Prioritising conservation translocations in Scotland

MSc in Biodiversity and Taxonomy of Plants Thesis Project

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Abstract

There is a biodiversity crisis in the globe and Scotland. Conservation translocations are good tools for remedying these losses. A method should be developed for prioritising the translocations. The IUCN threat categories and expert interviews were used to prioritise endangered native Scottish species. The IUCN categories were found unreliable for prioritisation. Suggestions were made for ideal approahes.

Contents

Introduction

The global biodiversity crisis and the plants

The world is facing an unprecedented environmental crisis. Recent extinction rates are estimated to be 100-1000 times higher than pre-industrial levels (Pimm *et al.*, 1995). The Living Plant Index (2021) lists intensive agriculture, over-exploitation, competition with introduced invasive species and other pressures of anthropogenic origin as contributing factors to changing climate, habitat loss and fragmentation. This is causing a major decline in the wild plant populations and a loss of biodiversity. This rapid loss of species means that there is an urgent need to develop policy strategies that reduce the anthropogenic pressures on biodiversity (Spangenberg, 2007). Plants as sessile organisms are particularly affected by these unfavourable conditions. As plants form the foundation of the food pyramid, any declines in biodiversity are likely to have a cascading effect on the other plants and the higher trophic levels.

Threats, conservation challenges and the state of nature in Scotland

Scottish biodiversity has affected by centuries-long exploitation, and suboptimal land management policies such as overgrazing, intensive agriculture and overexploitation have been the cause. More recently climate change has also had an impact (SWT, 2021). The majority of the forest cover in the British uplands had been lost by the beginning of the 19th century and less than 20% of Scotland's land mass currently supports woodland. This is far below the 46% European average (SWT, 2021). An increase in animal grazing of sheep and wild deer in the Scottish uplands is leading to habitat loss. This has an impact on other species, with loss of habitat reported to have been adversely affecting the bird and insect taxa since the (Gardner *et al.*, 1997; Dennis *et al.,* 2005). High grazing intensities are also reducing the regeneration of Scotland's native flora and fauna for decades (Fenton, 1940; Mardon, 1990; Thomas, Simcox and Clarke, 2009; Evans, Pocock and Memmott, 2013). Due to a combination of overgrazing and climate change, some vascular plant species in the UK have already shifted their distribution patterns during the last century (Braithwaite *et al,* 2006). This is expected to worsen as climate change impacts in Scotland predict longer heat spells and more frequent drought in the future (Nature Scot, 2019). A bioclimate model for

vascular plants at a Scottish mountain range estimated that 8 out of 10 focal montane species will lose all suitable climate altitude range at the native sites due to increasing temperatures by 2080 (Trivedi *et al.*, 2008).One out of 11 species in Scotland is already at risk of extinction (Highland Titles, 2021).

Research has been performed and initiatives were implemented to improve the conditions of Scottish wild habitats. Nonetheless, the majority of the wildlife zones are not being protected efficiently enough and remain fragmented (Humphrey and Patterson, 2000; Robertson, Newton and Ennos, 2004; Hobbs, 2009; Sing, Towers and Ellis, 2013; Bunce *et al.*, 2014a). There are conservation stories of success and guidance reports being published for better practices (Moseley, Ray and Bryce, 2005; Britton *et al.*, 2009; Nature Scot, 2020) . However, many threatened vascular plant species may have already reached the minimum viable population sizes in which they can de driven to extinction due to gene losses in the ever-diminishing isolated populations across the landscape (Flather *et al.*, 2011). As these taxa are very likely to reach these tipping points under the current circumstances, if they have not already done so, the restoration of viable free-ranging populations cannot be achieved by reliance on natural recruitment, dispersal and protected areas alone (Seddon, 2010). Therefore, it is necessary to determine the species that are in peril, to give them priority and support the wild populations of the endangered species urgently by practices such as conservation translocations with respect to the threats faced by the taxa.

Conservation translocations

Conservation translocations are the intentional movement and release of plants, animals or fungi into the wild for conservation purposes (IUCN, 2013). They can be very useful in the improvement of wild populations of the target species and are able to reverse the loss of biodiversity occurring due to anthropogenic disturbances in the habitat. Translocations may be focused on benefitting the ‘focal species’ or on restoring the degraded habitats or ecosystem functions as ‘ecosystem species’. There are four types of conservation translocations under two categories: population restorations and conservation introductions.

Population restorations are the common and non-controversial conservation translocations that aim to reinforce or reintroduce a species compared to the much-debated conservation introductions which aim at translocating the taxa outside their native range either to avoid their extinction in the site where they are threatened or to introduce them for performing a specific ecological function lost in the recipient site (Imms, 1941; Ricciardi and Simberloff, 2009; Thomas, 2011). This report is only concerned with the population restorations of the focal species.

As outlined by NSRF (2014) conservation status of a focal species can be improved in several ways such as: increasing the stability of the populations (increasing the number of individuals, improving the population structure, increasing the number of sites); introducing genetic diversity for healthier and more resilient population; establishing the bridging populations facilitating migration and gene flow and establishing populations in areas where the species will be less threatened by land management, diseases, climate change etc. to reduce its risk of extinction. The translocation of the species may also have positive impacts on the ecosystem and on the socio-economics of the local site. Yet, it is important to have a good understanding of the biological needs and the ecology of the species, to choose a protected site with high ecological quality for the release, to ensure appropriate site management e. g. monitoring post-release of the species and to assess the costs of the project (Yackulic*et al.*, 2021). Any possible negative impacts of the translocation on the livelihood and well-being of the local society and on the biology of the recipient site should also be considered. The degree of constraints in the legislations are crucial at this point since the regulations on licences may put forth additional legal challenges (Hodder and Bullock, 1997).

When they are practiced properly, conservation translocations are one of the best ways for recovering the status of the threatened species (Ren *et al*., 2016; Silcock *et al.*, 2019). In some cases, these projects that have financial costs and are supposed to give hope for the future practices can fail due to the faulty practices, to the lack of baseline information for the ecology of the species and to the improper site management (Fiedler and Laven, 1996; Jusaitis, 2005) Furthermore, rather than focusing on the local and native species in need, there has been an ununified approach by the organisations in Scotland, and the UK in general, to make transplants haphazardly and, not the species that would benefit the most from the translocation (Peterken, 2001). Thorough planning and extensive study of the focal species

are prerequisites for maximising success (Adamec and Lev, 1999; Dalrymple, 2007). If the necessary permits are obtained, risk assessments thoroughly made, and best practices followed, then translocations can be efficient tools for the conservation of the focal species. In addition, if the efforts and funding are placed on the 'correct' species, translocation projects are more likely to be beneficial, successful and provide positive examples which may overcome anti-translocation attitudes. Additionally, if the taxa to be translocated are native plants, even less controversies would be expected to occur.

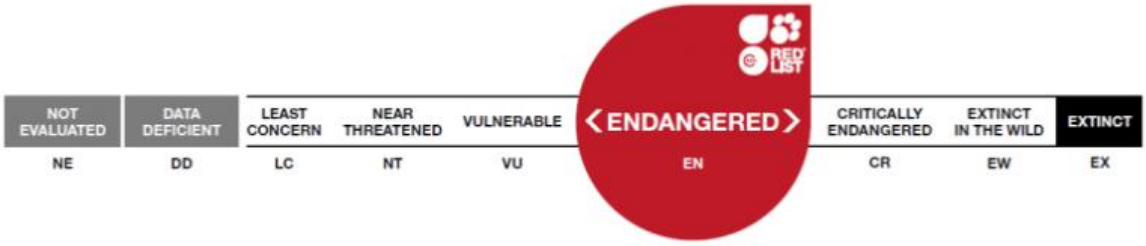

Figure 1: The IUCN Red List threat categories in descending order from right (EX) to left (LC). (IUCN, 2021)

Ideally, a conservation translocation must almost guarantee the successful establishment of the released species. Therefore, the primary targets should be the species that would benefit the most from the practice i. e. species that are in higher threat than the others. As a measure for the threat status and the extinction risks, the International Union for Conservation of Nature (IUCN) Red List of Threatened Species is the most comprehensive inventory of the global conservation of plant and animal species. The IUCN Red List threat categories that are formed by a set of quantitative criteria to evaluate the extinction risk of the taxon under investigation provide one of the best guides available for the decision-making of the most translocation-appropriate taxa (IUCN, 2021). The assessments are based on the global perspective, but they can be adjusted to regions. The assessed species are assigned into one of the categories (Figure 1) and they can be prioritised for conservation translocations based on their threat status.

Latest updates suggest that out of 134,425 species assessed, more than 35,000 are threatened (CR, EN and VU) (IUCN, 2021). The 382 of taxa of ~1816 native or archaeophyte British vascular plant species are also falling within these categories (SSAG, 2021). It is essential to have a reliable system for decision making to reduce the risk of failure, to prioritise conservation resources wisely, and to have a higher number of successful conservation translocation stories for the placement of future efforts in these practices and in the constructive engagement of the public with this topic (Bubac *et al.*, 2019). The opinions of the experts on the translocation of the species are an ideal way to prioritise the species for the next conservation translocation projects and to test the reliability of the regional IUCN Red List assessments. For instance, the translocation of a focal species with little knowledge on its ecology and questionable IUCN threat category into a site with unimproved management or predicted adverse climatic conditions would be undesirable. This paper examines the accuracy of the regional IUCN Red List assessments and investigates more robust methods for the prioritisation of the focal species for conservation translocations.

Aims

This thesis therefore aims to:

1. Develop a methodological approach that allows to objectively prioritise conservation translocations for plant species and possibly other taxonomic groups.
2. Evaluate the efficiency of regional IUCN Red List criteria and, use expert elicitation and online resources to assess urgency and feasibility of plant translocations.
3. Produce a list of Scottish plant species that will benefit most from conservation translocations.

Methods

Summary

The list of 1817 British vascular plant species comprised of native and archaeophyte species and, maintained by the vascular plants Species Status Assessment Group (SSAG), dated 19.02.2021, was inspected (SSAG, 2021). SSAG manages a regional IUCN based assessment for vascular plants for Great Britain (Scotland, Wales & England). IUCN criteria were applied to the three countries as a single region and reviewed approximately every six months. The species on the SSGA spreadsheet were evaluated by country (England, Wales & Scotland) and by IUCN-based threat status.

Firstly, the species that are CR or EN and, native (non-archaeophytes) to Scotland were filtered from the SSAG Red List on MS Excel. The selected species were searched in the BRC species distribution map database (BRC, 2021) to see the distribution of the species and, to gather information on the status (native or archaeophyte), growth type (tree, herb etc), type of life cycle (annual, biennial or perennial) and the presumed cause of the threat. Further sifting was performed using online resources and expert advice from Iain Macdonald as the Nature Scot biodiversity and vascular plant advisor, on the practicality of the possible translocation for the species. Two more lists that contain VU species were produced based on the habitat building potential of the species and, on the number of individuals that are 1000 individuals or less as they could potentially reach EN status if there are further losses. Three lists of species were sorted to be included in the final translocation priority list as follows:

- List 1: Scotland > native > CR & EN
- List 2: Scotland > native > VU & ecosystem engineer
- List 3: Scotland > native > VU & ≤1000 individuals left in the wild.

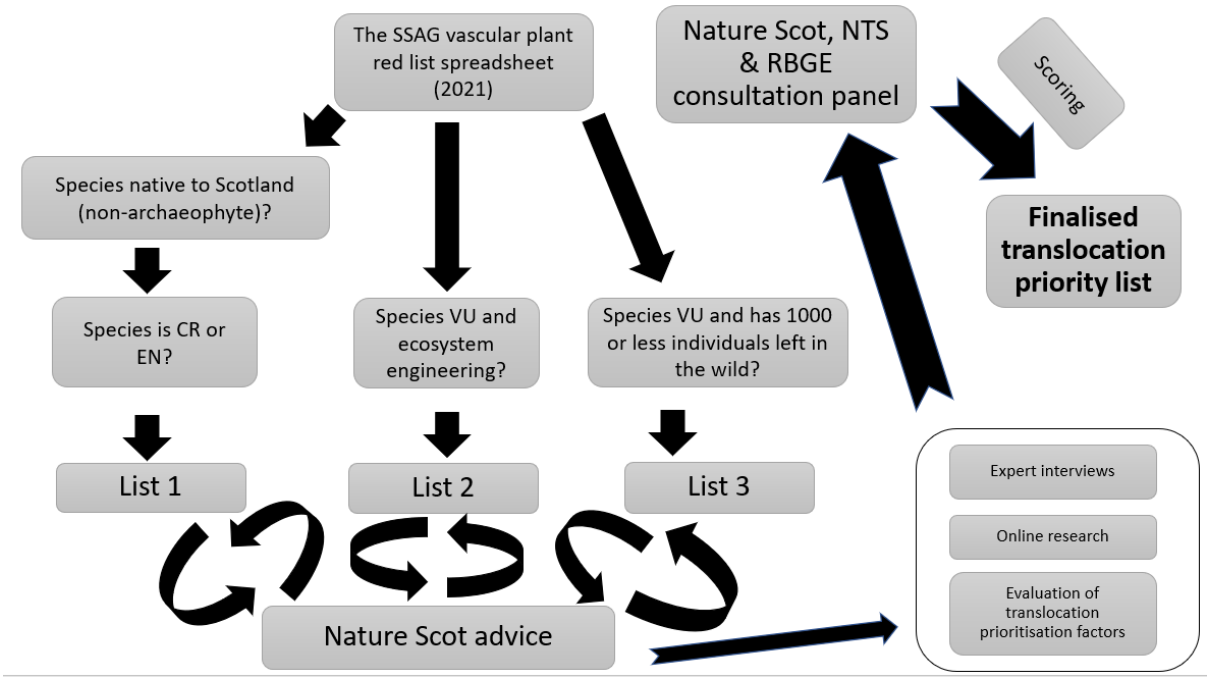

Figure 2: The decision-making flow chart.

