to the gorge woodland (phase 1), and a 181 ha block in the main bowl of Gleann a'Chlachain (390-600m). In total, over 230,000 trees were planted across these two blocks.

Prior to planting, a contractor mounded the ground using a mechanical mounding machine. Numerous archaeological sites and substantial areas of peatland and flush were left un-

mounded and unplanted. A third of the trees were cell grown plants and two-thirds were bare rooted. Fertilizer was applied to the trees in 2000.

Following poor establishment, substantial beating up (replacement of trees that had died) was carried out over five refurbishment phases, the last of which was completed in 2009. This entailed mechanical mounding, remedial drainage works and the planting of 25,000 trees from seed collected at local high-altitude sites and grown at a local nursery. Despite additional consideration being afforded to provenance, establishment continued to be a challenge.

> *"Even the ones in our final beating at high altitudes, sourced locally, [locally] grown, ones which were targeted planting, all had voleguards, all got a bit of fertiliser, and again, there's no real evidence that any of them did any better than any of the others."*

Table 5.3 - Planting Summary for Phase 1

Species	Initial Planting 1998	Beating-up 1999	Beating-up 2002	Beating-up 2003	Beating-up 2004	Beating-up 2009	Total	Percentage
Betula pendula	16000	4000	0	0	0	0	20000	21%
Betula pubescens	15000	0	4000	0	1500	1600	22100	24%
Salix cinerea	6000	0	3000	0	0	0	9000	10%
Alnus glutinosa	3500	1000	4000	0	0	0	8500	9%
Sorbus aucuparia	3500	1500	500	0	500	100	6100	7%
Salix caprea	2500	0	5000	0	0	0	7500	8%
Pinus sylvestris	2250	0	5000	0	0	300	7550	8%
Fraxinus excelsior	1500	50	2000	0	0	0	3550	4%
Quercus petraea	1500	50	6000	0	0	0	7550	8%
Salix aurita	0	250	0	0	0	0	250	0%
Salix lapponum	0	0	0	750	0	0	750	1%
Populus tremula	0	0	500	0	0	0	500	1%
Total	51750	6850	30000	750	2000	2000	93350	100%

Table 5.2 - Planting Summary for Phase 2

Species	Initial Planting 1999	Beating-up 2000	Beating-up 2001	Beating-up 2004	Beating-up 2009	Total	Percentage
Betula pubescens	116010	44000	12100	5500	20000	197610	50.5%
Betula pendula	29005	12000	2500	0	0	43505	11.1%
Pinus sylvestris	28000	4500	0	5500	3750	41750	10.7%
Alnus glutinosa	17015	10000	2750	5500	0	35265	9.0%
Sorbus aucuparia	16010	10000	2750	2000	1250	32010	8.2%
Salix cinerea	8000	4500	1750	0	0	14250	3.6%
Salix species	10005	0	0	0	0	10005	2.6%
Salix aurita	0	4750	1250	0	0	6000	1.5%
Salix mysinifolia	5010	0	0	0	0	5010	1.3%
Corylus avellana	3000	300	0	0	0	3300	0.8%
Quercus petraea	1000	300	0	0	0	1300	0.3%
Populus tremula	510	100	0	0	0	610	0.2%
Fraxinus excelsior	510	0	0	0	0	510	0.1%
Total	234075	90450	23100	18500	25000	391125	100%

5.3 Species Choice

Decisions around the choice of tree species (Tables 5.1 and 5.2) were largely based on the presence of existing species on the site (i.e. to expand the current treescape), as well as discussions with the Forestry Commission. This resulted in what was considered a somewhat restricted palette. However, aside from the inclusion of silver birch (*Betula pendula*), those involved in the scheme remain assured that the most appropriate species were selected.

> *"I think it was all based on looking at what was going on locally in terms of the tree species and their establishment."*

> *"There was quite a lot of silver birch planted for some bizarre reason and I've never understood why any silver birch was planted. We don't have any silver birch in the area. It's not the habitat you would want to plant it. But they were planted. They did really well in the first five years and then all died."*

> *"The species that were planted - apart from the silver birch - were the ones that any ecological site tool would have chosen. I mean, you really are restricted to downy birch, Scots pine in the drier bits and alder in the wet bits and various willows. And then some of the drier bits you can get away with hazel. And more or less, that's what we planted [...] there was nothing daft planted up there."*

5.4 Supply Chain

The majority of trees were acquired from a large Scottish nursery. This choice was driven by the nursery's prices and their capacity to supply the contract within the given time. Ultimately, it was necessary to secure trees from additional nurseries in order to fully meet the extensive planting and replanting plans. Although there is little to suggest that biosecurity was a prominent factor when choosing suppliers, there was recognition that tree health related risks

could be heightened through a reliance on several nurseries.

"It was a number of suppliers to get a number of trees [...] from a plant health point of view it's a bad idea to do because you're bringing in from diverse places and not knowing but from a point of view of getting in trees that would grow, getting them from multiple sources was a better risk and a better chance that some of them would do okay."

"In terms of the level of planting that's going on, that's actually made it quite challenging again for the nurseries [...] to have what they need to meet needs, but also, they've either had too much or too little."

"It was to do with who could provide numbers of particular species in the timeframe required. So yeah, that's why we went with those."

"As long as we were in budget and [the nurseries] were competitive prices..."

Trees were delivered after reaching a specified size and having been 'hardened' in an attempt to prepare them for the conditions of the planting site. However, there were some issues with the deliveries both in terms of received trees differing from the agreed specification (height), and the timing, meaning that some trees sat dying before they could be planted.

"I did have one delivery where all the trees were too big [and] if you plant bigger trees you have two problems, one is the root to shoot ratio in that you get on poorer soils you really wanted a high root to shoot ratio to give the tree more chance to get used to the site, and acclimatise, and also the other problems, you can get the tree just literally burling round; when you get a long top to the tree on an exposed site the wind can just burl the plant round and rip it out of the ground."

"Certainly, there were some trees that came that never got up a hill. Quite a lot of pine that were brought in had problems within their bags so they never moved, never got out the bags, given the timescale of getting the tree supply, but also getting appropriate people on the ground to physically put them out there in quite a challenging area. [...] it was also quite tragic to me to see these bags of moulded oak tree [...] they were being held up in a shipping container or something down at the bottom of the farm."

In spite of efforts to select an appropriate mix of species for the site, establishment proved difficult particularly at higher elevations. This was primarily put down to the challenging biophysical characteristics of the site, including the exposure and substantial rainfall. In addition, it was acknowledged that in hindsight, greater care could have been taken to match individual tree species to specific planting areas.

"Some of the trees should have been planted in some areas and others in others, and perhaps that didn't necessarily happen. But I think when you're trying to

plant several hundred thousand trees and you've got a team of planters out there, it doesn't always necessarily go to plan."

5.5 Tree Health

While the decision makers did their best to source appropriate species from reputable suppliers, biosecurity was not a mainstream issue at the time and awareness around threats and pathways was not to today's standards.

"From my point of view, I had no great knowledge or concern at that time about the things that have now become much more relevant and interesting that we should do."

"I don't think biosecurity within a woodland was a consideration at that time. There might have been biosecurity issues around the farm in terms of going through the farm, livestock, but even then, I don't recall any particular issues."

