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Moneses Translocation and Site Management Report

RSPB Abernethy

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Summary

One-flowered Wintergreen, *Moneses uniflora*, is a vary rare pinewoods flower now present at less than twenty sites in Scotland. It is rapidly declining in the UK, with recent surveys by Plantlife indicating it has gone extinct at 3 of 7 sites checked in 2023 in the last 15 years. The flower is widely distributed across boreal habitat in the northern hemisphere, but may be suffering a serious global decline, with surveys in Sweden showing 84% extinction of sites within 10 years (Eriksson, 2022). Moneses appears as a small leafy rosette that takes two to four years to develop a single flower head, after which the plant is thought to die. It spreads via dust like seeds, but also commonly reproduces vegetatively via rhizomes. It inhabits the bryophyte layer of pinewoods, preferring nutrient poor thin acidic sandy soils, often growing in disturbed ground and near the edges of wetter areas. However, our understanding of its niche is poor, as it is declining and rare despite apparently suitable unoccupied habitat.

Moneses is known to associate with ectomycorrhizal fungi, it gathers some of its energy through fungi, a particularly important step during seedling development. These fungi associate with pine trees, although aren't specific to *Pinus sylvestris*, and are also saprotrophic, breaking down dead wood. Current niches of remaining populations also correlate with recent or historic disturbance by grazing or forestry operation. Study on Moneses has suggested its decline may relate to a reduction in disturbance to the pinewoods forest floor via grazing, and an increase in single age structure plantations and clear felling (Eriksson, 2022).

In October 2023 Plantlife led a small-scale trial translocation of Moneses into RSPB Abernethy. This translocation is not only to reinforce the remnant population of 60 Moneses (in 2023) at Abernethy, but also to test if translocation is a viable conservation strategy for the preservation of both recipient and donor populations. A total of 103 plants were collected from two populations, with 12 sent to Royal Botanic Gardens Edinburgh for further study, and the remaining 91 planted at Abernethy. Moneses was translocated in clumps of soil to avoid disturbance to roots and encourage mycorrhizal associations to persist. Four sites 30-50m from the relic population were selected, mirroring micro-habitat as close as possible. Follow up surveys at 1, 3, and 6 months are to be completed to assess translocation success, after which point a review will be carried out. The 3-month survey, carried out in January, showed less than 15% loss of plants, with no evidence of widespread stress.

Providing land management advice for this species is very challenging. It is more specialist than most pinewood plants, perhaps adapted to move to sites of suitable disturbed habitat and declining quickly where sites become unsuitable. It is also reliant on mycorrhizal associations, particularly for seedling development, which we do not yet fully understand. Additionally, it is likely that many, if not all remaining populations lack genetic diversity due to their small population size, which may be reducing fitness and further exacerbating the decline. Management advice for this species focuses on cycles of moderate disturbance every 3-4 years by grazing or forestry operation, further research on mycorrhizal associations, genetic testing of remaining populations, and possibly further translocations (depending on results of this trial).

1. Background and Introduction

This report for RSPB Abernethy brings together current research on habitat preferences and management needs of One-flowered Wintergreen, *Moneses uniflora,* from herein referred to as Moneses, and summarises the trial translocation carried out in October 2023.

Moneses is a small flowering pinewood specialist plant with a distribution across boreal habitats in the Northern hemisphere. It sprouts in individual rosettes, which appear to take at least two years to reach maturity and flower. Individual plants are thought to be perennial, although whether plants cease flowering after 1 or a few years or persistently flower, and then die back or remain as green rosettes, is not clear and in need of further study. The flowers are buzz-pollinated by bumblebees, although some observers suggest large moths may pollinate Moneses at night as well (Knudsen and Olesen, 1993). Thousands of dust like seeds are produced from each single-flowered head. Moneses can also reproduce vegetatively via rhizomes, with small clumps commonly found together, presumably from a single origin plant.