The resulting lists of species were then discussed with experts using interviews and further supported by a literature search to prioritise species within these lists (Figure 2). Species were scored according to five factors (IUCN-based threat status, distribution, feasibility of the translocation, habitat building capacity & endemism) based on the information gathered from the interviews and literature search. A group of plant scientists from Royal Botanical Gardens of Edinburgh (RBGE), NatureScot and National Trust of Scotland (NTS) were re-consulted on the sifting and scoring process during a discussion panel. Expert opinion was also used to test whether this approach is effective or whether it misses important species. Consequently, the species were scored with alternative methods and a finalised native Scottish vascular plant species translocation priority list was produced (Figure 2).

Interviews

The interviews focused on the suitability of recipient sites for translocating in Scotland, the ecology of the species, the benefits and potential risks associated with the conservation translocation, and the interviewees' view on optimal practices for increasing the chances of successful establishment (techniques, future management of the site, inclusion of associated taxa) (Figure 3). Replies to the interview questions were summarised and returned to the interviewees for any editing necessary. Interview summaries are included in Appendix 2.

1. Which sort of habitat/environment does the species tolerate and thrive in your experience?
2. Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?
3. Which sites do you consider the most appropriate for the translocation of the species in Scotland?
4. What sort of benefits of translocation can you predict for the recipient site?
5. Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?
6. What sort of technique would you suggest for the process? Starting from seeds, transplanting nursery-grown plants? What time of year would be the best to start translocation?
7. Are there particular practices to do in the recipient site management for successful establishment?
8. Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

Figure 3: The interview questions.

The factors for conservation translocation prioritisation

IUCN threat status

The sifting of the lists was mainly based on the IUCN threat status. The IUCN red list categories are formed by factors for priority with their own assessment criteria. These criteria include reduction in population size (A), geographic range (B), population size estimated to number fewer than 250 mature individuals (C), population size estimated to number fewer than 50 mature individuals (D) and quantitative analysis showing the probability of extinction in the wild is at least 50% within 10 years or three generations, whichever is the longer (up to a maximum of 100 years) (E). Even though, these categories are intended for use at a global level, they can be adapted at regional level as applied in the SSAG spreadsheet (IUCN, 2012).

The species with the highest risk (CR & EN) were filtered from the original list to safeguard against global and regional extinction and, were further analysed for prioritisation. Considering that the regional IUCN red list assessment may not be accurate for every species, some VU species were also included in the list. For example, the VU species with declining numbers of individuals were included in the list as the shrinking population size will decrease the genetic fitness and variation which makes some taxon more prone to extinction (Leimu et al., 2006). In this case, a higher priority for translocation was given for some VU species over the ones assessed as EN and CR.

Distribution

The SSAG red list excludes neophytes but there a significant number of archaeophytes occurring in Scotland and assessed by SSAG, but which are assessed as out with native range in Scotland. As the conservation translocations were to be conducted in Scotland, the species that are native to Scotland were given priority and the archeophytes were discarded.

According to IUCN guidelines, the conservation translocations can accommodate species out with native range (IUCN, 2012), yet, there is a big difference between how non-native species are considered in Scotland compared to England and Wales. Non-native species provisions were significantly amended by the Wildlife and Natural Environment (Scotland) Act 2011 (2011). In Scotland, causing a non-native species to grow in the wild is an offence.

Although, with the obtainment of special permits and licenses, it is possible to translocate species out with native range in Scotland, the study exclusively focused on the Scottish natives.

As reflected in the marking scheme (Table 1), the species noted on the SSAG list with a low number of sites supporting viable populations were given priority for conservation translocation due to the theoretically higher risks posed by diseases and other disturbances.

Feasibility of translocation

Conservation translocations are complex and multifaceted projects that cost both time and money (Yackulic *et al.*, 2021). They require thorough knowledge of the ecology of the species and the recipient site, and good predictions on the future of the site for successful and locally beneficial establishment. When the translocation is conducted, it should require minimum management of the site, maximum efficiency in terms of costs and adjustment with preferably no (or acceptable) risks for the environment in which the translocation is taking place. An example of risk is the spread of pathogenic species, making bio-security measures particularly important.

There may be significant gaps in our knowledge of the species such as its taxonomy, native status, invasive potential, preferred habitat, or irremediable uncertainties regarding the donor site such as adverse conditions due to future climate change or future changes in land use. If the future projections of environmental changes and stressors such as the climate change are expected to render any site unviable for the taxa, the practice should be performed where it will be successful (Wilson and Lotze, 2019) or perhaps should not be attempted at all. Since the reason for the endangerment of some taxa are direct anthropogenic effects such as over-exploitation in the first place (Barañano, Fernández and Méndez, 2018), it is crucial to make sure that the donor site will be protected in the future. Conversely there can be cases where the conservation translocation may have a negative impact on the local people while benefiting the species and even the ecosystem.

The filtered list of CR and EN British flora comprised many arable weeds. The reason for the high threat category for these species was largely the intensification of agriculture (BRC, 2021). These species were also much less common in Scotland than in Wales and England.

Conservation translocation of these arable species to Scotland or within Scotland would not be best practice considering that their favoured conditions are less likely to exist in the Scottish sites and more importantly, the assisted colonisation of these species could prove a challenge for local agricultural practices to sustain. Therefore, the arable weed species were excluded on the preliminary stages for conservation translocation. For species where translocation might not be the most suitable, or unnecessary conservation action, targeted management in their current localities, suitable wider habitat management, or the use of small *ex-situ* populations, may be more cost-effective and lower risk options (NatureScot, 2021). Nor are the survey records impeccably reflective of the true threat status of the species. This factor was especially scored for the List 3 species which had less than 1000 individuals recorded according to the SSAG red list.

Habitat building capacity

Every species is important as it preserves a niche in the ecosystem in which they are an integral part. Some species are particularly pivotal in the way that they not only balance the system by occupying a trophic level but also create habitats and support the habitat that they are in. These species are referred to as the ecosystem engineers. In the past, the conservation translocation of several animal species had a remarkable impact in the health of the ecosystem (Beschta and Ripple, 2016; Barry *et al.*, 2019). Beavers (*Castor* spp.) are a good example of ecosystem engineers. The reintroduction of European beavers in Scotland has proved to be very effective in the improvement of biodiversity (Gaywood *et al.*, 2015).

Certain plant species are just as effective, if not more so, than animals as ecosystem engineers (Mardon, 1990; Kuzovkina and Volk, 2009; Rueda *et al.*, 2009; Warren *et al.*, 2010; Röhr *et al.*, 2016). Although the focus of the priority listing is to benefit the species themselves rather than to provide ecosystem services, the consideration of these taxa from the SSAG list was seen fit as an additional prioritisation factor. The logic behind it was that the presence of the habitat-builders would increase the resilience of the donor site to adverse conditions, e. g. mitigating the potential impact of climate change or dominance of weedy taxa. The conservation translocation of habitat-builders has the potential to benefit other species in addition to the species being translocated. In the same manner, the local extinction, or a significant decrease in the population sizes of habitat-builders could place multiple

species into a more threatened situation. For this reason, a separate list (List 2) was formed for VU habitat-builder species.

Endemism

In terms of vascular plant endemism, Scotland is not the richest country in the world (Gibby, 2003) and perhaps this is why the conservation of any endemic Scottish plant is nationally and globally so important. Endemism is a widely used conservation criterion globally, i.e. there is an onus on the responsible countries and regions to protect unique species within their borders (Kier *et al.*, 2009). Studies on the endemic taxa show that they are integral parts of their communities and habitats (Matthews, Wyk and Rooyen, 1999; Dhar, 2002; MacRoberts *et al.*, 2002; Leroux and Schmiegelow, 2007; Burlakova *et al.*, 2011). Manes *et al.* (2021) report that the risks for endemic species are 3-10 times higher than for the native species and 100% those in islands, 84% of alpine, are in risk of extinction due to climate change (Manes *et al.*, 2021)

Marking scheme

To make the final list as objective as possible, a scoring system was attempted (Table 1). The five factors for conservation translocation mentioned in the previous subsections were assigned numerical scores totalling a maximum of 30 'credits'

	IUCN-based threat status	**Distribution**	**Feasibility of the translocation**	**Habitat building capacity**	**Endemism**
Values of credits	➢ CR (6) ➢ EN (5) ➢ VU (3)	<u>Number of sites:</u> ➢ single (2) ➢ multiple (1)	<u>Likelihood of success:</u> ➢ Ecology well-known (0-2) ➢ Suitable habitat (0-2)	2	*1,5
		<u>Population condition:</u> ➢ Deteriorating habitat (2) ➢ Small population size (2)	<u>Costs ;</u> ➢ Absence of site management (1) ➢ Absence of risks (1)		
Maximum credits	6	6	6	2	30

Table 1: The scoring table with the credit values given for each factor and their sub-factors (IUCN-based threat status and distribution factors .

IUCN-based threat status was given a relatively high 6 credits at maximum with three categories treated according to their level of threat. CR species were given the highest score of 6, EN species 5 credits and VU species 3 credits.

Distribution of the species was marked based on the number of sites and the conditions of the populations as sub-factors. For the number of sites, species that are restricted to single sites in Scotland were given 2 credits and species that are found in multiple sites were given 1 credit whilst habitat deterioration and, small population sizes as described by the experts, were given 2 credits for each sub-factor. The rational for giving these two additional criteria a relatively lower score is that the information they provide (restricted range size and/or

declining populations) partly overlaps with the overall IUCN threat status, depending on what categories were used to score the IUCN status of the species.

The feasibility of translocation was evaluated under two criteria as the likelihood of success and the costs for the translocation project. The likelihood of success of the translocation was accounted for in terms of the baseline information on the ecology of the species and of the presence of suitable habitat e. g. in the climate change scenario ranging from 0 to 2 credits. Costs for the translocation project was evaluated in terms of possible socio-ecological costs i. e. 1 credit if none is predicted to have a negative impact on the well-being of the local society and of the wildlife and, in terms of the necessity of the site management such as grazing control which would give 1 credit if it was not required.

The habitat building capacity was marked as a less important factor, scoring +2 credits based on its presence or absence since the list was aimed at the conservation of the focal species themselves rather than the ecosystem. However, it was still accounted for, for the reasons mentioned in the previous section.

The endemism was exceptionally treated as a coefficient of 1,5 instead of with credits as it is important for the global safeguard of the species and as it would have an effect concerning every factor.

Thus, the overall scoring system assigns a relatively high weight to threat and rarity with additional scores for the feasibility of the translocation and the role of the species as ecosystem engineers. It is fully noted that a scoring system with different weighting may lead to a different priority list.

Results

IUCN-based threat assessment

The results revealed that the regional IUCN Red List criteria were not efficient in reflecting the true threat status of the species and therefore, the prioritisation of conservation translocation. The IUCN Red List criteria was not taking account of the population genetics which was a major concern for the obligately cross-breeding taxa. For instance, *Linnaea borealis*, a species of great concern by many conservation scientists was assessed as least concern (LC) in the SSAG Red List (Figures 1; 3) (Appendices 2.5; 2.6 and 2.9). Another species with an unrealistic status was *Astragalus danicus*, a perennial herb of great abundance and with stable population in Scotland (BRC, 2021), was assessed as EN under the IUCN population criteria (Criterion A) (IUCN, 2012) (Introduction forum). Similarly, *Omalotheca sylvatica (Gnaphalium sylvaticum)*, was assessed as EN even though it was fairly common in Scotland according to expert opinion and *Omalotheca norvegica (Gnaphalium norvegicum)* that was suggested as fit for translocation was assessed as LC by the SSAG (Appendix 2.8).

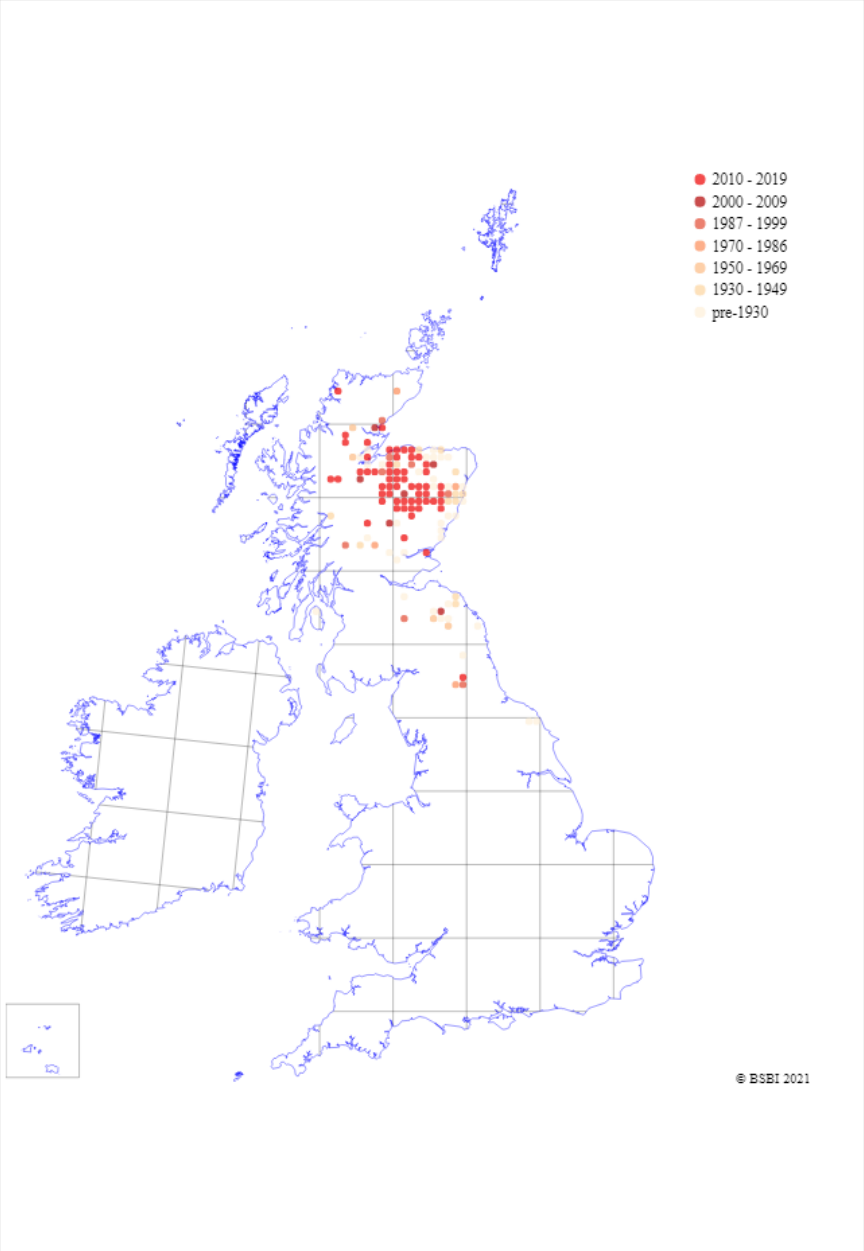

Figure 3: Distribution map of Linnaea borealis in the UK.