Thus, concerns around biosecurity and tree health were superseded by more apparent challenges, such as grazing pressures from deer and sheep. Additionally, there is a feeling that even known pests and diseases can be unavoidable, fostering the belief that resources are better spent on dealing with threats that are known, tangible and preventable.

"I don't think many people, the occasional hill walker, would have gone up, and even the hillwalkers didn't have to go through that glen. So, my impression at the time and even now would be that public access isn't a massive [biosecurity] issue there."

"The physical issue of 'how do we control herbivores, deer and sheep' were very much more of a big management issue, whereas the individual plant health was probably less important but also pretty challenging to do anything about it."

"I suspect that any major disease problems will probably be hidden by deaths from the actual environmental conditions and browsing"

Despite any shortcomings in awareness of tree pests and diseases, or imperfect practices, the trees have experienced few incidences of infection or infestation. Birch dieback which results from pathogenic fungi was reportedly the biggest issue. It is possible that the adverse site conditions (e.g. exposure) would have exacerbated this threat. As understandings around the disease have improved, there is now some recognition that the selection of different provenances may have reduced susceptibility to birch dieback.

"I'm not aware of any [pests and diseases]. Even as we speak, I don't think we've got an issue of Phytophthora *or anything like that."*

"We would have paid more attention to birch, species and provenance. I think we have more information now on that, and I think that could have reduced birch dieback, although again that's not definitive, but I think we'd have looked more

closely at that."

In more recent years, ash dieback has also been detected on the site. Given the causal fungus (*Hymenoscyphus fraxineus*) was not described as a new species until 2006 - and that symptoms were not seen until recent years - it is likely that its presence is a result of windblown spread, rather than having arrived with the original trees or the individuals involved in the planting process.

5.6 Scheme Success

Trees planted in the lower section of the gorge (phase 1) established well. At higher elevation (above 270m), establishment proved increasingly challenging and many trees were lost as a result of the high altitude, harsh climatic conditions, nutrient-poor and poorly drained soils, browsing by red deer and mountain hare and field vole damage.

Initially, trees were protected by stock fencing, with deer fencing regarded as unsightly, difficult for walkers to navigate and susceptible to damage from snowdrifts. In light of deer damage, more pro-active deer control measures were initiated in 2005, namely weekly visits by a deer controller, including licenced night visits over the winter period. In addition, an off-set electric wire powered by a solar panel was installed in 2006 to discourage deer from entering the woodland.

After repeated refurbishment and negotiation with the Forestry Commission, all areas were signed off under the Woodland Grant Scheme in 2013. Although it was agreed that a proportion of the woodland had failed to meet the required standard, there was no requirement for any grant funding already received to be repaid. However, the final instalment of the establishment grant was considerably lower than had originally been expected.

Figure 6 – Trees planted in phase 1 (L) and phase 2 (R) in 2009, a decade after the initial planting (images provided by research participant).

Although the trees have been slow to establish, the combination of mountain woodland and open areas has created a diverse and species-rich habitat and enhanced the landscape aesthetics. Ground vegetation within the un-grazed woodland blocks has changed rapidly, leading to spectacular seasonal floral displays. An array of insects, birds, mammals, amphibians and reptiles have also been recorded in the woodland blocks.

5.7 Reflections

- It is essential to factor in site conditions when considering if woodland creation is feasible, and when deciding which species should be featured. Since a site's biophysical conditions can hinder establishment and increase susceptibility to some pests and diseases (e.g. birch dieback) it is necessary to have the 'right tree in the right place'.
- Use of provenances suited to local conditions is generally accepted as a means of ensuring adequate levels of tree establishment, since trees grown from locally collected seed are more likely to be suited to the site's conditions. Furthermore, in some cases, the suitability of the tree to the site fostered by use of appropriate provenances can minimise stress and in turn reduce susceptibility to pests and diseases.
- The need to source large numbers of trees can force decision makers to rely on several nurseries. This addition of actors into the supply chains was felt to effectively increase the number of potential pathways open to pests and diseases
- The logistical challenge of receiving and planting trees in a relatively short timeframe may lead to tree stress and mortality if the delivery schedule does not take account of the available labour force and storage areas.
- All personnel, vehicles and equipment involved in ground preparation, deliveries, planting and monitoring should be subject to biosecurity protocols. This is particularly pertinent for those who frequent other sites.
- An area and period for stock checking and quarantining at the planting site could help to ensure that trees are healthy and meet the required specification (i.e. are suitable for the site).
- Low awareness of pests and diseases, pathways and preventative measures - and/or recognition of greater threats - may inhibit comprehensive biosecurity planning. However, awareness has improved over the last two decades, both among the scientific community and practitioners. Regrettably, the number of threats continues to rise and so the need to raise awareness looks set to persist.
- Even with growing appreciation of the pests and diseases in the environment, some feel it is not possible to manage for some threats and pathways. This may contribute to decisions to focus on more tangible threats.
- In the establishment phase, deer are perceived to be a greater threat to tree health than other pests and diseases. The introduction of maintenance grants has made the possibility of erecting deer fencing more plausible. Nevertheless, this option may be rejected due to the fences' visual impact and susceptibility to damage, e.g. from snowdrifts.
- Whether a scheme is deemed successful depends on the criteria it is measured against. Where establishment is low and/or slow it is understandable that the funder(s) will be disappointed. However, it possible that other successes are occurring, e.g. increasing biodiversity and improving landscape aesthetics. As the funding landscape diversifies to account for different types of woodland (including montane) and benefits, it is possible that assessments of success will need to be re-evaluated.

6 Case Study 4: Beinn Eighe & Loch Maree NNR

6.1 Site Characteristics and Objectives

The National Nature Reserve (NNR) of Beinn Eighe and Loch Maree Islands covers 4758 hectares and is located in north-west Scotland, 80km west of Inverness. The reserve is owned and managed by Nature Scot (formerly SNH) with Nature reserve Agreements or lease agreements with the other major landowners, National Trust Scotland, Forest and Land Scotland and Gairloch and Conon Estates. Housed amongst the rich tapestry of habitats is the largest remnant of ancient Caledonian forest in Wester Ross. Heavily grazed in the 19th century by the introduction of large numbers of sheep and deer combined with clearfelling for timber led to a degraded ecosystem. A programme of woodland restoration over the past 85 years has focussed on connecting large stretches of near continuous native woodland to increase resilience to future threats such as climate change. Beinn Eighe was established in 1951 as the first NNR in Great Britain and expanded in 1962 and 1973 before being merged with the Loch Maree NNR in 2014. Beinn Eighe is a Site of Special Scientific Interest (SSSI), part of the Wester Ross UNESCO Biosphere Reserve and Water Ross National Scenic Area (NSA) and the Loch Maree complex Special Area of Conservation (SAC), Special protection Area (SPA) and Ramsar Site. It also holds a Council of Europe Diploma, an award that recognises important natural and semi-natural landscapes and excellence in management. Beinn Eighe has an oceanic climate which is mild and often wet with more than 2 metres of rainfall annually, supporting rare mosses and liverworts. The reserve's uplands are recognised for its dry, wet, alpine, sub-alpine and moss heathland whilst the open ground and woodlands also contains areas of blanket bog.