1.1. Literature Review

Moneses is the only member of its genus, closely related to Pyrola, a group containing other true wintergreens, such as Intermediate Wintergreen (*Pyrola media*). It is nationally rare, recorded from only twelve 10 km grid squares in Great Britain since the year 2000 (Stroh et al., 2023). It is confined to pinewoods in northern areas of Scotland. Due to its restricted range and small populations, Moneses is classified as 'vulnerable' in the Red Data List for Great Britain (Cheffings et al., 2005). It is noted as in need of action in the Scottish Biodiversity List and is a priority species in the Cairngorms National Park Nature Action Plan. However, recent surveying and literary work carried out by Plantlife suggests that Moneses is declining rapidly in the Cairngorms, with 3 of 5 populations apparently extinct since 2010. Given recent loss of other populations in Scotland, this decline is of great concern for the UK's Moneses population.

Widespread declines in vascular plants are occurring in Scotland, due broadly to a reduction in suitable habitat (Walton et al., 2023). Moneses is thought to be becoming rarer globally, though the plant is poorly recorded and may have a naturally patchy distribution. Similar declines to that observed in the Cairngorms have been recorded in Sweden, with an 84% increase in site absence recorded in less than 10 years in one area surveyed (Eriksson, 2022). This shocking decline mirrors Plantlife surveys in Scotland and suggests a more serious situation for Moneses than most species. However, the reason for such a sharp decline is unclear. Moneses is often observed disappearing from pinewood sites that have not changed from seemingly ideal condition (Eriksson, 2022).

True wintergreens are partial-mycoheterotrophs, they can uptake organic carbon directly from fungi in the soil, rather than via photosynthesis (Johansson et al., 2017). It is unclear whether this relationship is parasitic or commensal. As with orchids, it is believed that Moneses seedlings require a broad but perhaps specific range of fungal hosts to germinate and support their development. They are obligate-mycoheterotrophs until maturity, when their fungal host range narrows and they may rely more upon photosynthesis (Johansson et al., 2017). This is likely part of why Moneses are so challenging to understand and propagate (all historic captive propagation attempts have failed). Recent research has shown that they associate

with a range of common saprotrophic fungi in pine woods, and are likely to thrive at sites with a high diversity of ectomycorrhiza (Johansson et al., 2017). This complex interaction with fungi is almost certainly a significant element in their decline, as well the challenges in propagating them.

Moneses grows in similar pinewoods habitat to *Linnaea borealis*, *Goodyera repens*, and other Pyrola species. However, its realised niche is far more specific than the fundamental niche it should be able to inhabit given our understanding of its preferences and the inhabitation of similar species, and it continues to rapidly decline. As part of this project, habitat commonalities of so far ~half of the likely extant Moneses populations in the UK have been summarised [1]:

- Always recorded growing within 10m of pine trees, although it is not specific to *Pinus sylvestris*, growing under *Pinus nigra* on the Moray coast, and other species globally.
- Nearly always within 50m of *Pyrola media/minor* populations, but while Pyrola may inhabit waterlogged dips, Moneses may be on slightly raised ground nearby.
- Grows within and through the bryophyte layer of species such as Hypnum, Dicranum, and sparse Hylocomium, but appears to compete poorly with denser bryophyte layers of more than ~3cm, such as denser Hylocomium, Polytrichum, or Sphagnum.
- Usually recorded growing on bare soil, areas disturbed by animals, old forestry tracks, sites with historic grazing, etc.
- Associated with the presence of dead wood on the ground, usually smaller brash and branches rather than fallen trees.
- Appears to favour thin, poor, sandy, acidic, and better drained soils, although can also be found at more waterlogged peaty sites.
    - Low nitrogen, low nutrient, high ectomycorrhizal diversity soils are expected to be key.
- Often found near loch edges, the edges of wetlands, or the coast.
- Appears to recover quickly to local disruption, observed with sometimes >80% apparent fluctuations in abundance year to year, and populations can move from previous sites.
    - Appears to behave as a successionary plant, rather than persisting at a site, perhaps adapted to move to more suitable habitat as it arises and previous populations will not persist. This may mirror the transitional mobile nature of natural *Pinus sylvestris* woodlands.
    - It may not be possible to preserve Moneses at a single site in perpetuity.