Prioritisation and details on the species

A total of 34 species were studied in the report. Ten experts were interviewed for 31 species out of 36 listed on the three preliminary lists (Table 2) (Appendix 1). For the assessments of the species *Potamogeton compressus, Erigeron borealis* and *Scleranthus annuus* were depended on the literature search only. Remaining species *Astragalus danicus, Dactylorhiza incarnata* subsp. *cruenta* and *Omalotheca sylvatica* were discarded based on the expert advice, the incorrectness of the IUCN-based threat status in Scotland and the infeasibility for translocation.

List 1: CR and EN

1. *Alchemilla sciura*
2. *Alchemilla wichurae*
3. *Arabis alpina*
4. ~~*Astragalus danicus*~~
5. *Carex maritima*
6. *Crepis mollis*
7. ~~*Dactylorhiza incarnata* subsp. *cruenta*~~
8. *Dryopteris pseudodisjuncta*
9. *Euphrasia frigida*
10. *Euphrasia marshallii*
11. *Euphrasia rostkoviana (*subsp. *rostkoviana* and *montana)*
12. *Euphrasia rotundifolia*
13. *Monotropa hypopytis*
14. *Lycopodiella inundata*
15. *Melampyrum sylvaticum*
16. ~~*Omalotheca sylvatica*~~
17. *Potamogeton compressus*
18. *Potentilla rupestris*
19. *Sagina saginoides*
20. *Salix myrsinites*
21. *Saxifraga cespitosa*
22. *Scleranthus annuus (*+ subsp. *annuus)*
23. *Sorbus arranensis*
24. *Sorbus pseudofennica*
25. *Sorbus pseudomeinichii*
26. *Woodsia ilvensis*

List 2: VU habitat builders

1. *Salix lanata*
2. *Salix lapponum*
3. *Zostera noltei*

List 3: VU with 1000 individuals or less

1. *Calamagrostis scotica*
2. *Cicerbita alpina*
3. *Dryopteris pseudocomplexa*
4. *Erigeron borealis*
5. *Phyllodoce caerulea*
6. *Poa flexuosa*
7. *Woodsia alpina*

Table 2: Preliminary lists for the species from the SSAG Red List.

	Status	Distribution	Feasibility	Habitat building	Endemism	Final score
Sorbus spp.	6	6	5		1.5	25.5
E. rotundifolia	5	3	4	2	1.5	21
E. marshallii	5	1	4	2	1.5	18
A. sciura	5	4	3		1.5	18
Salix spp.	5	5	5	2		17
C. scotica	3	2	6		1.5	16.5
C. mollis	5	5	5			15
P. rupestris	5	5	5			15
W. ilvensis	5	5	5			15
E. rostkoviana subsp.	5	3	4	2		14
M. sylvaticum	5	3	5			13
W. alpina	3	5	5			13
C. maritima	5	3	5			13
A. alpina	5	4	4			13
S. saginoides	5	3	4			12
E. frigida	5	1	4	2		12
D. pseudodisjuncta	6	3	3			12
E. borealis	3	5	4			12
S. cespitosa	5	3	4			12
S. annuus	6	3	2			11
A. wichurae	5	3	3			11
P. compressus	5	4	2			11
C. alpina	3	4	4			11
M. hypopytis	5	1	4			10
L. inundata	5	1	4			10
P. caerulea	3	3	4			10
P. flexuosa	3	3	4			10
Z. noltei	3	1	4	2		10
D. pseudocomplexa	3	3	3			9

Table 3: The prioritised list for the translocation of the species based on the factor scores (species for which no expert was interviewed are highlighted in orange and the species for which some experts unrecommended translocation are highlighted in gray).

The experts had differing opinions on the actual IUCN-based threat statuses of the species and the translocation which was reflected on the scoring of the translocation prioritisation (Table 3) (Appendix 2). Much of the allocation of the credits per factors and sub-factors were based on the information retained from the experts (Table 1). Following the expert treatment, some species were scored in groups in which case the highest credits from the species among the group was applied to the whole group. Even though some species were not recommended to be translocated by the experts, they have received higher scores than many others (Table 1) (Table 3). The exclusively literature searched species had medium scores. The endemism coefficient had a significant influence on the prioritisation and all the endemic species had the highest scores. Despite their high IUCN threat category, some species were of lower priority for translocation (Table 3). Some experts believed that there were species which were more

threatened than the species in this study and *ex situ* conservation was a more feasible option for the conservation of the species on the list rather than translocation due to their doubtful IUCN threat category and the availability of the suitable habitat (Appendix 2).

Alchemilla spp.

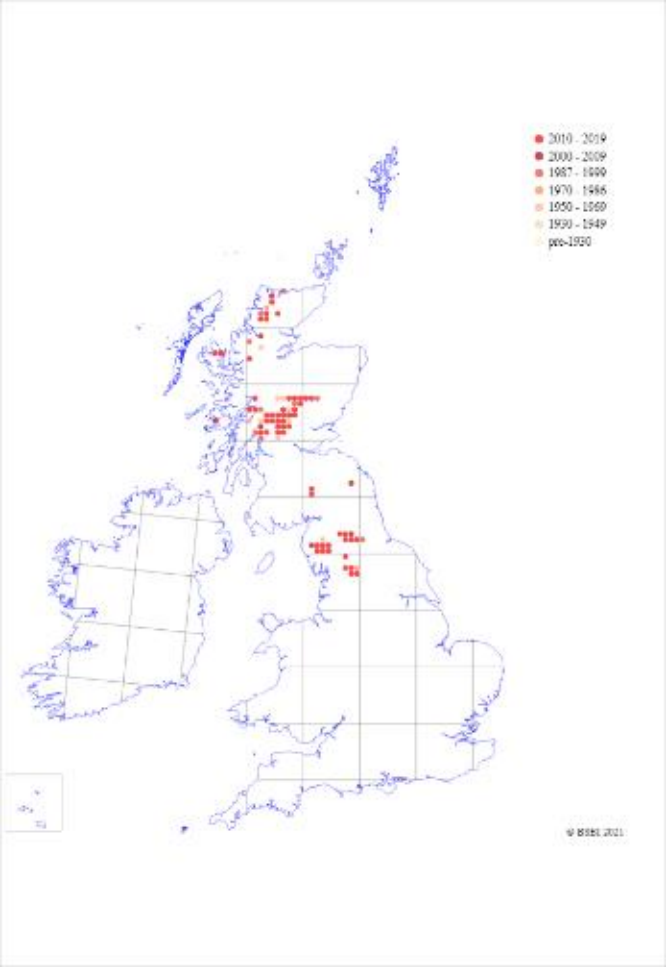

Figure 4: Distribution map of *Alchemilla wichurae* in the UK (BRC, 2021).

Alchemilla wichurae

Score: 11

IUCN-based threat category: EN

Growth form: perennial herb

Habitat: lowland (in high latitudes)

Alchemilla sciura

Score: 18

IUCN-based threat category: EN

Growth form: perennial herb

Habitat: lowland (in high latitudes)

Advice / Comments / Recommendations :

For the purposes of translocation, two taxa were treated the same. Both species require flushing, alkaline soils and do not seem to have big differences habitat preference (BRC, 2021) (Appendix 2.8). Species are suspected to be susceptible to climate change, however, they are expected to cope with it (Figure 4). Benefits include safeguarding the species (Appendix 2.8) and their potential in biomedicine like other *Alchemilla* taxa (Shrivastava and John, 2006; Trendafilova *et al.*, 2011). For the endemic *A. sciura* occurring on a single site (Lynes, 2019), some sort of conservation action would be ideal. No risks were predicted for any recipient site. Translocation of the species was not recommended. Priority was given to collection of seeds for the Millennium Seed Bank (Appendix 2.8).

Arabis alpina

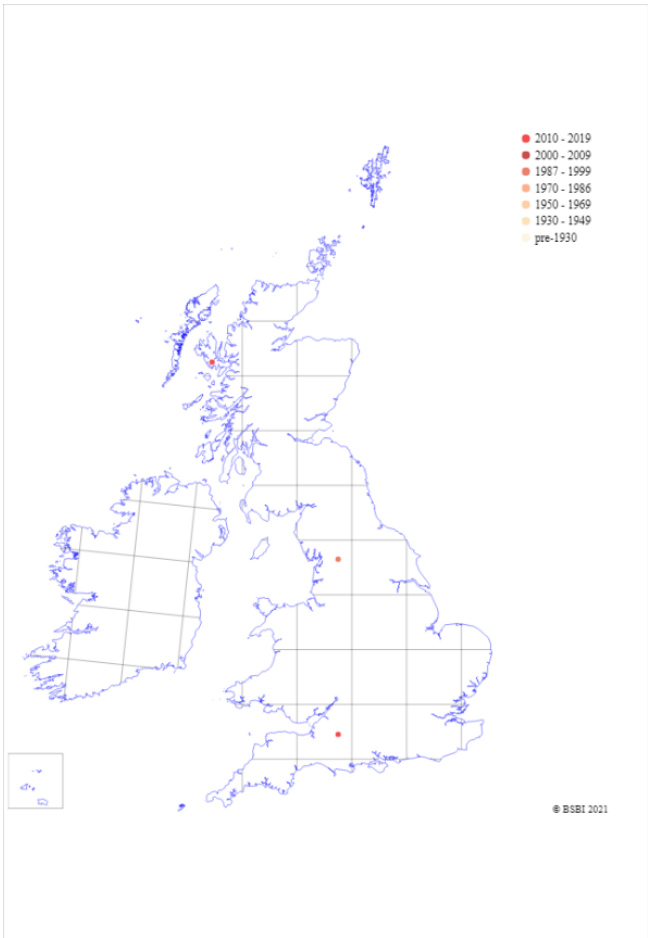

Figure 5: Distribution map of *Arabis alpina* in the UK.

Score: 13

IUCN-based threat category: EN

Growth form: perennial herb

Advice/ Comments / Recommendations :

The species has a wide global distribution (POWO, 2021) but, it is only known from a few populations in the UK which are restricted to a single site in the Isle of Skye (Figure 5). Population in the Cuicuillin Hills has generally remained stable since 1887 (BRC, 2021). The other two sites are in the map are introductions. Its native habitat in the UK significantly differs from the ones in the other European alpine habitats. The narrow British range suggests that the populations may be relics from the last Ice Age. Benefits or risks for translocation are unlikely. Climate change and grazing pressure are not considered as grave threats. Propagation and techniques of translocation of plant is easy however the project may be

challenging both for planting and monitoring phases as the populations grow in ledges. New populations may have been discovered. *Ex-situ* conservation from native seeds may be an ideal option as the species require little maintenance. The site and the Scottish populations hold significant potential for research (Appendix 2.3).

Calamagrostis scotica

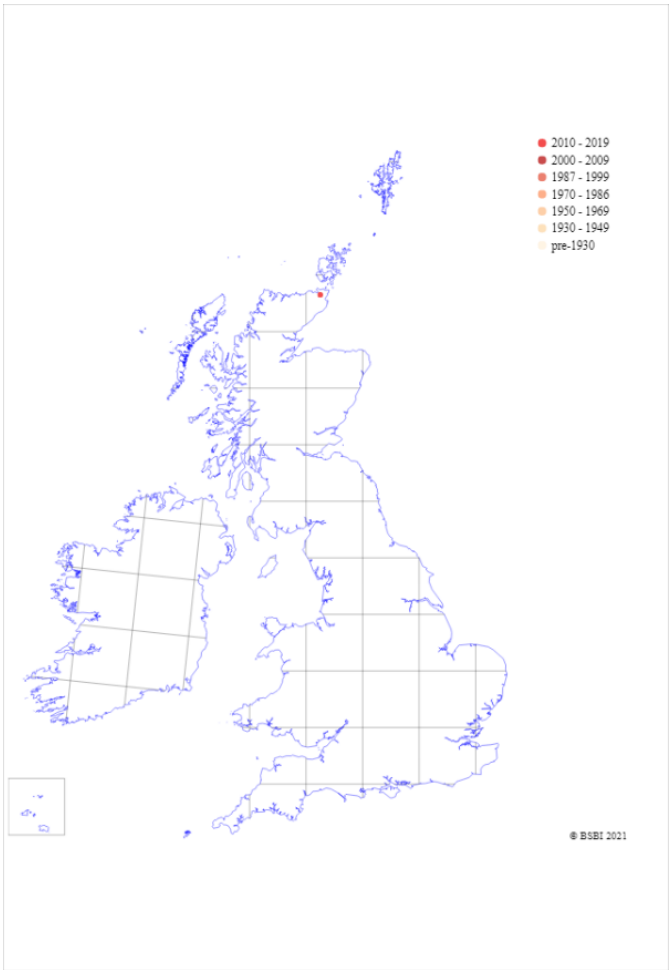

Figure 6: Distribution map of *Calamagrostis scotica* in the UK.