An important aim of the reserve is to integrate the two objectives of conservation and increasing public access to nature and cultural heritage. It is estimated that the reserve hosts more than 50,000 visitors a year who are attracted to the visitor centre, trails and facilities.

> *"We have got a network of trails that cater to different abilities and groups… We've got two Munros on the site so we get a lot of hill walkers coming to climb those hills and other peaks on the Reserve and in recent years, we've seen quite a large increase in visitors who probably don't get into the hills but visit our visitor centre and some of the shorter trails and I suppose that's more of a general tourist, so last season (2019) we had just over 20,000 visitors through the visitor centre door and that was from the start of April to the end of October."*

The reserve also offers volunteering and education/research opportunities:

> *"We get all sorts but usually they're people who are wanting a job in that kind of sector, environmental sector, looking for work experience to progress their careers. We also get quite a lot of student placements who need to do a placement as part of their course, so we have the students from the School of Forestry, different universities that offer conservation and environmental courses and they're here for up to a month minimum stay, but stays range from a month to four or five months depending on how much they enjoy it and how much time they've got."*

One of the key objectives listed in the Management Plan for Beinn Eighe and Loch Maree Islands NNR (2015-2025) is NH1 "Expand and enhance the quality of the native woodlands by improving the age structure, species diversity and connectivity with woodlands in the wider Wester Ross landscape, whilst maintaining the genetic integrity of the Scots pine and habitats for important woodland flora and fauna communities". Genetic conservation is a high priority:

"We've actually fairly recently become Britain's first Genetic Conservation Unit and that recognises the unique genetics of the Scots pine we have here and the importance of keeping that, so our planting, seed collecting system has allowed us to keep those genetics…"

6.2 Planting Activities

The focus for management at Beinn Eighe has been on the natural regeneration of ancient woodland such as at Coille na Glas Leitir (the wood of the grey slope), and the restoration of woodland in other areas of the reserve. The planting schemes are perhaps a little unusual for a NNR which tend to focus exclusively on natural regeneration:

"… on most of our reserves natural regeneration is much more of a way of expanding woodlands. But on a lot of them woodland expansion isn't so much an aim as managing what we've got."

There are 16 planting compartments at various stages of development representing the changes in emphasis and approach to woodland restoration over the decades as new knowledge and scientific discoveries have emerged. *The Story of Beinn Eighe and Loch Maree Islands National Nature Reserve* (2015) note that in the early 1950s a number of approaches for establishing new native woodlands were trialled that included variations in cultivation, fertiliser and planting methods. A tree nursery was set up onsite and mixed tree species were hand sown and planted with minimum disturbance. Growing trees is particularly difficult in this area and the slow process coupled with poor survival rates, particularly of broadleaves, increased pressure to consider alternative approaches. More conventional forestry methods were used with a focus on Scots pine. The tree nursery fell into decline and between the late 1960s and early 1970s planting stock was procured from other sources rather than from local trees. However, in 1980 new research discovered that the Wester Ross pines were a genetically distinctive race. The tree nursery was re-opened to concentrate on growing trees from local seed and planting slowed. A programme of removing non-native trees also ensued and was completed in the early 1990s. Seed is collected from trees on the reserve to safeguard local genetics and around 20,000 are grown per year. Some of the pine trees are planted on neighbouring ground. Mechanical mounding is used to increase the trees chances of survival. Techniques for growing and planting trees have improved considerably through the use of polytunnels, fibre pots and ensuring that any introduced soil is matched to the existing soil type.

As the planting programme nears its end the focus will shift to thinning of mature trees and restructuring of some woodland blocks, natural regeneration and small amounts of enrichment planting with a mix of native broadleaves to increase diversity.

6.3 Species Choice

The reserve woodland is predominantly made up of Scots pine with a mixture of birch, rowan, alder (*Alnus spp.*) and some holly. On the Loch Maree islands, the pine woods include a large number of juniper which is considered unusual due to the wet climate and conditions. Species choice for new planting is governed by existing native species. A key aim is to increase resilience of the woodlands by ensuring that there is a diversity of native tree and shrub species, albeit without including some species susceptible to pests and diseases. To inform the selection, a variety of information sources have been used in addition to observations around the reserve:

"It's just looking at what's there I suppose and what you would actually expect to find in native woodlands, and because we're collecting on the site, we're not really, well collecting seeds from things that aren't supposed to be there. There's a few, you get a few ash, not in the designated part of the Reserve, but in the area so we don't collect things like ash. But most of the native trees that you would expect to find in the native woodland, we'll collect seed from."

"…we have used the NVC [National Vegetation Classification], so to look at what other tree and shrub species are present in the woodland communities that are present. We might also look at tree and shrub records on the NBN [National Biodiversity Network] to see what tree and shrub species are present within say a 10 km square that are not in that individual woodland. But also looking at areas of the woodland that have been more out of reach of herbivores, so what's on cliffs and crags, what's on outcrops, what's inside river gorges and really trying to develop a better idea of the, well, natural is a loaded word, but what a more natural diversity might be for that woodland in that place".

6.4 Supply Chain

The level of external involvement in the growing and planting of trees in the reserve is relatively controlled. Seed sources are limited to collection from trees on the reserve, stored on site and then grown on in the on-site nursery before being planted out in the reserve.

The reserve relies heavily on volunteers to collect seed and help out in the nursery but they were not felt to present any biosecurity issues:

"Even when we're using volunteers, they're living on site, they're working just on Beinn Eighe, we're effectively a fairly closed system and we've got more experienced staff just keeping an eye on them, managing them. So no, I don't have any particular concerns."

Ground preparation such as mounding is contracted out. Contractors were expected to be experienced with working in natural looking woodlands but also to maintain a level of biosecurity standards by ensuring that any machinery brought onto site is cleaned:

"So, we're looking for well, a mix of experience, cost, I think I definitely value operator experience because I think if you get a good operator who has a

knowledge of, especially when you're looking for a natural looking woodland, of just where to put the mounds and can identify good ground but can also just get that not regimented look, so and with the operator, just an understanding of what our aims are. I think that's really valuable, so definitely good when it comes to the tendering process. They, well, [are] considered quite highly".

"Just with machines, making sure that they're clean before they come on site, that would be the main one"

Cleaning stations are also provided for contractors to avoid any introductions of diseases into the nursery.

Although growing mediums are sourced from elsewhere there is a focus on matching these to the local soil conditions, such as having the same PH balance and thus preventing acid shock. Furthermore, only sterilised growing mediums are used which helps to minimise the risk of introducing pests, diseases and weeds. Planting is carried out by an external and experienced team of professionals to guarantee the best start for the trees:

"It's pre-mounded, so the team we get, the guy that runs it, he's really knowledgeable and experienced so we value his knowledge, so rely on that but also we'll go and meet them on site and show them the area, talk about the species and mix but yeah, they're professionals so they'll know that, well, alder will go in there and then with the water, willow will go in wet bits. Pine on higher dry ground. That kind of thing, we'd expect them to know that."

"I think historically in the past there has been areas that have been planted, which probably weren't that suitable for the trees that went out there and you can see there's some tiny wee stunted pine and that's something that we try and target [to] the better drier ground."

The planting professionals are solely responsible for putting trees in the ground and the reserve staff continue with monitoring the condition of the reserve's woodlands.