Eriksson, 2022 discuss the possibility that Moneses are suffering a substantial global decline in response to modern changes in woodland management. It was regarded as a common plant in the 19th century. It does not appear to thrive in habitats where understories are dominated

[1] It is important to note that this is based on the current, anthropogenically reduced realised niche.

by taller growing herbs, competing particularly poorly with graminoids. Historical woodland management may have produced more suitable habitat for Moneses, with less clear felling and dense single age structure woodlands, and a prevalence of livestock grazing in woodlands preventing a dominant understory (Eriksson, 2022). Hypothetically, a non-human niche for Moneses may be disturbed and grazed ground created by large herbivores in pinewoods.

1.2. RSPB Abernethy

Abernethy is a large nature reserve to the south of the river Spey protecting some of the oldest and most undisturbed pinewoods habitat in Scotland. The reserve is key for many rare pinewood plants including Moneses. Many Moneses populations have been recorded historically, though from 2007, only three populations were known (Stroh et al., 2023). All populations were confined to a small area of the reserve on the Western slope above the river Nethy in open semi natural *Pinus sylvestris* woodland. Soils at the site are very wet, peaty, and acidic. The site is downhill from a settlement, historically a croft and now an occasional residence, with fields still used for grazing. Soils may be enriched from runoff, although no tests have been performed. Surveys from 2019 only re-found a single population at NJ 01747 14929. Less than 20 rosettes were visible in 2019.

In Autumn 2019 a small group of Highland/Beef Shorthorn cross cattle were introduced to the woodland where Moneses was present for a few weeks, grazing at a moderate density, as part of a wider grazing trial. Initially, the impact appeared negative, with 0 rosettes found in 2020. However, subsequently, this grazing may have positively impacted the population. In 2021 over 100 Moneses rosettes were found, while the population peaked over 160 in 2022. In 2023 number were down to nearly 60. 7 flowering heads were recorded in both 2022 and 2023, suggesting Moneses that may have established in 2020 is reaching maturity and starting to flower.

Cattle grazing visibly affected the site with creation of significant patches of bare and disturbed ground. “The field layer, including tussocks dominated by rank heather and interspersed by wet grass and sedge dominated flushes, was significantly knocked back, allowing more light to the ground layer and initiating a noticeable response by a variety of flowering plants and ericaceous shrubs.” – Chris Tilbury Assistant Warden RSPB Abernethy. Cattle grazing on site was renewed in late summer 2023. 23 Highland/Beef Shorthorn cross cows and 20 calves were grazed in the area for two weeks again to maintain disturbance to the field layer prior to translocation.

Given the proximity to grazing land, it is possible that the reason for Moneses persisting at only this site at Abernethy is historical grazing. Perhaps the surrounding pinewoods and Calluna dominated habitat were used for summer cattle grazing by traditional crofters, maintaining a reliable niche, unlike most of the rest of Abernethy where grazing has been minimal, other than deer grazing (which has been heavily reduced over the last four decades).

1.3. Objectives

- Identify optimal habitat characteristics and subsequently management advice for effective Moneses conservation.

- Test whether Moneses translocation is a viable conservation technique, both for the preservation of genetic material from a threatened donor population, and for the reinforcement of a recipient population.
    - Investigate whether being sourced from recipient sites of different bioclimatic regions may impact the success of donor plants.
- Successfully reinforce and improve the outlook for Moneses at Abernethy, both via the introduction of new genetic material, and more individual plants.