Score: 16.5

IUCN-based threat category: VU

Growth form: perennial herb

Habitat: lowland, fenland

Advice/ Comments / Recommendations :

The species is only known from a single site in Scotland which is a wetland habitat that suggests the water level must be quite critical for its survival. It was agreed to be an endemic of Scotland, the species is understudied yet, some information on its ecology may be derived from that of *C. stricta*, a closely related species with a much wider and southern distribution. The genetics of the species was not studied therefore it is unknown whether hybridisation may occur between the taxa if they were to be in the same site. It grows in the tussocky

habitat with no particular symbiotic relationship to other taxa, although occurs in areas of *Juncus* (BRC) and *Phragmites* dominated pasture (Appendix 2.7). Currently under no risk at the site and populations seem to be thriving, possibly has more than 1000 individuals (Appendix 2.10). Seed collection for *ex-situ* cultivation may be considered.

Carex maritima

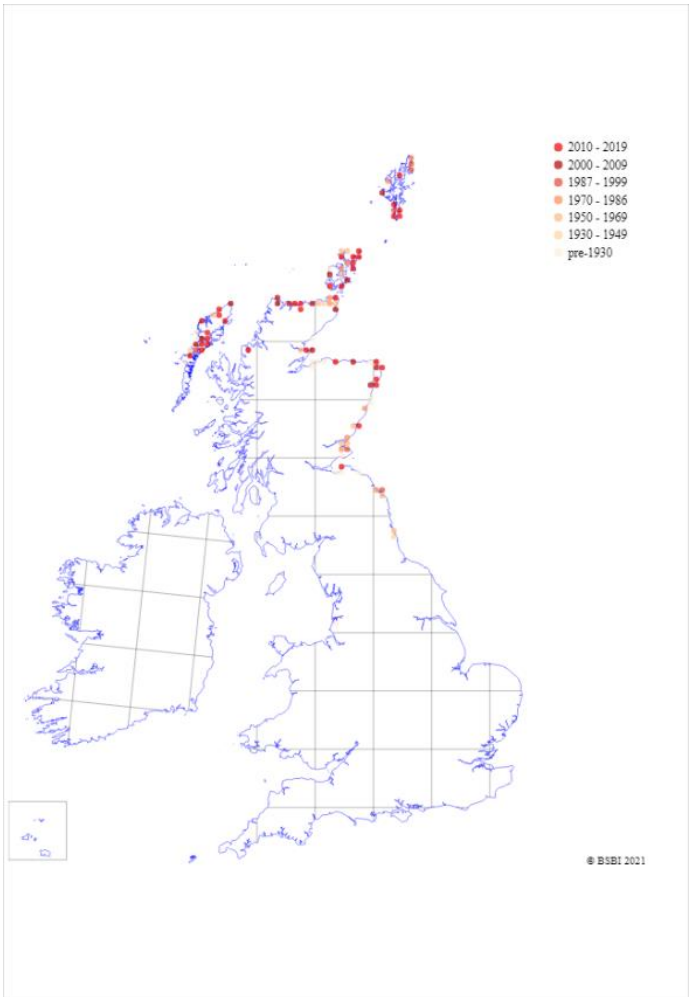

Figure 7: Distribution map of *Carex maritima* in the UK.

Score: 13

IUCN-based threat category: EN

Growth form: perennial herb

Habitat: lowland

Advice/ Comments / Recommendations :

The species grows on bare grounds, newly exposed habitats in very low coastal areas with freshwater influence. Assessments of more recent trends are difficult because it is a very inconspicuous and under-recorded species (BRC, 2021). The UK distribution is getting narrower, expanding north and, it seems to be sensitive to the local hydrology (Appendix 2.7) (Figure 7). No threats or considerable benefits are predicted for the translocation site. For a translocation, the site would have to be monitored for ~12 months to see the water regime.

The preferred habitat does not seem to be rich in species, but *C. maritima* is not a good competitor. So, site management may be necessary post-translocation (Appendix 2.7). The species is mobile and can colonise new sites with suitable habitat, forming large populations (BRC, 2021). Therefore, the remediation of the habitat may be a better option.

Cicerbita alpina

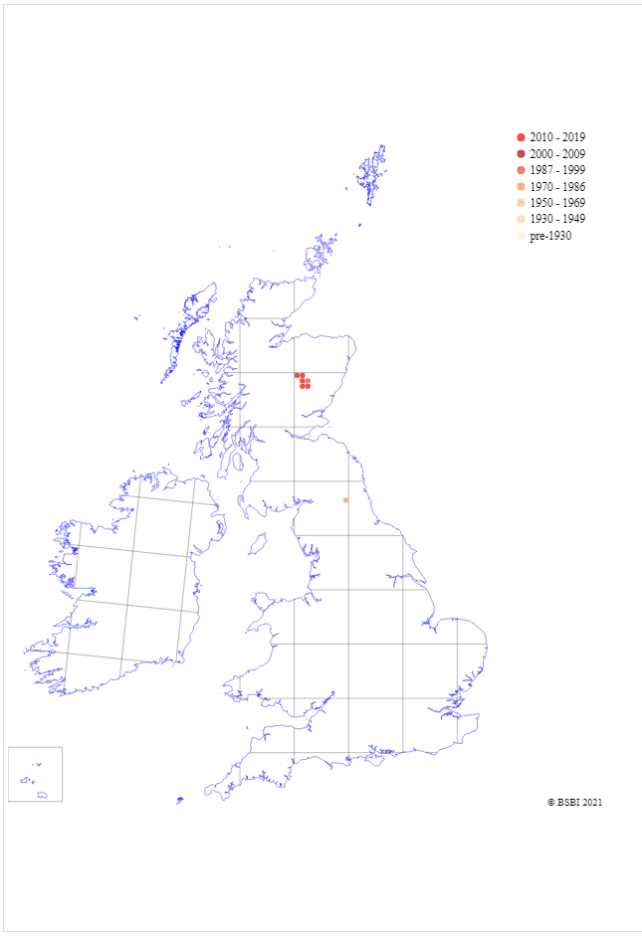

Figure 8: Distribution map of *Cicerbita alpina* in the UK.

Score: 11

IUCN-based threat category:

Growth form: perennial herb

Habitat: alpine

Advice/ Comments / Recommendations :

The species is one of the UK rarities, with only 4 populations. In Scotland, it occurs on very steep ledges which is thought to be a refuge habitat escaping from the herbivore taxa as it is very palatable (Figure 8). Scandinavian populations occur in a much wider habitat range, including birch and pine woodlands (Appendix 2.6). As an outbreeding species, it is also suffering from the reduction in genetic diversity. It is a poor competitor. It favours shady, slightly acidic, moist but not waterlogged conditions (Appendix 2.6) (BRC, 2021). It is

observed to attract many invertebrate taxa and therefore, it has a potential for increasing the local biodiversity provided there is a population large enough e. g. 100 plants at minimum (Annex 2.6). The edible shoots of *C. alpina* is also rich in antioxidant caffeic acid derivatives and might therefore be of interest as chemopreventives (Fusani and Zidorn, 2010). No risks were predicted for the translocation of the species. Germination rate for the seeds is very low. Yet, it can be vegetatively propagated easily. Translocation projects are in motion for the species and its ecology is being understood better (Appendix 2.6). Supporting the future projects and high grazing management in the sites would be ideal until the populations recover.

Crepis mollis

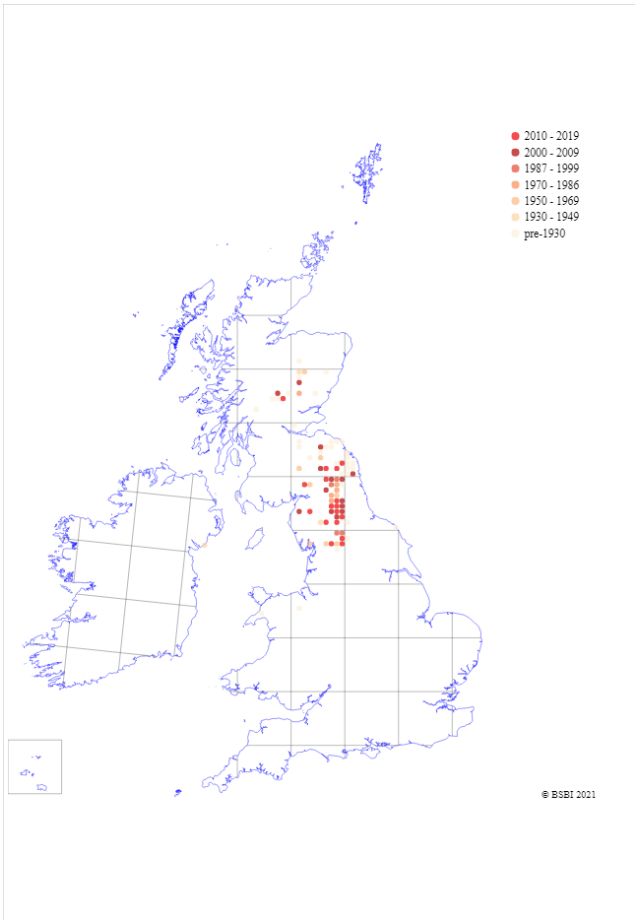

Figure 9: Distribution map of *Crepis mollis* in the UK.

Score: 15

IUCN-based threat category: EN

Growth form: winter-green perennial herb

Habitat: grassland

Advice/ Comments / Recommendations :

It is a grassland species that has declined due to faulty conservation practices (Annex 2.2) and possibly due to some grazing and changes in climate (Figure 9). It has high potential to enhance the site biodiversity and no risks are associated with it. The Scottish populations are restricted to a small native range, but it is suspected to be under-recorded (BRC, 2021). Its big spatial isolations and small populations of the populations in German uplands showed no signs of inbreeding (Duwe *et al.*, 2018), suggesting that the number of the individuals with high genetic diversity of the taxon can be easily improved with little effort in material

collections from the Scottish populations. Propagation from the seed is seen successful and translocation into a monitored site with grazing control and good amount of precipitation (Annex 2.2) or, *ex-situ* cultivation could be viable options for its conservation.

Dryopteris spp.

Dryopteris pseudodisjuncta

Score: 12

IUCN-based threat category: CR

Growth form: herbaceous (pteridophyte)

Habitat: low altitude woodland

Dryopteris pseudocomplexa

Score: 9

IUCN-based threat category: VU

Growth form: herbaceous (pteridophyte)

Habitat: low altitude woodland

Advice/ Comments / Recommendations :

Both apomictic taxa (*D. pseudodisjuncta* & *D. pseudocomplexa*) were given the same treatment by the expert (Appendix 2.1). No distribution maps for available for the taxa (BRC, 2021). The translocation of the species was not advised as these taxa were very hard to identify as most subspecies of *Dryopteris affinis* (Jenkins, 2006; Golding, 2015) and they could be under-recorded. It was recommended that the spores from the mother plants could be collected and taken into conservation in the botanical gardens where they can be grown by horticulturists and translocated in the future if needed. The most critical advice for the collection of spores was to wash the fronds on site to prevent the gene pollution from other taxa (Appendix 2.1).

Euphrasia spp.

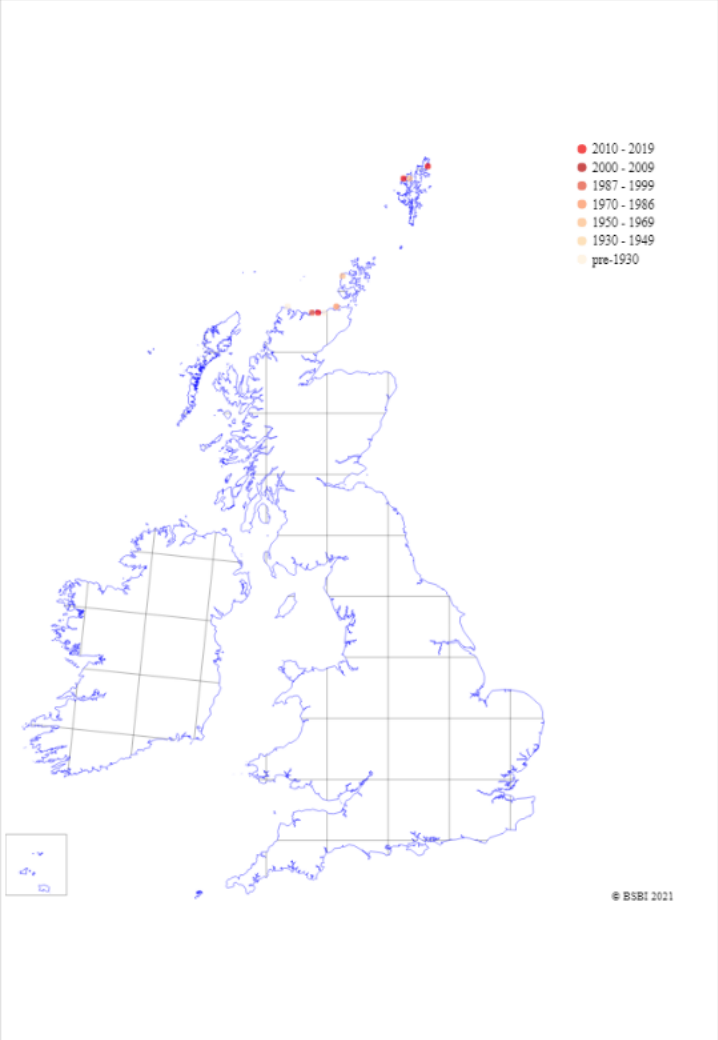

Figure 10: Distribution map of *Euphrasia rotundifolia* in the UK.