6.5 Tree Health

Deer predation is a key concern for tree establishment in the reserve. When the reserve was first started in the 1950s, the legacy of its previous incarnation as a sporting estate meant that deer populations were in high numbers. It quickly became clear that any new planting carried out by the reserve and regeneration potential of native species would be stymied through excessive deer browsing. Plant growth is slower in this area due to the climate and environmental conditions which makes trees more vulnerable over a longer time period. A number of deer fences were subsequently erected to protect woodland sites including the Ring Fence in 1988 which encloses 1200ha made up of smaller woodland areas. Attitudes have since changed and most of the fences have been removed to allow natural processes to shape the wooded landscape including some controlled deer browsing. The aim now is to keep deer at manageable levels through a programme of culling.

" I would say in the past, deer have been a problem, and well they still potentially are if we don't keep on top of them, so a lot of our planting, the planting now is in the presence of deer so we're not using, well there are some potential deaths on the Reserve if they're not tight, so we manage our stalking to manage the deer to a level that allows the majority of trees to get away."

Tools such as the habitat impact assessment and deer population model are used to monitor deer pressure and to facilitate regulation of deer numbers.

"We don't manage according to deer density, we manage according to deer impact and within the woodland areas our aim would be to have low impact. Not no impact, because deer are a natural part of the ecosystem but certainly low impact to allow the woodland structure to develop and to allow some of the more browsing sensitive or palatable trees and shrubs to regenerate."

The reserve use a zoning approach to manage deer maintaining densities at 1-2 deer per km^2 in the woodland zone. However, keeping deer at a fairly low level can be controversial with neighbouring sporting estates:

"[We've] got lots of private estates neighbouring our ground and their management objectives are very different to ours, so our management doesn't always sit well with them…And we shoot just because we're trying to allow natural regeneration of the woodland, well we cull quite heavily and have a really low deer density compared to the private estates, so well they're stalking estates, managing for sporting interests so. Much higher deer numbers to ours".

There is also high awareness of tree diseases which is exemplified in one of the Management Plan actions (NH1.10) to "Monitor for signs of tree and scrub pathogens and implement best practice protocol should pathogens be recorded". NatureScot work closely with forest experts in Scottish Forestry, Forest Research and Universities to inform themselves of biosecurity issues and to make decisions on best practice regarding issues around sourcing stock and the role of genetic diversity in promoting resilience. At the time of writing, Dothistroma needle blight (DNB) was not believed to be present in the reserve and the nursery receives regular plant health inspections. Establishing a tree nursery onsite means that only locally sourced seed is used so there is little risk of spreading DNB through introductions.

"Our management really focusses on trying not to bring anything in and encouraging genetic diversity and species diversity to make the woodland more resilient."

Visitors welcomed to the reserve may pose a tree health risk, particularly in terms of carrying infected material into the woodlands on their shoes, clothing or equipment that has been picked up from other sites. It was considered that most visitors stick to allocated areas but that some consideration could be given to raising awareness about biosecurity threats.

"I suppose just the majority of visitors will stick to trails and stuff, so in itself

that's managing them a little but the vast majority aren't venturing off trails […] maybe there's more we could do of putting signs up, asking people to wash their boots and stuff, but I don't know, in my experience places that have done that in the past I don't know how effective it is and I would say most people would just ignore that kind of stuff"

There is an ongoing programme of rhododendron and other non-native species removal where it seeds on the reserve.

6.6 Scheme Success

The reserve has seen a huge management effort over the last 70 years which has contributed to the significance of the area for wildlife, biodiversity and people. It also provides an important record of research and learning on conservation of native woodlands, particularly during the period when more conventional forestry methods were used to speed up planting.

"There's so much that we've learnt over the last few decades. At the time there was no thought to genetic provenance, there was a lot of pine planted, and a lot of that was from elsewhere in Scotland. And then later on a lot of that was felled to preserve the genetic provenance. I don't know if there was enough non-local provenance planted to actually make a difference, but it was what we did at the time. If we were starting from the beginning then we would take a lot more account of genetic provenance, of other species in particular, rather than just pine, because for a long time it was just pine. We would probably do different ground preparation, there was some pretty heavy ground preparation, we would look at planting patterns and try to plant in a more sensitive way to the micro topography. We would probably do pretty much everything differently. It was the 60s and 70s, things were done differently then."

That learning has contributed to a deeper understanding of how to create and enhance an ecosystem rather than just planting trees and involves not only genetic provenances but also minimising ground disturbance to retain understorey vegetation and carbon capture as well as including a broader range of species to increase woodland resilience to change. Future activities will focus on restructuring of some compartments to include smaller scale broadleaf species that can enrich the woodlands.

"In the far past it was pretty much pine because pine woods are pine, why bother planting anything else. But particularly in the west of the country, pinewoods largely are a lot more diverse in terms of broadleaved species as well. And that's really what the most recent work at Beinn Eighe is starting to focus on as well, the smaller scale species that are within the pine woods but perhaps not in very great numbers, perhaps because they are a lot more preferred by herbivores to the pine and so over the past decade, centuries, they've been grazed out. So a lot of the work in the Beinn Eighe nursery now is focussing on these smaller scale species like aspen and alder and whatever, and that will really be the next stage of management, enrichment planting some of these areas with these smaller scale species."

The reserve is also using fixed point photography amongst a range of tools to monitor the success of natural regeneration which will no doubt contribute to further learning. The monitoring programme overall plays an important role in demonstrations and training. The adaptive management approach taken by the reserve over the years has been hailed as a success for both nature and people. *The Management Plan for Beinn Eighe and Loch Maree Islands NNR* (2015-2025) highlights how the "*reserve is renowned in the Highlands amongst land managers, conservationists and academic institutes for demonstrating best practice conservation management, and internationally amongst volunteers for providing worthwhile medium to long term volunteering opportunities*".

6.7 Reflections

- Beinn Eighe and Loch Maree islands NNR have provided 70 years of learning reflecting the changes in approach to woodland creation and management alongside improvements in scientific understanding.
- Lessons have been learned that have implications for tree health and biosecurity. For example, genetic studies that revealed the distinctiveness of Wester Ross Scots pine led to a system of collecting local seed and the revival of the on-site nursery to prevent contamination. This has indirectly offered protection against introduced diseases as the planting of Scots pine sourced from other areas was discontinued several decades ago.
- Use of sterilised growing mediums matching local soil conditions also helps to reduce the risk of introducing pests, diseases and weeds, and the possibility of acid shock.
- However, disease threats may be introduced through other pathways. Contractors are required to follow biosecurity protocols such as arriving with clean equipment.
- Experiences of establishment failures through drought and other environmental or human-induced factors has increased the drive to ensure the right species is planted in the right place. Trees that are less stressed contribute to a more resilient woodland environment that could potentially withstand some biosecurity threats.
- Deer are perceived to be the greatest pest threat currently and management now relies on deer culling to keep population levels low rather than deer fencing. Establishment of new planting and natural regeneration relies on the continuation of deer management even if neighbouring sporting estates have different objectives.
- As highlighted in other case studies, visitors to the area could present risks through the introduction and spread of pathogens i.e. via contaminated soil on footwear. While it is expected that most visitors will stick to designated pathways, the strong emphasis on promoting engagement with nature offers an opportunity to raise awareness of biosecurity threats.
- Involving local communities, students and volunteers in the management of the reserve also presents opportunities to highlight potential pest and disease threats and to train a cohort of committed enthusiasts that could act as ambassadors for biosecurity.