2. October 2023 Translocation

2.1. Translocation Sites

Due to cattle grazing discussed above in September, all translocation sites were recently disturbed, and the soil and surrounding vegetation should be in ideal conditions for Moneses colonisation. Translocation sites were all placed more than 30m but less than 50m from the original plot, according to the Nature Scot translocation license submission. This keeps all rosettes within expected distance for cross-pollination by bumblebees or moths, but far enough from the remnant population to avoid disturbance through planting or monitoring activity.

2.2. Material Collection

On the 12/10/23 the translocation was carried out. This was led by Plantlife with support from RSPB, RBGE, CNPA, and FLS. Plants were collected from two Moneses populations. There are limited healthy populations of Moneses remaining in Scotland, with only 3 or 4 sites likely to be substantial enough to sustain the removal of rosettes (Stroh et al., 2023). The two nearest suitable sites were selected for this translocation, Roseile Forest on the Moray coast near Burghead, and Old Grantown Wood near Grantown-on-Spey. Table 1 lists precise collection locations.

Table 1: Grid references of translocation receptor sites.

Collection	Grid Reference
Roseile 1	NJ 11327 67691
Roseile 2	NJ 11303 67715
Roseile 3	NJ 11304 67740
Roseile 4	NJ 11328 67766
OGW 1	NJ 03762 29137
OGW 2	NJ 03745 29127
OGW 3	NJ 03690 29157
OGW 4	NJ 03745 29124

The Roseile population is substantial, expected to contain at least 2000 mature rosettes, though a full count has not been completed. It can easily sustain being the donor for this and future translocations. It is very different to Abernethy in habitat. Moneses at Roseile grow under young *Pinus nigra*, within 100m of the coast, in a dense shady habitat, as seen in Figure 1. The woodland floor is mostly bare of vascular plants, covered in pine needles and thin matts of bryophytes such as Rhytidiadelphus, Hylocomium, and Hypnum species. Peltigera lichens are also common, as well as areas of bare soil and woody debris. The soil is very sandy, thin, and free draining. This woodland is not historic, planted 100-150 years ago after extensive effort to stabilise the dune system through the establishment of marram grasses, and actively managed for timber production until recently. Prior to this, it is not clear whether Moneses

may have inhabited the site. It is possible that isolated native patches of pine among the dunes and rough grazing land may have sustained small Moneses populations. However, it is more likely that Moneses established on site along with woodland planting, perhaps brought with seed or saplings, or on the tracks of vehicles which foresters were using.

Figure 1: Moneses habitat at the collection site at Roseile Forest.

The Old Grantown Wood population is less substantial, last surveyed in summer 2023 giving a total of 730 rosettes. Long term surveys show the population fluctuates significantly, but is stable, and it can currently sustain being the donor for a single small translocation. This site is more like Abernethy in habitat, although still with considerable differences. Moneses grow under mature and sparsely distributed *Pinus sylvestris* in open pine woodland habitat, see Figure 2. There is some evidence of deer grazing on heather stems, but grazing pressure is likely light to moderate. The site has been grazed historically by sheep and cattle as part of a nearby field, mirroring potential commonalities in Moneses habitat recorded at Abernethy. The site has been treated to control *Rhododendron ponticum* since 2014, which was threatening to overrun the area prior. This has left large artificial patches of bare ground with dead wood lying on the surface, a habitat that Moneses seems to favour for colonisation. *Culluna vulgaris* and *Vaccinium myrtillus* are encroaching and producing a denser scrub layer in open areas. There is plentiful regeneration from nearby non-native pines and Rhododendron (on going management and advice continues), but minimal native *Pinus sylvestris* regeneration. Moneses grow in areas of bare ground and wood, and among bryophytes (Hylocomium, Rhytidiadephus, and Dicranum species) and under Calluna. The

substrate is acidic and is thin and free draining. This woodland was likely grown as a plantation over 150 years ago but has been thinned and kept as ornamental gardens for much of the last century. It is thought that Moneses, as well as local *Linnaea borealis*, may have been translocated during establishment of the plantation. However, as with Roseile, habitat on site prior to the establishment of the plantation is not clear, and it is possible Moneses has been resident for longer.