Euphrasia rotundifolia

Score: 21

IUCN-based threat category: EN

Growth form: annual herb

Habitat: coastal

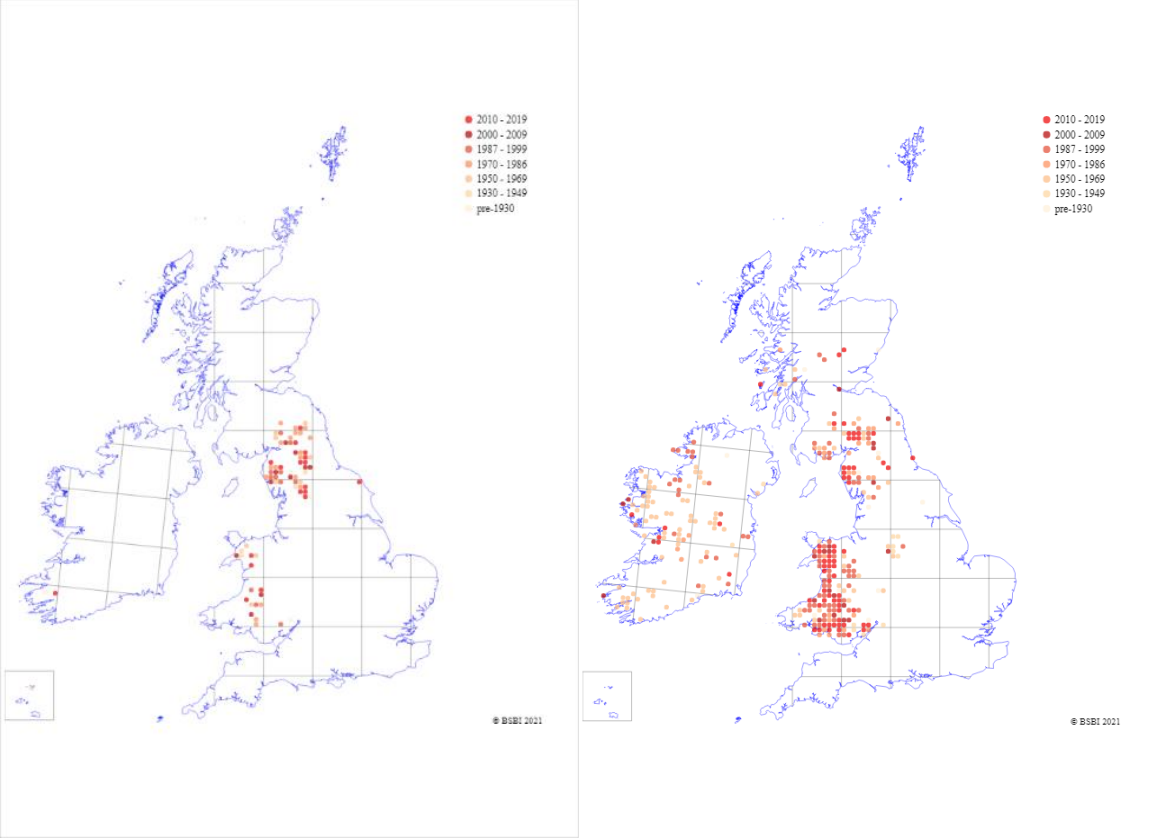

Figure 11: Distribution maps of *Euphrasia rostkoviana* subsp. *montana (left)* and subsp. *rostkoviana (right)* in the UK.

Euphrasia rostkoviana* subsp. *montana* and subsp. *rostkoviana

Score: 14

IUCN-based threat category: EN

Growth form: annual herb

Habitat: upland grassland

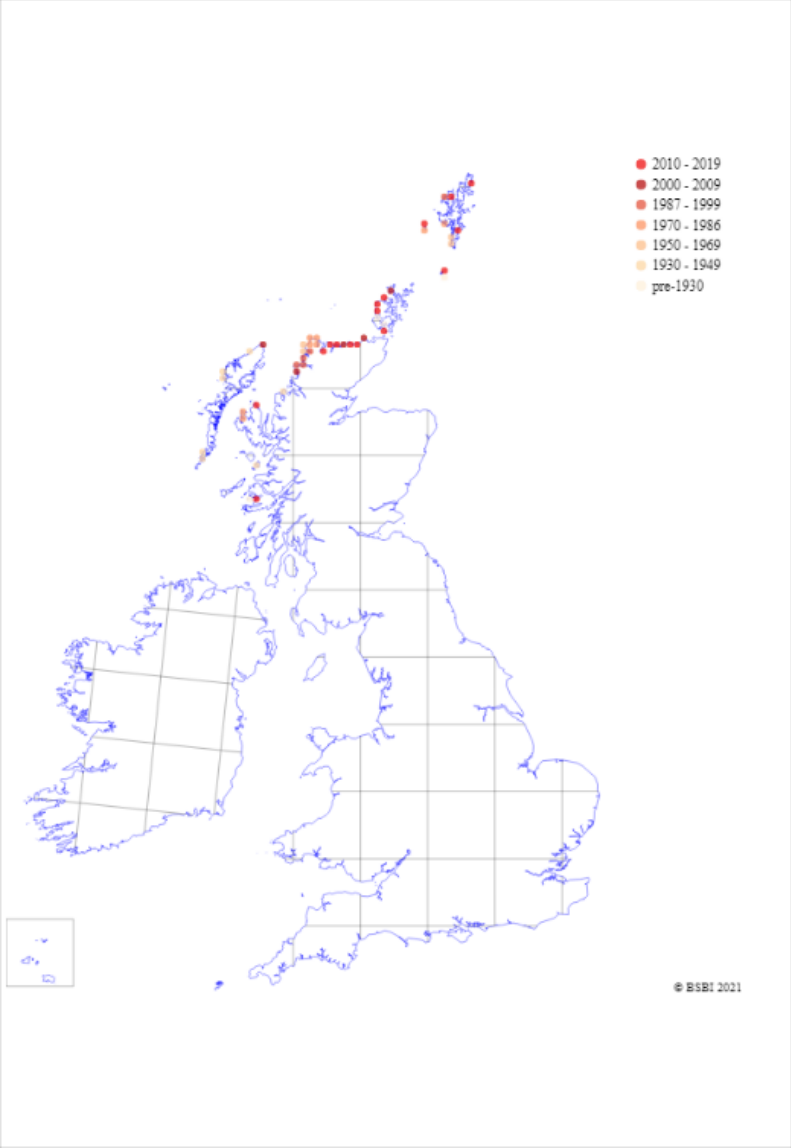

Figure 12: Distribution map of *Euphrasia marshallii* in the UK.

Euphrasia marshallii

Score: 18

IUCN-based threat category: EN

Growth form: annual herb

Habitat: coastal

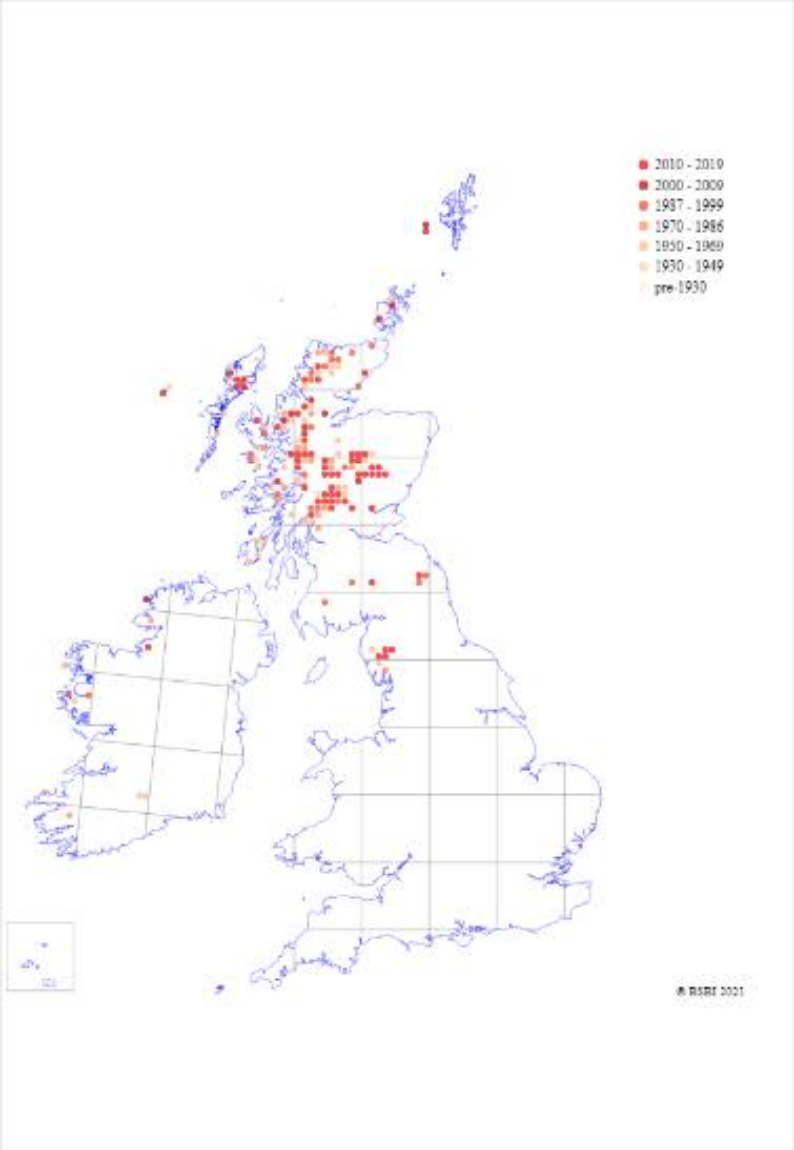

Figure 13: Distribution map of *Euphrasia frigida* in the UK.

Euphrasia frigida

Score: 12

IUCN-based threat category: EN

Growth form: annual herb

Habitat: alpine grassland

Advice/ Comments / Recommendations:

Euphrasia are found in a wide variety of habitats ranging from coasts to mountains. *E. frigida* is associated with very damp, alkaline cliff edges at high elevations. *E. montana* prefers moist but sunny conditions and is predominantly found in hay meadows at low elevations and is rare in Scotland. *E. marshallii* and *E. rotunfolia* are UK endemics with northern distribution. *E. marshallii* is found on coastal rocky cliffs. *E. rotundifolia* is much rarer and its taxonomic status is doubtful. Benefits include ecosystem engineering via hemiparasitism which is likely to reduce the vigour of the dominant taxa like graminoids, to allow growth of outcompeted smaller herbaceous taxa and possibly to improve the local pollinator taxa biodiversity (Appendix 2.4) (Figures 10; 11; 12 and 13). Additional biomedical benefits can be derived from *E. rostkoviana* (Sticher and Salama, 1981; Teixeira and Silva, 2013; Novy *et al.*, 2015) and potentially from the sister taxa as well. Only significant foreseen risk was the hybridisation of the translocated that may pollute the local gene pools. Mowing or support of grazing are essential practices for site management as they are poor competitors, with the exception of *E. frigida* which is likely to be less vulnerable to competition at the elevations above the tree line (Appendix 2.4). Translocation of the taxa is not particularly recommended despite the benefits due to the taxonomic and horticultural complexities (Zopfi, 1998) (Appendix 2.4). However, ecological-habitat matching is encouraged (Appendix 2.4). Especially, since the taxa are hemiparasites, host plant taxa e. g. legumes (Seel and Press, 1994) or other species-specific plant communities should be ideally present at the recipient site. (Appendix 2.4). The species hold a great potential to benefit from the translocation. Therefore except for *E. rotundifolia*, should be prioritised, provided that the donor sites will be local. Translocations can be performed in grazing grounds where no site management may be necessary.

Erigeron borealis

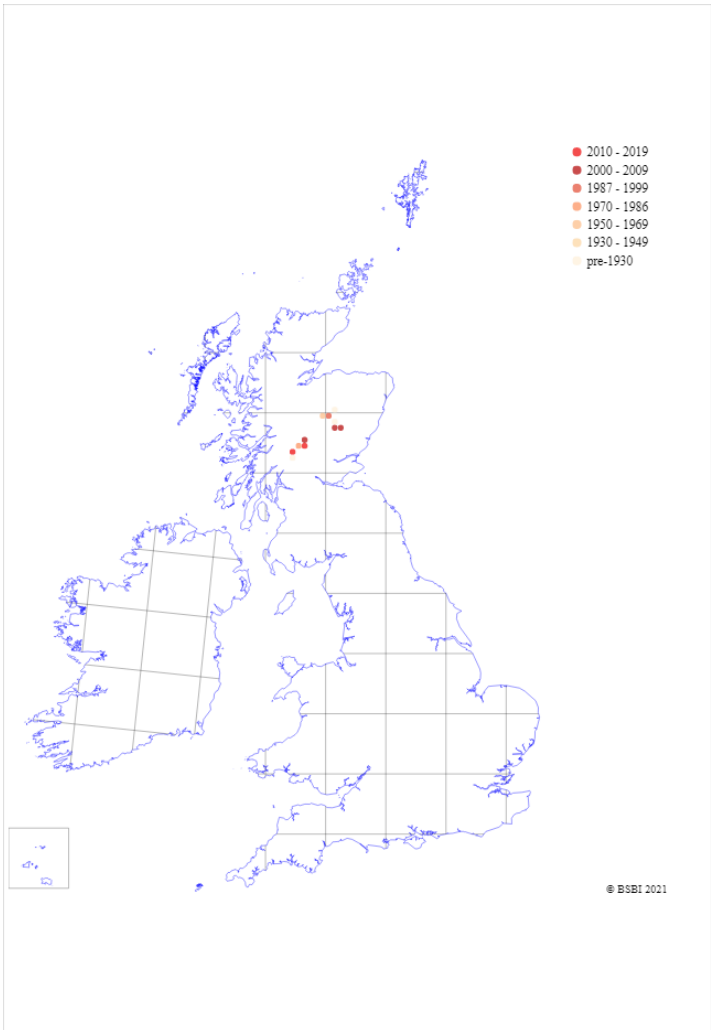

Figure 14: Distribution map of *Erigeron borealis* in the UK.