7 Case Study 5: Cambusmore Estate

7.1 Site Characteristics and Objectives

Cambusmore Estate is a private estate of over 5000 ha bordering the sea loch, Loch Fleet approximately 50 miles (80 km) north of Inverness. Being within close proximity to the sea, the area experiences a maritime climate with relatively low variation in temperature, averaging around 8°C. However, the climate is wet, with approximately 900mm of annual rainfall.

The Estate's land is comprised mainly of heath, bog and grassland habitats with areas of native woodland as well as an area of recently felled conifer. There are a number of designated sites on and adjacent to the Estate including Loch Fleet National Nature Reserve, Dornoch Firth and Loch Fleet Special Protection Area (SPA), The Strath Carnaig and Strath Fleet Moors Site of Special Scientific Interest (SSSI) and SPA, Torboll Woods SSSI, and The Mound Alderwoods Special Area of Conservation (SAC).

Figure 6 - Looking north towards the Estate's high ground from the western edge of Loch Fleet (image from Google maps streetview, accessed 2020)

Cambusmore once generated income as a sporting estate but now hosts only the occasional shooting party. The primary land use in recent years has been sheep and cattle farming. However, hill management has proven difficult with only a short window of opportunity for heather burning. This was recently compounded by an uncontrolled fire which spread from a neighbour property and burnt about 2000 ha at Cambusmore. In response to the deteriorating condition of the land, the owner has outlined two objectives: i) to improve grazing on the hills and ii) to support an increase in biodiversity through new habitat creation. It is hoped that these objectives can be met through the Strath Carnaig Woodland Creation Scheme which will see a proportion of grazing land fenced off from a number of planting areas made up of native woodland, expanding and complementing existing native woodland including that within the SSSI sites. So as not to disadvantage the area's breeding hen harrier (*Circus cyaneus*) population, substantial areas (15%) of the planting area will remain as open ground, allowing the birds ample space to hunt. While the recently approved planting scheme is not commercially driven, the proposal outlines a number of productive species. Furthermore, it is thought that in future decades there may be opportunity to integrate livestock and woodland for the benefit of both.

7.2 Planting Activities

In late 2020, following an extensive Environmental Impact Assessment, Scottish Forestry approved the planting of 1.4 million trees to assist in the creation of 933 ha of woodland spanning 12km along Strath Carnaig. £3.2 million in funding was awarded to support the planting which will occur over three years, beginning in autumn 2021. The planting will be made up of:

- 589.27ha of Upland Birch (W4) planted at 1700/ha to achieve 1100/ha at year 5
- 265.68ha of Native Scots Pine (W18) planted at an average of 1800/ha to achieve 1600/ha at year 5
- 152.47ha of Low Density Native Woodland planted at 700/ha to achieve 500/ha at year 5
- 90.11ha of Diverse Conifer with commercial conifers planted at 2800/ha to achieve 2500/ha at year 5, and broadleaves planted at 1800/ha to achieve 1600/ at year 5.

Cultivated planting positions will be used to encourage successful tree establishment using a combination of continuous mounding, excavator mounting, inverted excavator mounting and direct planting/screefs, with the specific method for individual areas being selected on the basis of soils, landscape, terrain/slope, sensitivities such as water courses and site access. Any areas of unmapped deep peat uncovered during works will be left unplanted. Half of the trees will be cell grown and the other half bare rooted. Density of planting will be varied and the most appropriate tree species for individual areas will be allocated after cultivation.

"We're making sure that what we're putting in there is the most suitable species for that site to give it the best chance of growing and also thriving and not putting the tree under stress through not being suited to the site it's being planted in."

"Certain trees are difficult to take root, like the Birch, so you don't really want it up in the air on a dry mound."

"I would like to use cell grown trees across the whole thing but they are quite expensive compared to bare root. And also, if you've got inaccessible areas, trying to get cell grown trees sometimes can be quite labour intensive to areas which are quite remote. So maybe bare root trees are a bit more transportable around the site."

"We tend to overstock what we start with. If it's says 1,600 I'll plant between 1,800 and 2,000 […] So actually you've got some accepted losses in the first couple of years, you're still meeting the grant requirements […] You are going to lose some trees but it will be a natural loss from the right places, usually for a good reason. So, you end up with the trees growing in the right place."

An application of fertiliser will be made to all the planted trees on the native scheme at the rate of 120g of PK fertiliser per tree. This will be broadcast evenly around each tree, following Current Forest & Water Guidelines around water courses and water extraction points so as to protect sensitive water catchments. Richer brown earth and diverse conifer areas are deemed

not to require fertilisation. Weeding will be restricted to rich ex-agricultural grounds hosting the Diverse Conifer mix and will involve curb grass weeding in the spring and herbicide spot treatment in the summers until species such as Norway spruce (*Picea abies*) can establish.

Given the presence of red (*Cervus elaphus*), sika (*Cervus nippon*) and roe deer (*Capreolus capreolus*), the decision has been taken to deer fence the planting areas with seven separate fences. As deer are considered the chief threat to establishment, the erection of fences is considered to preclude the need for tree shelters and voleguards. However, monitoring for voles and deer will take place so that management can be adapted as necessary.

7.3 Species Choice

The broad categories of species proposed in the application reflect the management objectives to expand the site's native woodland and increase biodiversity. In addition, the species choice has been informed by extensive surveying of the site's biophysical conditions, particularly its soils. These proposals were reviewed by the funder and approved following minor changes to the soil-species matching and the expanse of planting, with a reduction in area at higher elevations.

The native woodlands will feature downy birch, silver birch, oak and alder for which seed has already been collected from the site's existing trees i.e. existing local provenances. Other trees including rowan, juniper, eared willow, goat willow and aspen will come from within the sites seed zone or where necessary, an adjacent seed zone. Native scots pine will be N2 Scotia provenance (Native Caledonian). Where ground conditions are deemed appropriate, or richer flushes allow more diverse species, small numbers of holly, hazel, hawthorn, blackthorn, elder, bird cherry, crab apple and grey sallow could also feature. In addition to the management objectives and site suitability, the inclusion of these specific species is also shaped by the conditions of the grant which prescribes particular species and proportions for the agreed mixes. These constraints can limit the possibility for experimentation.

> *"Under different options there're limits on how much open ground or how much of one species they can have. That's pretty fixed and they have to comply with that to be able to get the grant."*

> *"I would have liked to have tried something like Sweet Chestnut (*Castanea sativa*) in areas [but] because it's not native, it wouldn't come under the native woodland designation. I can use it in other areas where we've harvested the woodland but you obviously don't get the grant on it. And I would like to have put in more non-native berry bearing trees for the birds and things like that [but] we're sort of locked into certain species which is frustrating […] they've got the funding, so you've got to kind of go along with it."*

The diverse conifer planting will include a relatively small area (58 ha) of productive timber species, namely Norway spruce and Douglas fir (*Pseudotsuga menziesii*). To include this mix the applicant must demonstrate that there is a market. However, in the case of Douglas fir the owner deemed this species to be beneficial not for its ability to generate income but rather its potential to encourage red squirrels to return to the site.