Figure 2: Moneses habitat at the collection site at Old Grantown Wood.

We collected a total of 72 Moneses rosettes from Roseile and 31 from Old Grantown Wood. These came in 4 clumps of rosettes and earth from each site, each measuring 15-25cm wide and long, and dug 5-10cm deep (Figure 3). Rosettes were collected in clumps due to their distribution at collection sites (they grow in clumps) and to minimise disturbance to roots and fungal hyphae. We kept the surface undisturbed, but removed any obvious vascular plants that could be removed without significantly disturbing Moneses rosettes. Photos and grid references were taken of the location each clump was collected from for follow up surveys. A chunk was cut from the Roseile clump to be planted at Site 3 containing 12 rosettes, which was taken with Jenny Baker to RBGE for further study. The remaining plants were taken to RSPB Abernethy.

2.3. Planting

Clumps holding Moneses were planted out within 5 hours of collection. Sites were chosen approximately prior to planting. Microhabitat selection for planting each clump was based on the site the current population at Abernethy inhabits. This resulted in avoiding waterlogged areas, and planting near or slightly under *Calluna vulgaris*, and within proximity to a *Pinus sylvestris*. Additionally, sites were chosen close to cattle trampling and grazing routes due to evidence in Section 1.1, i.e. to ensure rosettes were not swamped by vascular species or bryophytes, and that bare ground was present nearby for potential propogation. Holes were dug of approximately the size of each clump, and they were slotted in, giving them a gentle firming into the soil.

Figure 3: A clump of Moneses rosettes just after collection at Roseile.

They were planted in pairs at each site, one each from the donor sites. Clumps were planted with 1-3m between pairs. A bamboo cane was used to mark each planted clump, and the centre of each pair was recorded via GPS. The nearer of the pairs to the track (Eastern) is from OGW, and the farthest (Western) is from Roseile. Photos of each plot at time of planting were taken. Figure 4 shows an example of Moneses planting.

Figure 4: Translocation receptor site 2. An example of the setup of a plot with two clumps planted within a few metres of each other in suitable habitat.

Table 2: Details of each translocation site and number of Moneses rosettes planted at each.

Site	Grid Reference	Old Grantown Wood Cuttings	Roseile Cuttings
Site 1	NJ 01752 14901	8	9
Site 2	NJ 01731 14905	8	14
Site 3	NJ 01730 14941	4	13
Site 4	NJ 01740 14970	11	24

2.4. Results

2.4.1. 1 Month Survey Results

The 1-month survey was completed on 15/11/23. A photo was taken of each plot, Moneses rosettes counted, and additional notes/photos taken of any noteworthy features or changes.

Within the first month, a small but noticeable decline in the number of rosettes has been noted. This is not unexpected when performing a translocation, as plants are heavily disturbed, and it is hoped that this pattern of decline will stabilise. However, additional Moneses rosettes appeared in some plots and in the sample collected and taken to RBGE after the translocation

event. In total, 8 less rosettes were counted on the 1-month resurveys. Two sites (Ros 1 and 2) increased in number of rosettes, meaning actual losses may have been higher. However, given that Moneses rosettes may remain hidden under the bryophyte layer and undetected, rosette counts will not perfectly reflect population status and longer-term data is required to draw conclusions.

Plots were significantly wetter than when planted after Autumn rain. There was also evidence of disturbance, with sticks and pine needles either having been washed away or moved by animals. Roseile site 2 was partially waterlogged, although rosettes appeared green and healthy at time of surveying. Some rosettes in Roseile site 3 showed accelerated seed head browning and in some cases seed heads coming free from the plants. OGW site 4 rosettes contained a few plants healthily developing next year's flowering spikes which appeared uninterrupted by translocation.

Table 3: Number of rosettes re-found during 1-month surveys.