Score: 12

IUCN-based threat category:

Growth form: perennial herb

Habitat: grassland, upland

Advice/ Comments / Recommendations :

No expert could be consulted for the species. 600 individuals are left in the wild (SSAG, 2021). The surviving sites are inaccessible to deer and sheep (BRC, 2021) (Figure 14). (Karban and Strauss, 1993) found that grazing by insect herbivores had an adverse effect on the plant growth and reproduction of a related species *E. glaucus.* Current distribution of the

taxon may be stable, however, the size of some populations varies greatly from year-to-year (BRC, 2021). The species may be suffering from climate change and the lowland herbivore invertebrate taxa dispersing uplands. More studies should be conducted and seed collection for Millennium Seed Bank would be the best option as a conservation action.

Lycopodiella inundata

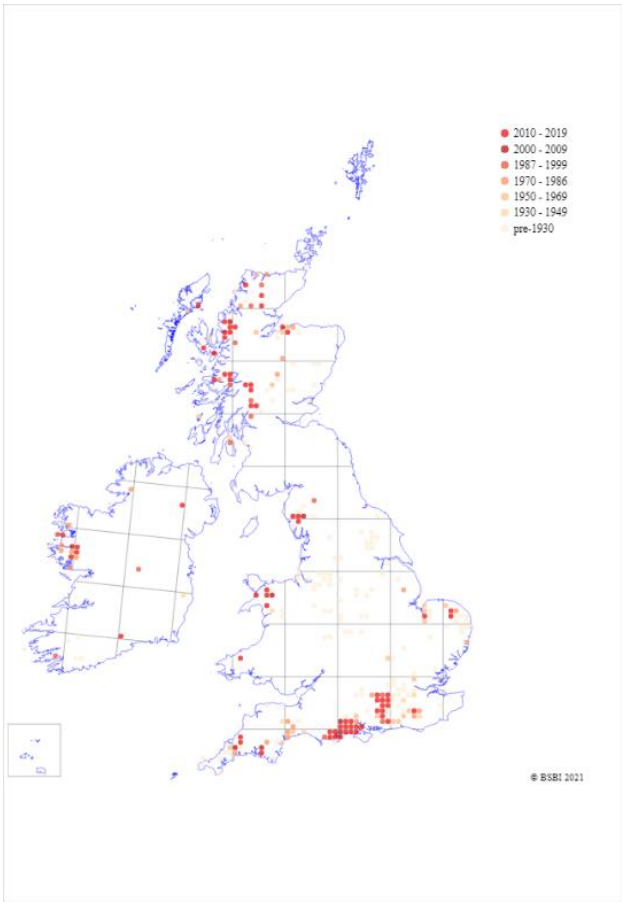

Figure 15: Distribution map of *Lycopodiella inundata* in the UK.

Score: 10

IUCN-based threat category: EN

Growth form: perennial herb (pteridophyte)

Habitat: lowland freshwater

Advice/ Comments / Recommendations :

An aquatic lycopod occurring on the margins of fluctuating freshwater margins, spreading mainly by vegetative fragmentation usually in freshwater lochs (BRC, 2021) (Figure 15). Besides adding to the local biodiversity, species have potentially optimised use in neurologically degenerative disorders (Sylvie *et al.*, 2009). No risks for translocation were found. Intermediate grazing pressure can be beneficial for the species. However, the translocation of the species was not recommended as it is likely to be under-recorded (Annex

2.10). *Ex-situ* cultivation from the fragments can easily be achieved and/or site management supporting poaching can be implemented as a conservation action.

Melampyrum sylvaticum

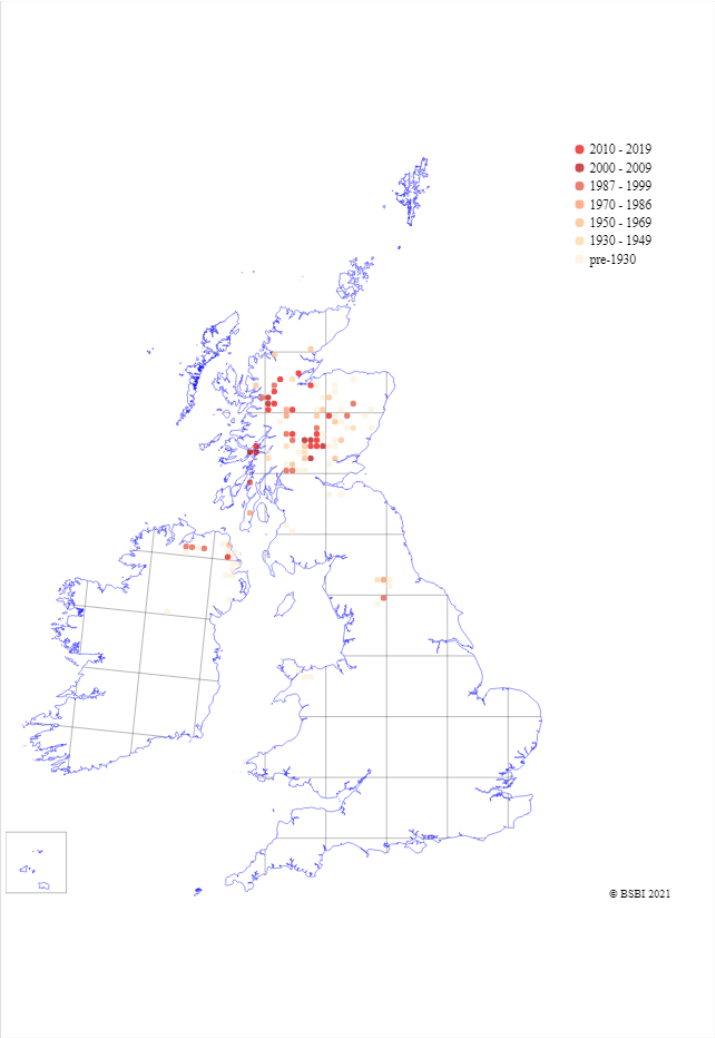

Figure 16: Distribution map of *Melampyrum sylvaticum* in the UK.

Score: 13

IUCN-based threat category: EN

Growth form: annual herbaceous (hemiparasite)

Habitat: high humidity woodland

Advice/ Comments / Recommendations :

The species is mainly in Scotland recently and has significantly lost its suitable habitats across Great Britain (Figure 16). Its decline has been observed for decades in the British Isles (Rich, Fitzgerald and Sydes, 1998) however, it is suspected to be under-recorded due to confusion with the sister taxon *M. pratense* (BRC, 2021) . It requires very specific conditions

which have been affected by habitat degradation (Dalrymple, 2007). It has no significant benefits to the ecosystem and no risks are predicted for a translocation (Annex 2.2). There has been attempts unsuccessful attempts in the Scottish Highlands for reintroductions mostly due to absence of suitable habitats (Annex 2.2) but seed translocation technique that involves the use of seeds from the donor site population to an ecologically similar recipient sites has been successful (Dalrymple and Broome, 2010). The incorporation of the species as an herbaceous understorey plant into a *Betula* woodland, in the vicinity of water bodies as described by Dalrymple and Broome, 2010, may be a viable option.

Monotropa hypopytis

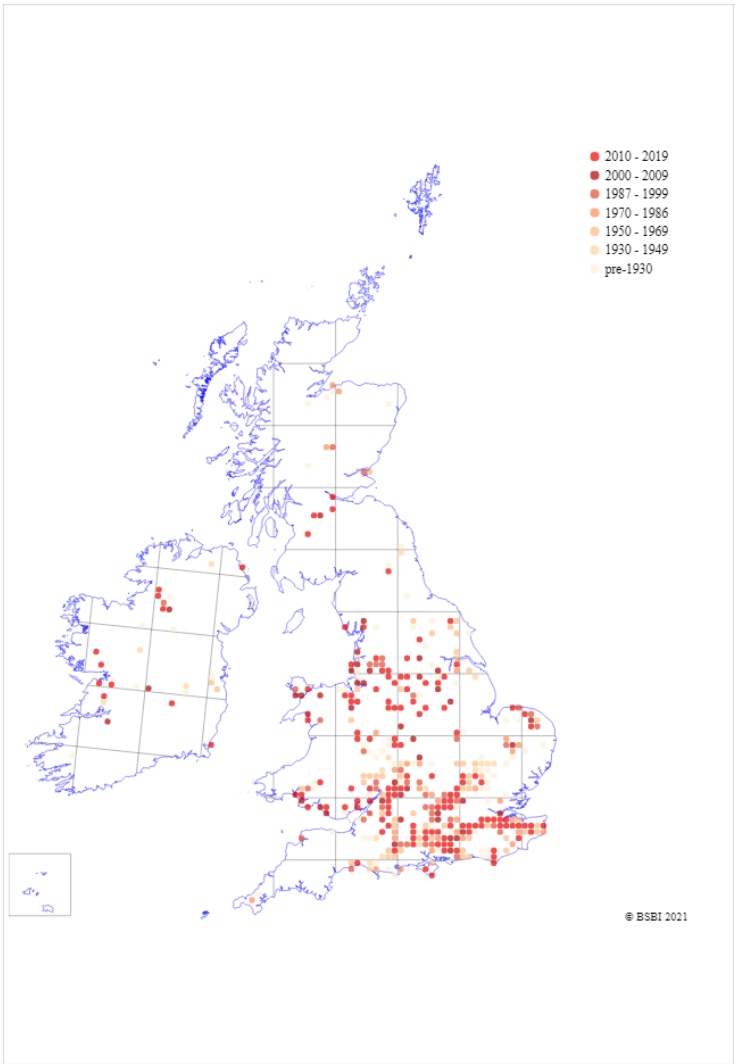

Figure 17: Distribution map of *Monotropa hypopytis* in the UK.

Score: 10

IUCN-based threat category: EN

Growth form: saprophytic perennial herbaceous

Habitat: lowland with impoverished soils

Advice/ Comments / Recommendations :

A rare, opportunist species that grows in the nutrient-poor, open, disturbed habitats, parasitising the mycorrhizal fungi of tree species from genera such as Fagus, Corylus, Pinus, Crataegus and Salix. The species has occurred in shale bings in the Scottish urban sites, such

as Greater Glasgow, far away from the original populations (Figure) (Annex 2.9). So far, the studies suggest that it obligately requires the presence of the ectomycorrhizal fungi *Tricholoma* spp. and their host trees (Leake *et al.*, 2004), yet the UK habitats suggest that they may have lower specificity for symbiosis (Annex 2.9). No risks for translocation were found. Shale bings were suggested as ideal recipient conservation sites that add to both natural and historical heritage (Annex 2.9). The past studies found that the taxon has antifungal phytochemical compounds (Trofast and Wickberg, 1977; Trofast, 1978) and, genomic and phylogeographic significance (Beatty and Provan, 2011b; Gruzdev *et al.*, 2016), which may have potential for further scientific discoveries. The Scottish populations may lose genetic fitness in Scotland due to the small sizes of populations (Beatty and Provan, 2011a). The genetic monitoring and management of the sites of the current populations, especially in terms of nutrient regime, can be recommended for its conservation.

Phyllodoce caerulea

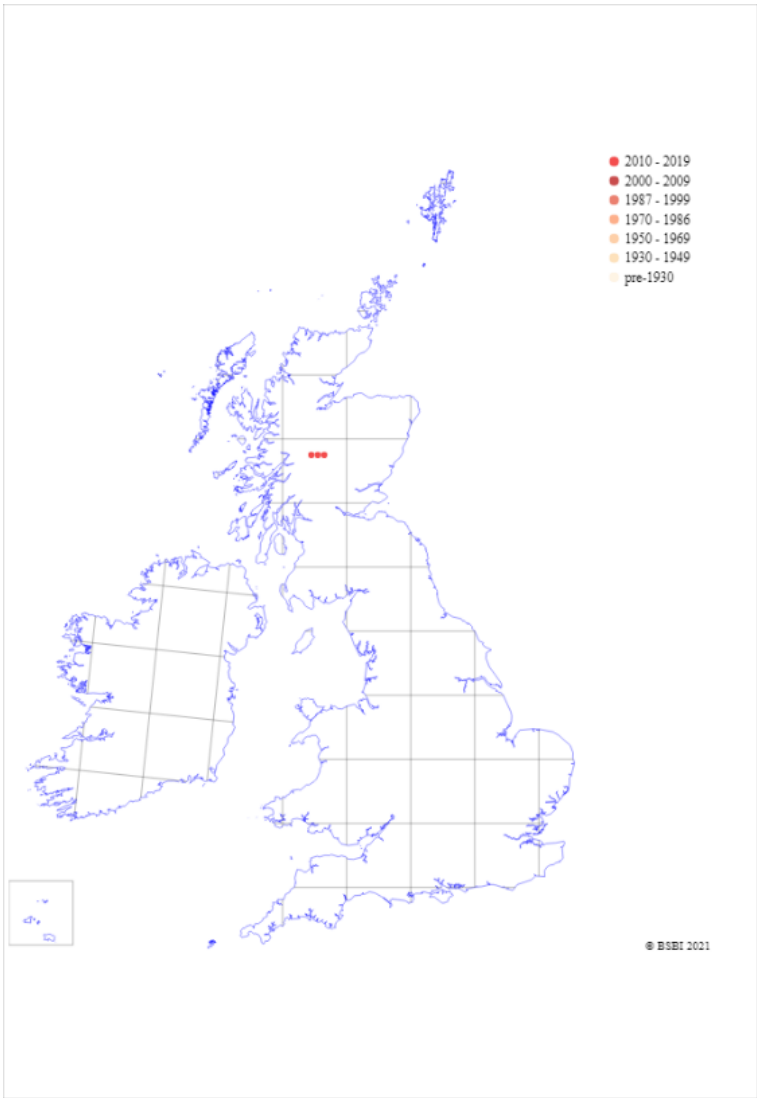

Figure 18: Distribution map of *Phyllodoce caerulea* in the UK.