"[an area] will be planted so as to afford some future income generation as well as, hopefully, being tailored to what local processors will need in the future - Norbord and pine. The aim is to incorporate a crop which is climate resilient and adaptable to change which is likely to provide and support local employment opportunities."

"There is a small commercial component but I think Douglas Fir, the attraction there was to try and get the Red Squirrels back."

7.4 Supply Chain

After initially approaching a local nursery directly to enquire about the possibility of being supplied a large volume of trees, the owner subsequently employed a land management agency specialising in forestry to assist with their application to Scottish Forestry, to source trees and to oversee initial work on the site, including ground preparation and planting. For these operational activities, the agent will subcontract the work while maintaining oversight through onsite supervisors.

The agency made use of its connections with forestry students to assist with the collection of the seeds which were then passed to the same nursery initially approached for growing on. This nursery was selected by the agency because of its close location to the site which has the advantage of logistical convenience as well as sharing the same climatic conditions of the planting site. Both a personal relationship and an existing working relationship between the agent and the nursery manager were also key factors in the selection. In fact, the agency is the nursery's chief customer with around 60% of all its stock used in schemes overseen by the agency. As a result of these experiences, a strong degree of trust in the quality of service and product has formed. However, it was noted that few nurseries would have the capacity to produce the number of trees needed for this scale of scheme. In the end, another nursery in southern Scotland has been tasked with providing a proportion of the supply on the grounds that having multiple suppliers in place helps to ensure that some trees will be supplied even if one supplier encounters problems e.g. losses of stock to pests and diseases.

"Even schemes much smaller than this, people end up using multiple nurseries just to get the trees that they need from the right seed zone. […] How they find that is kind of up to them. So, the nursery use does really depend on what the nurseries have got available."

"I'm using [nursery A] because they're local and they are obviously quite coastal so they're quite close in terms of climate to what Cambusmore would be. And we've got quite a good working relationship with them. But actually, I won't be buying all my plants from them; I'll be buying some from [nursery B] as well. And partly that is just to make sure you've got supply coming from two nurseries so if there is a problem with one for whatever reason, biosecurity and whatever, you've still got plants available from the other. We would do that on any fairly large scheme."

"This is a massive scheme and this is the first time [the nursery] have actually gone out and [assisted with] the seed collections, done everything from the start, and so I don't really know until I start sowing in March what the answer is. if it's a headache, I'll never, ever do it again!"

Once the trees arrive back on the site, those contracted to carry out the planting will follow written instructions and onsite supervision dictating which areas the trees are to be planted on, and the style of planting to be used e.g. whether they are on the side of a mound or in a strip.

"We can sometimes find that planters, because they're used to doing quite a lot of commercial stuff will just put every tree on every mound. Well we're not looking for that here. We're looking for diversity of density, diversity of species and different species like different planting positions."

Following successful establishment, the owner intends to oversee any further management themselves including the removal of deer fencing once appropriate.

7.5 Tree Health

Dothistroma needle blight (DBN) affecting pine species, birch dieback and *Phytophthora austrocedri* on juniper were highlighted as the key pest and disease related concerns for the Cambusmore scheme. For the most part, it is felt that these threats can be avoided with careful species selection including the use of local provenances (particularly in relation to birch), and through choosing to work with nurseries with established biosecurity protocols.

"I was chatting with [nursery staff] about where their stock comes from, where it's collected, whether they've got any testing done for biosecurity, mainly for the Phytophthora. You know, what their controls were on keeping juniper separate and that sort of thing."

"The nurseries which people are using are generally the big players. They've all got, as far as I know, pretty good biosecurity procedures in place, so I think the risk is probably pretty small."

One of the nurseries elaborated that their reputation relies on domestically grown stock, plant passporting, seed certificates, traceability, and footbaths for visitors. Furthermore, their recent decision to enrol in the Plant Healthy Certification Scheme is seen as a means of furthering staff training on matters of biosecurity so that practices continue to improve.

"Biosecurity is a massive issue but it's just a way of life now"

"The thing that all us nurseries will talk about is birch. Birch is notorious when it's a sapling, well when it's in a nursery or when it's trying to establish […] also their roots as well, they're quite susceptible to water logging."

Seed has been collected from as close as possible to the planting site, and in some cases – as

with birch – from the site itself, thus helping to ensure that the resulting trees will be less susceptible to environmental stresses thought to be associated with dieback. As well as reliance on local provenance, detailed consideration of generic and specific planting sites has been given so that individual trees are matched to their preferred conditions (e.g. species matched to soil type and location on/off mounds). This will later be ensured through onsite supervision of contractors. In the case of juniper, new planting will take place away from existing populations which are naturally regenerating. This is a deliberate precaution to minimise the risk to the existing stock from any incoming juniper trees which could harbour or later succumb to *Phytophthora*.

Although those involved in the scheme are aware of various pests and diseases and are acting diligently to reduce the likelihood of introductions and spread, it is notable that the threat posed to schemes such as Cambusmore in northern Scotland was considered by two interviewees to be low, relative to sites in southern England. However, with the onset of climate change (and increased trade) it was noted that Scotland may become at risk from new pest and disease threats in future years.

"Disease wise, the natives seem to be fine and there's nothing really hindering them, apart from the ash and all that elm but what can I say? it doesn't really affect us up here, in the north; that's more of the nurseries down south, I would say. They've got more of a problem. Up north, we don't really get hindered much with that up here."

"Because of where we are up here in Moray there's not a huge amount about. I think we miss out on quite a few things. Apart from red band [needle blight] which has gone through the local woodlands over the last ten to fifteen years. […] Less susceptible is a good way of putting it."

"[We need] to be a bit more aware of things that maybe aren't a threat or aren't in this country yet but might be out there that could be coming in the future. That's something that we should maybe be a bit more aware of and particularly with increased trade and climate change and things maybe changing how these things spread and how quickly they spread. We maybe need to try and be a bit more proactive instead of reactive."

Potential pathways for new pest and disease introductions on the site are thought to include arrival of stock from nurseries and transmission of pathogens by site visitors. Given that there are few recreational site users, and that the new trees will be behind deer fencing, it is the contractors involved in activities such as ground preparation and tree planting who are perceived as the most likely visitors to introduce and spread pathogens. For those overseeing the planting, background checks and a close working relationship with those in the supply chain throughout the planting process is considered key to minimising the risk of pests and diseases being introduced.

"We're in contact [with the nurseries] all the time and do make regular visits to look at stuff growing."

"If we're employing a contractor, generally, we would make sure they clean boots, clean tools, clean vehicles but we kind of specify that for quite a lot of areas anyway even if we're not planting or anything. Machinery has to be clean before it comes to site, we need to know where they've come from. And that's actually part of our work really, checking all these things."

Other perceived challenges to tree establishment on Cambusmore Estate include herbivory and climate. Despite a substantial deer population, it is expected this threat can be largely removed through the erection of deer fencing. Where damage is found to be above 5%, shooting in season, under general licence and under night licence will be considered. By fencing separate blocks of the incoming trees rather than a single large area, any necessary deer control will be more manageable. In this region, applicants of Scottish Forestry planting grants receive a premium for deer fencing due to the large populations, yet with the tender for fencing still open the owner remains uncertain as to whether the funding will be sufficient to cover the full cost. In addition to a deer management plan, there are also plans to monitor damage by rabbit and voles so that they too can be controlled as necessary.