Site	Old Grantown Wood Cuttings	Roseile Cuttings
Site 1	6	10
Site 2	7	15
Site 3	4	12
Site 4	10	19

2.4.2. 3 Month Survey Results

The 3-month survey was completed on 23/1/24. A photo was taken of each plot, Moneses rosettes counted, and additional notes/photos taken of any noteworthy features or changes.

Numbers remained almost unchanged across the plots, other than OGW Site 1, which has continued to noticeably decline. The survival of more than 85% of plants through the first half of winter and under snow cover is heartening. Both surveyors on this trip noted the remarkable unchangeable nature of nearly all Moneses in the plots, see Figure 5. Photography confirms that despite the translocation and the wintery conditions, most rosettes look no different than when planted.

Plots were wetter still than November. Rosile site 2 was almost completely waterlogged, with only some Moneses leaves above water. However, currently, plants appear entirely unaffected by water levels. One rosette which was submerged in November surveys has likely been submerged for 2 months or more but so far appears healthy still. Browning of some leaves, particularly of those which had previously flowered, seems to be continuing slowly. Developing flowering spikes remain unchanged.

Table 4: Number of rosettes re-found during 3-month surveys.

Site	Old Grantown Wood Cuttings	Roseile Cuttings
Site 1	3	11
Site 2	6	15
Site 3	3	12
Site 4	10	19

Figure 5: Site 1 Roseile planted at Abernethy. The photo on the left is after planting in October, the photo on the right is 3 months later in January. Individual rosettes appear identical to when planted. The only obvious change is that water has run across the plot at some point.

2.4.3. Follow-up Survey Plans

The site will be surveyed as 2.4.1 at 6-months post translocation. At this point a brief review will be carried out and discussed with RSPB Abernethy. Depending on the condition of Moneses translocation plots, further survey plans will be initiated.

3. Management Advice

It is extremely challenging to provide confident land management advice for Moneses. It is typically described as a pinewood specialist flower occupying sandy peaty acidic soils that remain moist year-round, growing under Calluna and among bryophytes. However, its distribution in Scotland is extremely restricted, while almost all habitat matching the above description supports no Moneses. Additionally, Moneses in Sweden is occasionally recorded growing in roadside ditches, and in Scotland the three most substantial populations grow on the coast in <150 year old and sometimes non-native pine plantations (Eriksson, 2022). Clearly other significant factors are restricting the distribution of Moneses.

(Eriksson, 2022) propose that the rapid modern decline of Moneses is due to a change in forestry management, specifically, reduced disturbance in plantation woodland via grazing and selective felling, widespread adoption of clear felling, and the spread of densely planted single age structure woodlands. Anecdotal evidence from Plantlife surveys support this hypothesis, with Moneses now only present at sites with evidence of recent or historic disturbance via grazing or forestry. The Moray coast populations all grow on forestry tracks, old sites of logging racks, and areas for turning and dumping wood. Both the Old Grantown Wood and Abernethy populations are close to grazed fields, and both have records of historic grazing. Additionally, both sites were in decline (no grazing had occurred on either site for >20 years), until recent grazing and rhododendron management, at which point both populations

significantly recovered. Conversely, two of the three sites in the Cairngorms which appear to have recently gone extinct show evidence of increased thickness of the bryophyte layer and increased cover of Calluna, Vaccinium, and Pteridium (Bracken) when compared with historical photos. Browsing by deer may have maintained these habitats in sub-optimal conditions, but management to reduce deer numbers appears to have caused further decline in habitat suitability for Moneses. We can conclude that maintained and repeated disturbance on Moneses sites is crucial to persistence, particularly to the production of new rosettes.

Ectomycorrhizal associations are also crucial for Moneses, particularly for the successful establishment of seedlings. Further research is needed, and is ongoing, but the simplest recommendation is to ensure optimal conditions for ectomycorrhizal fungi. Moneses associate with a wide range of saprotrophic and mycorrhizal fungi species non-specifically, but narrow their hosts and rely less upon them as they mature (Johansson et al., 2017). High density patches of Moneses in Grantown, Culbin Forest, and Roseile Forest tend to correlate with fallen wood, brash, and trampled woody material. This may suggest elevated densities of saprotrophic fungi in these areas promote germination of seedlings. Ectomycorrhizal fungal diversity tends to increase with low soil nutrient and nitrogen inputs, suggesting another possible target for site management.