Score: 10

IUCN-based threat category: VU

Growth form: perennial herbaceous

Habitat: alpine

Advice/ Comments / Recommendations :

An alpine species favouring prolonged snow lie in acidic, impoverished, and free-draining mountain slopes (Appendix 2.8) (BRC, 2021) (Figure 18). It has poor seed production and is stable within 10-km^2 distribution (BRC, 2021). No benefits are predicted. It is reckoned to be a part of montane willow scrub. No risks are projected. There are potential translocation sites

in slightly eastern highlands. No site management seems necessary, and the species is seen feasible for translocation (Appendix 2.8). Translocation of the species may be considered.

Poa flexuosa

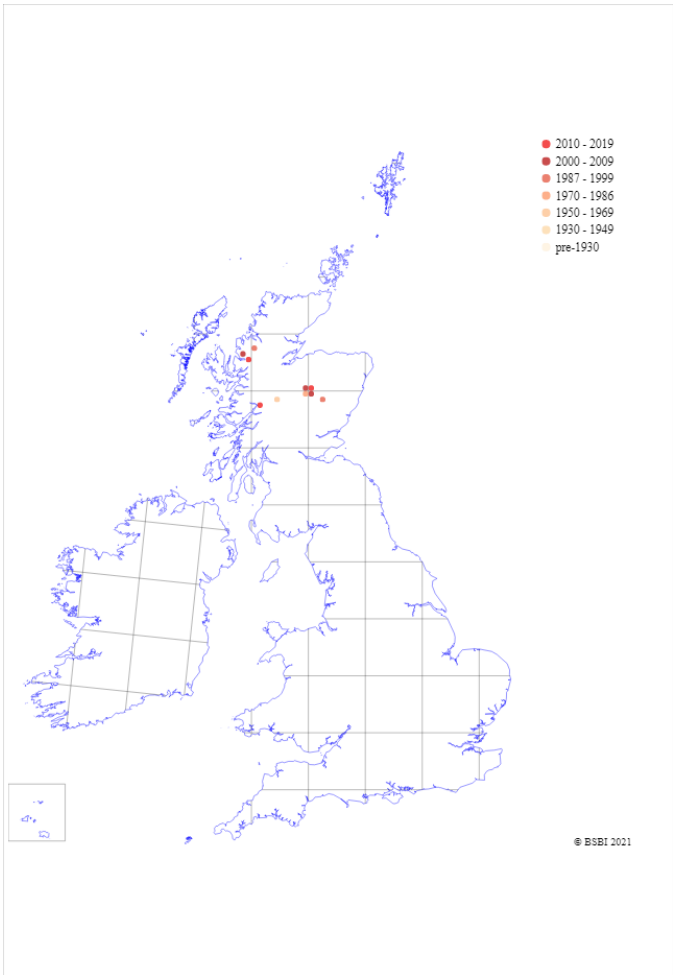

Figure : Distribution map of *Poa flexuosa* in the UK.

Score: 10

IUCN-based threat category: VU

Growth form: perennial herb

Habitat: upland

Advice/ Comments / Recommendations :

A rare and very high altitude species growing on stony mountain plateau (BRC, 2021) (Figure 19). It may also be suffering from grazing pressure. Benefits include structural and

biological diversity of the sites. No risks are associated with its translocation. However, the translocation of the species is not recommended as recently new populations were found and its rarity may be due to low surveying efforts (Annex 2.10).

Potamogeton compressus

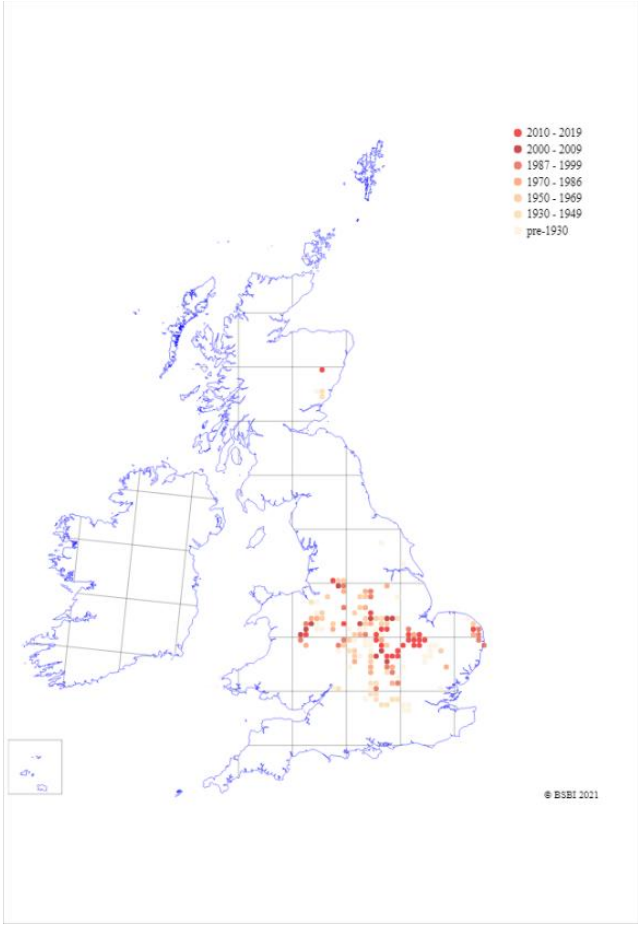

Figure 20: Distribution map of *Potamogeton compressus* in the UK.

Score: 11

IUCN-based threat category: EN

Growth form: perennial aquatic herb (freshwater)

Habitat: freshwater lowland

Advice/ Comments / Recommendations :

No expert could be consulted for the species. The species seems to be in decline in Scotland with a single site remaining in the east (Figure 20). It is mostly extinct in lakes and rivers. It favours slowly flowing or still waters with calcareous influence (BRC, 2021). An experiment on the effects of cutting on growth of *P. compressus* and *P. lucens* revealed that cutting *P. compressus* resulted in decreased shoot and below-ground biomass which caused decrease in tissue density, flower and turion formation and possibly led to a competitive disadvantage to

more disturbance tolerant species like *Elodea nuttalii* (van Zuidam and Peeters, 2012) or other *Potamogeton* spp. (e. g. eutrophication-tolerant *P. crispus* with an overlapping Scottish distribution) (BRC, 2021).

Potentilla rupestris

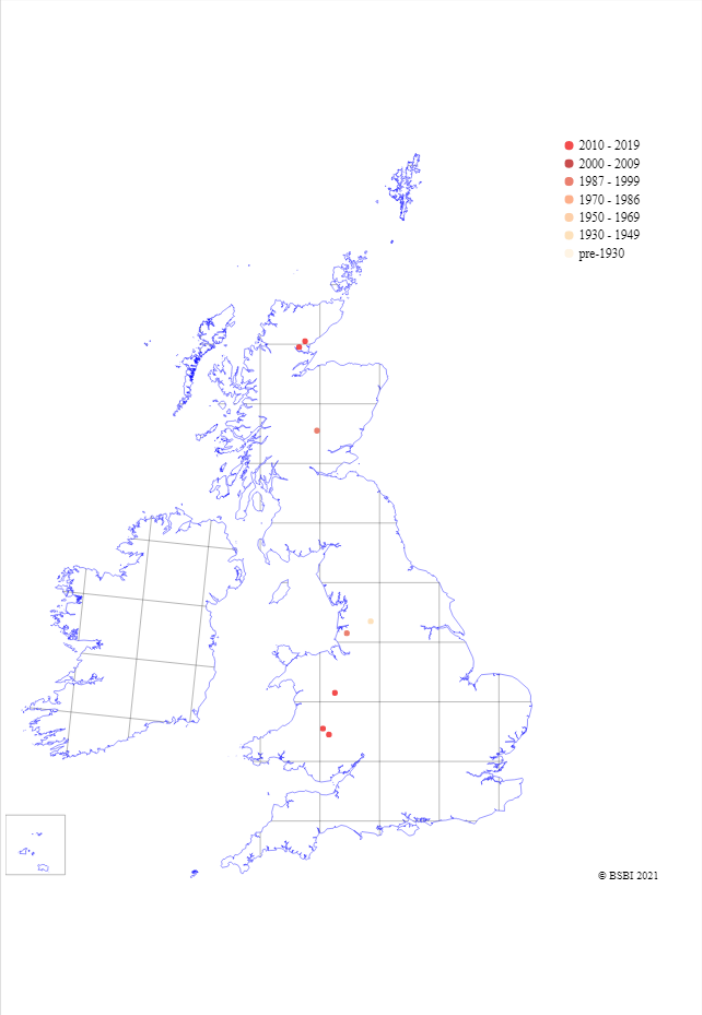

Figure 21: Distribution map of *Potentilla rupestris* in the UK.

Score: 15

IUCN-based threat category: EN

Growth form: perennial herb

Habitat: lowland (in high latitudes)

Advice/ Comments / Recommendations :

Species only occurs in a few sites with small populations in Scotland (BRC, 2021) (Figure 21). Southern high-altitude population is suspected to be an introduction. It is found in low elevations, basic and dry soil on open, cliff habitats subject to summer drought (Appendix 2.8). Not many suitable translocation sites exist in Scotland, however, previous transplants have been successful (Appendix 2.8) (BRC, 2021).Benefits would be increasing the biodiversity and safeguarding one of the Scottish rarities (Appendix 2.8). Extract of P. rupestris possesses antibacterial and antifungal properties (Tomczyk, Leszczyńska and Jakoniuk, 2008) and has potential to be used in the prevention of human colon disorders (Paduch *et al.*, 2015). The only risk for translocation would be removing too much material from small populations. The translocated plants should be protected from overshading by the shrubs and grazing animals if necessary. Transplanting the species with populations mixed from both sites is recommended as the genetic diversity should be low. Cultivation is likely to be, but horticultural expert advice should be taken (Appendix 2.8).

Sagina saginoides

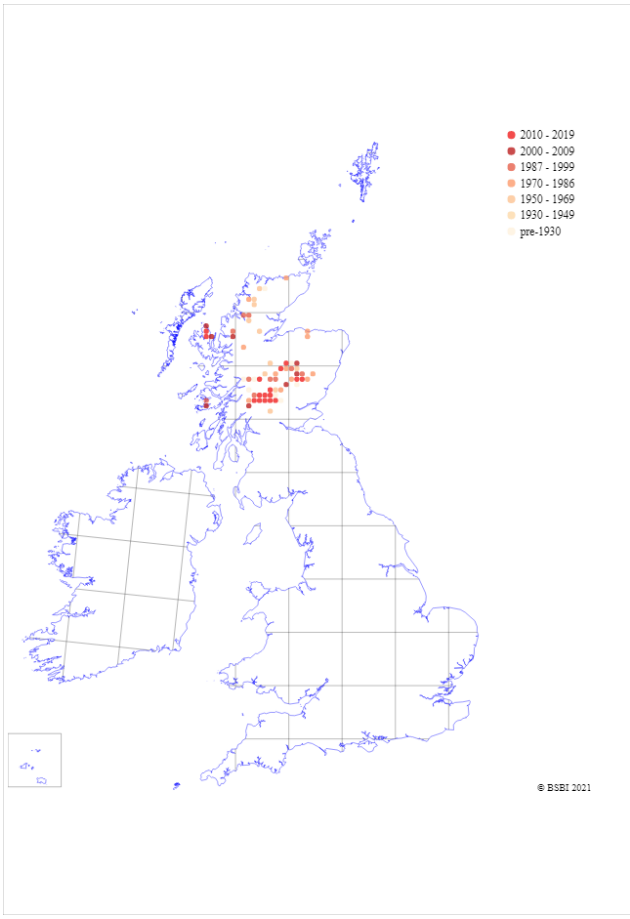

Figure 22: Distribution map of *Sagina saginoides* in the UK.

Score: 12

IUCN-based threat category: EN

Growth form: perennial herb

Habitat: arctic-upland

Advice/ Comments / Recommendations :

A small alpine species which grows in damp, well-draining, base-rich soils only in Scotland in Great Britain and hard to identify. It is threatened by the climate change and, is highly suspected to be under-recorded or misidentified (Annex 2.11) (BRC, 2021). It is a poor competitor like the sister taxon *S. nivalis* that is disappearing from the lower altitudes due to reduction in snow cover, hence out-competition by the up-hill colonising lowland vegetation and sheep grazing pressure in the lower elevations (Mardon and Watts, 2019) (Annex 2.11).

No risks or any benefits of a translocation besides increasing biodiversity were found. For the safeguard of both British and global populations of the species, an *ex-situ* establishment would be a better option for the conservation of the species (Annex 2.11) (Cannone *et al.*, 2008).

Salix spp.