"Herbivore damage is always a risk in the Highlands particularly."

"We're under pressure from all sides on the deer. They did an aerial survey of the south east Sutherland deer management area. From the helicopter they counted 392 deer of which 352 were on our operation […] I have somebody who comes and sort of looks after culling of deer and hinds"

Finally, recurrent dry springs are seen as a threat to tree establishment. While it is thought that a reliance on cell grown trees may counter this challenge to some extent, this is often infeasible due to the added expense relative to bare rooted saplings, and the issue of sourcing the necessary supply.

"The dry, warm springs we've been having have had quite a detrimental effect on establishment. If you put a tree in the ground last year in mid-March there was seven weeks of dry weather after that. So how likely is that tree to survive?"

7.6 Scheme Success

From the funder's perspective, success – and grant payment – will be based on fixed measures of establishment (tree height achieved over time). To help ensure the necessary establishment is achieved, there has been much consideration around biosecurity as well as a decision to overstock the site with the expectation that not all of the trees will survive planting or grow sufficiently. Nevertheless, beating up is still considered a possibility.

"What we would class as established - and we would sort of sign it off and say 'yeah we're happy that that area's fine' - would be that the trees are over 2m in height and meeting the stocking density requirements of the grant. Depending on the [species mix] option there's different stocking densities, and those densities have to be there at year five."

Following the initial planting phase there are plans to carry out yearly stocking density assessments as well as monitoring of weed encroachment, fence lines, herbivory damage and the overall condition of the trees. Where feasible, many of the tasks to addressing any emerging challenges will be undertaken by the owner and their existing contacts and workforce. However, for a scheme of this scale, it is noted that if any pest or disease related issue are experienced swift detection and action may be required to prevent widespread impacts. Thus, monitoring and contingency plans may prove key to the scheme's success.

> *"For large scale schemes probably one of the challenges would be the monitoring of it and identifying if there were any pests or disease that had started to outbreak on the site. Is it getting picked up quickly enough? And then if there is an issue identified is it possible to trace back where those trees have come from. You know, if it's come from multiple nurseries do they know which supply batch went to different areas of the site and can they follow that back so that if there's a chain that needs to go back, there might be other sites with a similar issue."*

From the owner's perspective, the perceived success of the scheme will also relate to their longer-term management objectives; to allow improved grazing on the hillside (eventually amongst the established woodland), and an increase in biodiversity, including the return of red squirrels. Continued input and advice from EIA consultees such as NatureScot and RSPB should help to ensure such success.

7.7 Reflections

- Dothistroma needle blight, birch dieback and *Phytophthora austrocedri* are all considered to be potential threats for the scheme, as are herbivory and recurrent dry springs.
- There is some feeling that planting sites such as those in northern Scotland are less likely to experience pests and diseases than in more southerly sites, such as those in the south of England. This is largely based on knowledge of past and current outbreaks which are absent or less prevalent in Scotland possibly as a result of remoteness and differing climatic conditions. However, there is recognition that climate change may alter the range and number of pests and diseases Scotland will face in future years.
- Use of local provenances (particularly in the case of birch) and reliance on a local nursery subject to the same climate as the planting site should help to ensure that the trees arriving for planting are suitably adapted to the onsite conditions. The trees are thus less likely to experience stress which could render them susceptible to pests and diseases.
- The use of site surveys (e.g. soil) by independent consultants and subsequent verification by forestry professionals can also help to ensure that the 'right tree' is destined for the 'right place'.
- Decisions about where to locate trees can also take account of existing species so as to reduce the likelihood of pests and pathogens spreading to other hosts. For example, incoming juniper trees will be planted away from the site's existing populations in an attempt to reduce the likelihood of widespread *Phytophthora* impacts (were any of the incoming trees to harbour or later succumb to infection).

- Reliance on nurseries with established biosecurity protocols have been chosen to propagate seeds for the site. However, it is also evident that factors such as personal relationships, existing working relationships, proximity, and ability to handle large quantities of stock also influence nursery selection. A requirement to provide large numbers of trees of certain provenances is particularly limiting when attempting to identify suitable nurseries.
- The decision to rely on two separate nurseries is seen as a way of ensuring that any pest and disease outbreak would not prevent some batches of healthy trees arriving. However, this strategy may also increase the likelihood of *some* batches being affected.
- Diligent oversight of the entire supply chain (e.g. by an agent or consultant) can help to ensure biosecurity related quality control for each actor at each stage, thus reducing the likelihood of pest and disease related incidences. This can involve, running background checks, seeking evidence protocols (past and present), providing detailed written instructions, and supervising contractors during onsite activities.
- In the case of a nursery supplying trees, trusted biosecurity measures may include appropriate spacing of trees while on the nursery, use of footbaths containing disinfectant for visitors, reliance on stock which is sourced and grown domestically, a traceability system including the use of seed certificates and plant passports, and dedicated training opportunities for staff. Some nurseries are looking to further enhance their biosecurity standards and reputation through engagement with the Plant Healthy Certification Scheme.
- Biosecurity for contractors working on planting sites should include cleaning/disinfecting of boots, tools and vehicles, as well as records of where machinery has been prior to being allowed on site.
- Planned monitoring programs for the trees as well as weeds and fencing are deemed important to allow for managers to quickly identify and address any threats to establishment and tree health.

8 Conclusions

8.1 Knowledge and Risk Perceptions

When relaying experiences and perceived threats from pests and diseases, ash dieback, Dothistroma needle blight (DNB), and *Phytophthora* species (*ramorum* and *austrocedri*) were the most commonly cited. Notably, there was scant mention of other emerging or existing threats to UK treescapes, such as Emerald Ash Borer, Bronze Birch Borer, *Xylella fastidiosa* (none of which are currently in the UK), or Acute Oak Decline, Oak Processionary Moth or Pine-tree Lappet Moth. Despite awareness and experience with a number of pests and diseases, there is a feeling that some – particularly those dispersing by wind – are difficult if not impossible to prevent. Lack of awareness about how best to manage for such threats may contribute to an acceptance of risk, or a decision to focus attention and resources on more tangible and manageable threats (e.g. deer browsing). Moreover, there is a perception in some quarters that planting sites in Scotland – particularly at more northerly latitudes – are less likely to experience pests and diseases relative to more southerly sites. This is largely based on knowledge of past and current outbreaks which are absent or less prevalent in Scotland, possibly as a result of remoteness and differing climatic conditions. However, there appears to be widespread acceptance that climate change may alter the distribution of pests and diseases, leaving Scotland prone to new threats. Relatedly, there are concerns that practitioners' preparedness to manage for newly arriving or previously unknown pests and diseases will likely be lacking, particularly if their presence and impacts manifest rapidly. There is however acknowledgement that guidance is available for preventing those pests and diseases currently posing a threat. Despite these resources, it can be difficult to find time to stay updated on the wealth of evolving information and guidance. Moreover, it is felt that in some cases, guidance does not reflect the complexities of real-world decision making (as described in Marzano et al., 2107). This can lead to a feeling that there is no single right answer about what action to take in the face of competing objectives, and thus it is inevitable that some degree of risk must be accepted.