It is likely that remaining Moneses populations are experiencing high levels of inbreeding and may be prone to population bottlenecks. When populations drop to tens or hundreds of genets (genetically distinct individuals), relatedness between individuals increases, and it is likely that offspring will be reduced in fitness. This reduction in fitness could be a significant part of the modern decline and extinction of Moneses at many sites. Additionally, Moneses commonly spread via rhizome, producing clumps of individual ramets (separate plants with the same genetic material, effectively clones) originating from a single seedling. It is unclear without further study how many genets may be present at a small relic site such as Abernethy, but with 60 rosettes in 2023, it is easy to imagine only 10 genets remain. The population was historically smaller, so inbreeding will be exacerbated. As well as translocations to improve genetic diversity on relic sites, and to protect remaining genetic resources in Scotland, further study of the heterozygosity (genetic difference) within and between remaining populations is crucial.

While we do not fully understand the causes of decline of Moneses in Scotland, recent work has given us a clearer picture of what can be done. Moneses is not a typical pinewood understory plant, such a *Linnaea borealis*. It is more specialist to disturbed ground, bare soil near wet places, rotting wood, and a thin bryophyte layer. It moves between sites, declining from unsuitable habitat quickly, but with good colonising success and rapid recruitment at sites where conditions are optimal. Disturbance is the most crucial element for its conservation. Moneses is a pinewood specialist, and disturbance via grazing or intermittent forestry management is now very rare in Scottish pinewoods. Changes to pinewood management can contribute most to its recovery. When combined with translocation to improve genetic diversity of each site, and further study on fungal associations, genetics, and habitat preferences, Moneses abundance and distribution will recover.

3.1. Key Recommendations

- Moderate and widely disruptive disturbance (sufficient to noticeably impact tall herb dominance and open up areas of bare ground) on Moneses sites and sites in the vicinity of Moneses every 3-4 years should be ideal. Moneses can reach maturity and flower in this period.
    - Moderate density cattle grazing for a few weeks around the site should provide this disturbance at Abernethy.
    - Any disturbance is better than none, if a 3-4 year schedule is not practical, fit to other plans. Consult with Plantlife or other experts if over-disturbance is a concern.
- Where the woodland canopy is open and Calluna and Vaccinium are dominant, then a gradual increase in density of *Pinus sylvestris* would be optimal.
    - If the woodland canopy becomes overly dense and dominated by younger trees, some thinning may be recommended.
- Ensure soils do not have external nutrient input either directly or via runoff from nearby sites.
    - Prior to planning cattle grazing on site, where possible, avoid the preceding site which was grazed being enriched grassland or equivalent to prevent input via excretion. Also check that the cattle have not been given any treatments or potentially exposed to pesticides or herbicides immediately prior to introduction to the site.
- The addition of dead wood such as tree branches or smaller logs onto sites near Moneses prior to disturbance may provide optimal habitat for seedling development (ensure any wood is sourced locally and there is no chance of pest or disease transferral).
- Genetic testing of the relic Moneses population at Abernethy is recommended to assess population diversity and guide the urgency of further translocation work.

4. References

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Plantlife is the global charity working to enhance, protect, restore and celebrate the wild plants and fungi that are essential to all life on earth. With two in five plant species at risk of extinction, biodiversity loss is now the fastest it's ever been – which means our work has never been more vital. We champion and accelerate conservation action, working at the heart of a global network of individuals and organisations, to influence and inspire landowners and land managers, public and private bodies, governments and local communities. As time begins to run out, we are using our position as the global voice for wild plants and fungi to bring lasting and positive change to our natural world – for everyone's sake.

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