8.2 Right Tree in the Right Place

Ensuring individual trees are suited to the planting site is seen as one of the most important factors in ensuring tree establishment and long-term health. This assertion derives from an understanding that if the tree is matched to the biophysical conditions of the planting site, it is less likely to be subjected to extreme stress which may impact its biological functions and its ability to combat the effects of pests and diseases. While elevation and windiness have proved to be limiting factors, it is the characteristics of the soil which are most commonly emphasised as being key. Use of tools such as the Ecological Site Classification is often found to be useful in assessing soils, but more specific onsite investigations are also considered beneficial for ground truthing and for providing a clearer picture of variation at a more granular level. Verification by experienced forestry professionals and planting teams can provide further confidence that the 'right tree' is destined for the 'right place'. Relatedly, use of local provenances and locally collected seed can help to ensure the trees' suitability to the site's conditions. This study suggests that while supply issues may necessitate use of stock from further afield or of different provenances, managers do tend to strive for use of local provenances and locally collected seed. As the effects of climate change become apparent, there is an argument that sourcing decisions should also account for probable future site

conditions (e.g. Whittett et al., 2019) – an approach which can be assisted with the use of Forest Research's Climate Matching Tool.

Pest and disease impacts can be rapid and widespread, particularly if areas contain an abundance of tree species which serve as hosts or vectors. Inadvertent movement of material across sites can further accelerate introductions and spread e.g. soil on boots and tyres harbouring *Phytophthora* propagules. Likelihood and severity of such occurrences may be reduced with careful consideration of which species are planted and how they are distributed across the site. High levels of tree species diversity will also likely limit the spread and scale of impact from pests and diseases (Bellamy et al., 2018). Soil used in a trees' potting process may also pose a risk depending on its origin. Use of sterilised growing mediums matching local soil conditions reduces the risk of introducing pests, diseases and weeds, and the possibility of acid shock.

8.3 Logistical Challenges

Caring for large volumes of trees as they are transported from nurseries to their individual planting sites typically involves several actors and requires meticulous planning. In some cases, it is necessary for trees to be temporarily stored at a depot (or similar) until the workforce is available to begin planting across the site. If deliveries are not scheduled accounting for available labour and storage facilities (e.g. watering infrastructure and equipment), stress, infection, cross-contamination and mortality may result. However, some have used the need to store trees to their advantage by using it as an opportunity for quarantining. If done well, this helps to check that trees are free from pests and diseases before being introduced into the wider environment, without risking spread between batches. Additionally, a period of time in 'cold storage' can allow trees time to adapt to the local conditions prior to planting. Occasionally, batches of received trees do not match the specification agreed between the customer and the nursery. In some instances, this may jeopardise the trees chances of establishing e.g. when overly large trees were delivered to exposed and windy sites.

8.4 Selecting the Right Nursery

With nurseries suspected of facilitating the introduction and spread of pests and diseases in recent times (Brasier, 2008; Jung et al., 2015; Chavez et al., 2016), those overseeing large-scale planting schemes recognise the delivery of nursery stock to their sites as a key pest and disease pathway. Biosecurity among the larger nurseries most commonly approached to supply large-scale planting schemes is generally trusted, and occasionally verified. However, it is commonplace to have to rely on multiple nurseries to source tree stock, (for example, when relying on hard to source provenances), meaning even those with imperfect biosecurity may be approached for involvement. While some see working with multiple nurseries as an effective way of spreading risk (not all batches are likely to be affected by pests or diseases), others feel it increases risk (it is more likely that at least some batches will be affected). In either event, the process of verifying standards and quality by those overseeing a scheme becomes more burdensome as the supply chain becomes larger and more complex. In addition to a nursery's capacity to supply stock, factors such as personal relationships, past partnering and proximity can influence which nurseries are chosen to supply a scheme.

The challenge of sourcing trees for large-scale planting schemes may come to be addressed by the Forestry Commission's recently announced plan to introduce a Nursery Notification Scheme (NNS). The scheme aims to inform UK seed suppliers and tree growers of forthcoming woodland creation and restocking projects, thus allowing them to adequately prepare their stock to reflect future demand. Additionally, the use of frameworks and scoring systems (such as those used by Scottish Forestry) to select suppliers of trees and contractors of operational works can help to ensure that only those adhering to Best Industry Practice and minimum biosecurity standards are involved in large-scale planting schemes. Alignment with the Plant Healthy Certification Scheme represents one means by which a supplier can demonstrate their commitment to biosecurity standards. Several nurseries committed to biosecurity are pursuing this path, and there is evidence to suggest that participation is looked upon favourably by some forest professionals. While such assurance is to be encouraged, there is already a feeling that most of the larger commercially minded nurseries are effectively implementing sound biosecurity practices. However, accounts of what best biosecurity looks like or entails by those selecting a supplier is at times vague, with some simply trusting that large, established nurseries are acting appropriately.

For those sites with their own nursery and the capacity to source seeds locally, the insular nature of operations can reduce the likelihood of new pests and diseases being introduced. Moreover, this scenario helps to ensure that the trees are adapted to the site conditions prior to planting. However, use of local seeds alone is no guarantee of healthy trees for those who must rely on an external nursery.

8.5 Onsite Visitors and Activities

Disinfecting of clothing, equipment and vehicles is of paramount importance when working on or visiting new and established woodland/forest sites. This is widely accepted by those selecting and overseeing contractors, as well as the contractors themselves. However, given the frequent reliance on subcontracted staff and volunteers during large-scale planting, knowledge levels and training received in relation to biosecurity will often be variable. Moreover, it is noted that monitoring and enforcement of practices does not always occur since it is resource intensive to carry out the necessary checks, particularly if people are operating over large areas. In addition to those contracted to undertake work on planting sites, recreational users may also pose a threat to tree health, for example, if transporting infected material onto or across the site. In addition to the recommendation to locate vulnerable trees away from frequented areas, attempts to raise awareness of the threats and pathways with users via outreach and information boards may also reduce the likelihood of spread. However, past studies (e.g. Hall et al., 2020) together with experiences described in this research suggest that such efforts do not guarantee that the desired behaviours from the public will result.

8.6 Other Threats

Consideration and management of pests and diseases may be reduced where other factors such as exposure, browsing and competition with weeds threaten tree establishment and long-term health. Issues such as cost of shelters and fencing, public safety, aims to conserve rare bird and mammal species, and reluctance to use particular products (plastics and herbicides) can complicate these challenges. Of all of these issues, herbivory from deer is the most commonly cited and emphasised. The introduction of maintenance grants and awarding of

premiums in deer dense areas has made the possibility of erecting deer fencing more plausible. Nevertheless, this option may still be rejected due to the fences' visual impact and their susceptibility to damage e.g. from snowdrifts. Regardless of the decisionmaker's preference, there is consensus that some degree of deer control will often be needed if attempts to establish trees are to have any chance of success. Monitoring programs for not only deer damage, but also weeds, fencing/shelters and incidences of pests and diseases can help to identify and address any issues. The greater the frequency and scope of the monitoring process, the more likely it is that any potentially devasting issues can be identified and tackled before escalating to an unmanageable level.

9 References

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