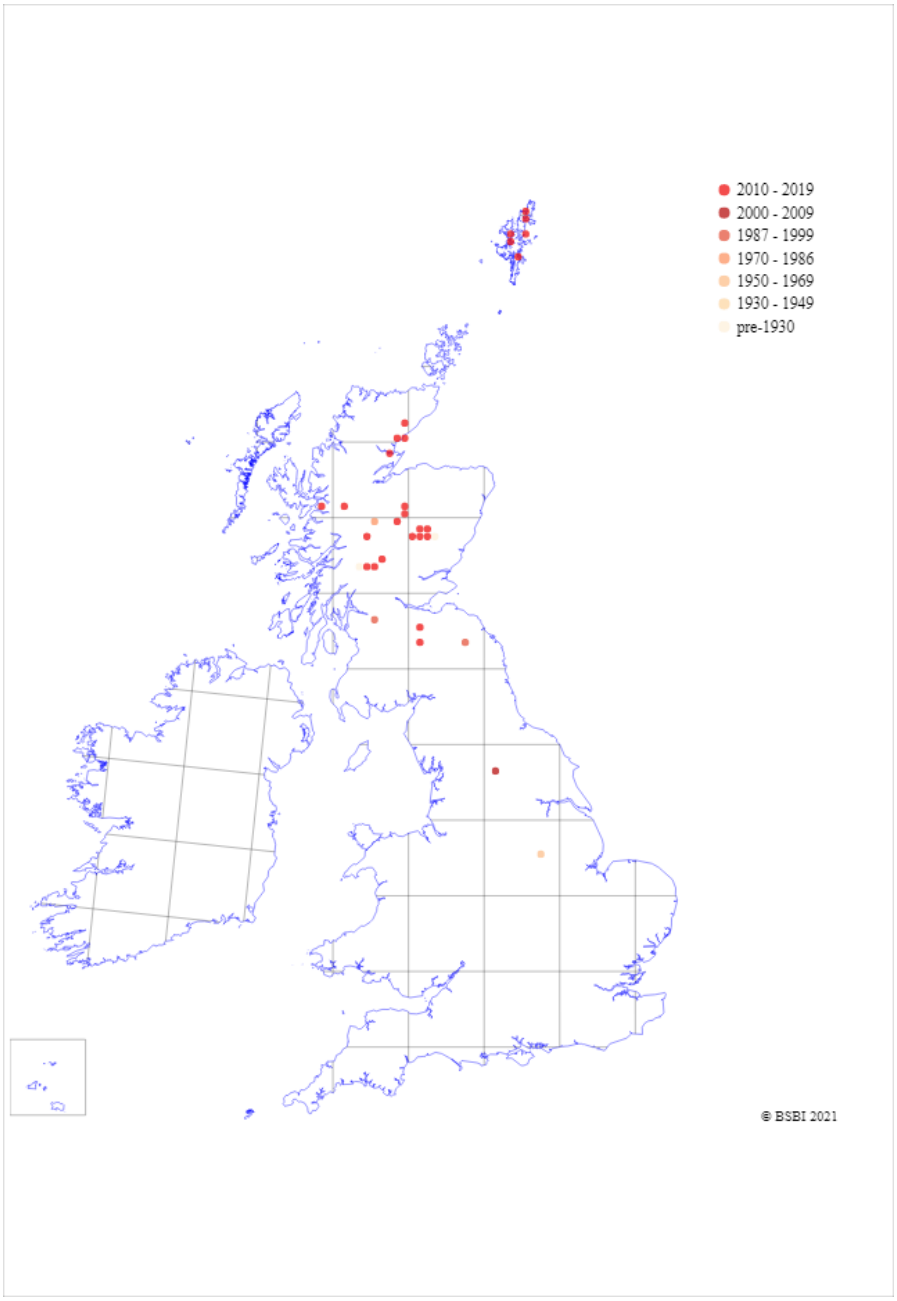

Figure 23: Distribution map of *Salix lanata* in the UK.

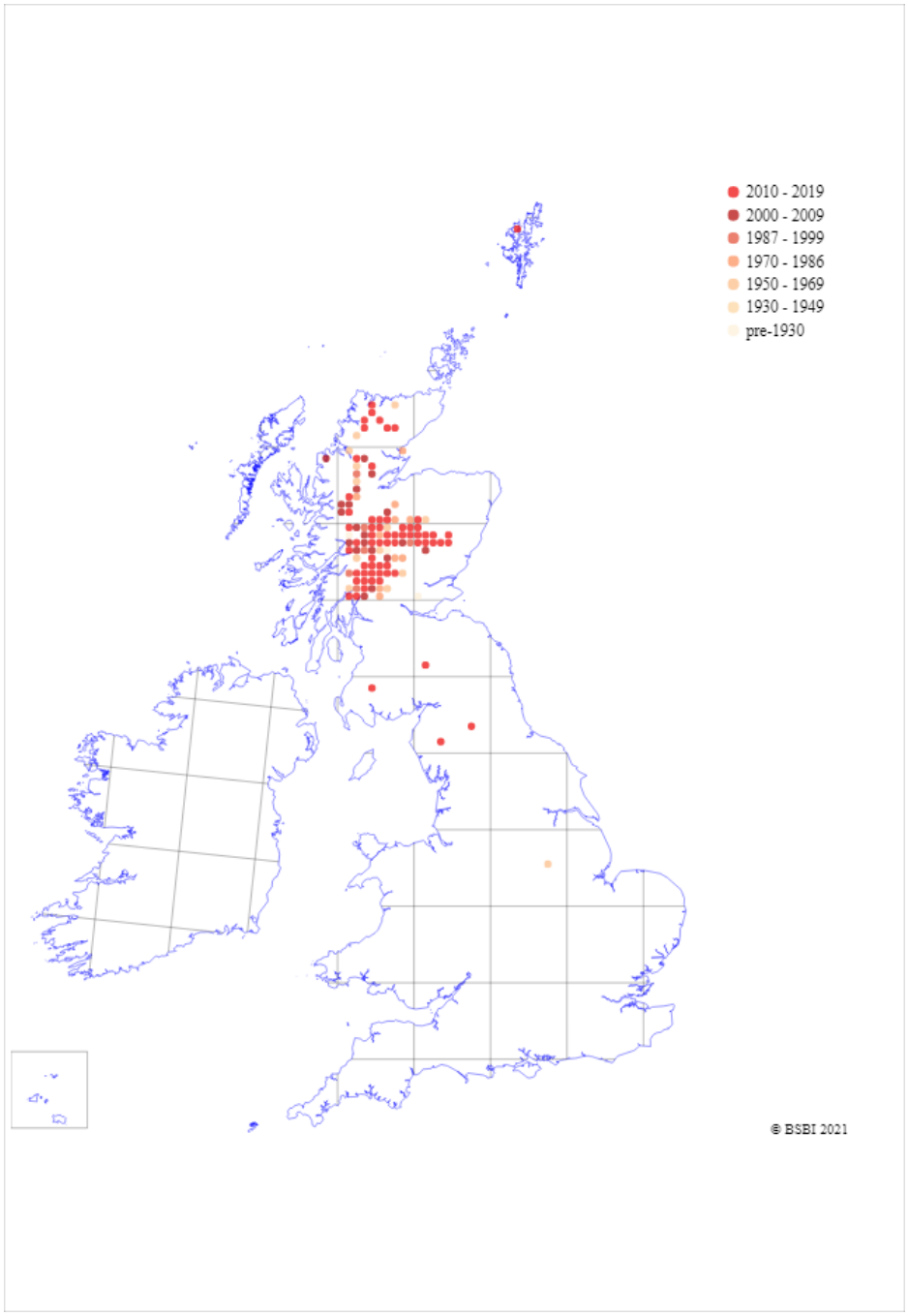

Figure 24: Distribution map of *Salix lapponum* in the UK.

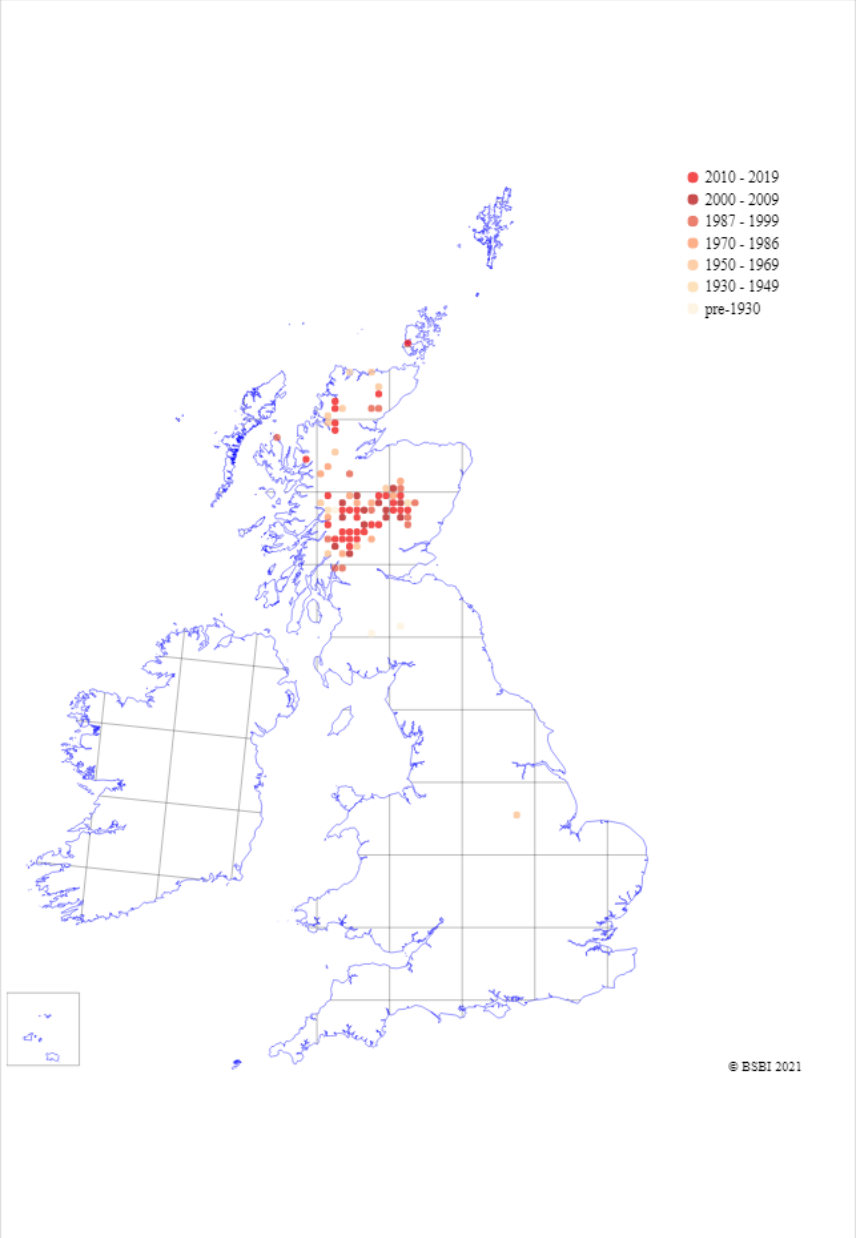

Figure 25: Distribution map of *Salix myrsinites* in the UK.

Score: 17

IUCN-based threat category: EN (*S. myrsinites*) and VU (*S. lapponum* and *S. lanata*)

Growth form: small tree-scrub

Habitat: alpine-montane

Advice/ Comments / Recommendations :

All three *Salix* species were treated as a group in the analysis due to their habitat similarities (BRC, 2021) (Appendices 2.2; 2.5). They are montane species that prefer slightly different soil alkalinity, wetness and are very susceptible to grazing. Although it is hard to tell the differences in terms of altitudinal preferences in Scotland as they have wider ranges in Norway (Appendix 2.5). The distribution maps are unlikely to reflect the true status of the species as 10-km2 maps may refer to single individuals with vast distances in-between as well as misidentifications (Appendix 2.2). *Salix* trees have separate male and female individual plants that make the proximity of the individuals to each other crucial for seed production and there is currently little to no regeneration in the Scottish populations (Appendix 2.2) (BRC, 2021). *Salix* can easily root from the branches that contact with soil so the genetic diversity and number of individuals may be overestimated. As montane species, they are likely to be suffering from the climate change. However, it is mostly because of exposure to herbivores due to lack of snow cover that exacerbates their vulnerability and are possibly easy to grow in lower altitudes (Appendix 2.2). Current Scottish ledge-dwelling populations are probably the refuge habitats where they managed to escape grazing (Appendices 2.2; 2.5). They are also threatened by the high grazing intensity and the habitat fragmentation that decreases the genetic fitness (Appendix 2.2; 2.5) (Figure 23; 24 and 25).

Benefits of their translocation include increasing the genetic fitness, improving self-sustainability of the populations, increasing biodiversity in the area in terms of both invertebrate and vertebrate taxa, significantly threatened bird species in particular (Appendix 2.2; 2.5). It is also the preliminary steps into creating the missing tree line that is almost entirely gone from Scotland (Appendix 2.5). Since the taxa are ecosystem engineers, re-creating the montane willow woodlands may also be beneficial in the improvement of habitat for other red listed herbaceous plant species (Appendix 2.2; 2.8).

There are risks associated with the translocation such as out-competition with the other rare calcareous grassland species and the introduction of nursery weeds and pathogens into the wild, however, these risks are limited and can be overcome by the application of biosecurity measures and proper conservation practices (Appendices 2.2; 2.5). No potential of becoming invasive is predicted (Appendix 2.2). It is best to pick sites that have communities of plants that the Scottish *Salix* populations are growing together and, to examine the cooccurring communities in the overseas habitats e. g. Norway. It is ideal to try translocations in new sites akin to that of the Scandinavian and bridge the populations by planting new colonies nearby

the original sites, as currently being done in the Mar Lodge Estate (Appendix 2.5). Genetic mixing between the populations and planting with more common *Salix* spp e. g. *S. mrysinifolia* to ease the grazing pressure on the focal species, creating new and good-sized populations and species-specific altitudinal habitat-matching is encouraged for translocation (Appendices 2.2; 2.5). No site management would be necessary besides the absolute control of grazing (Appendices 2.2; 2.5). Previous research and translocation projects were conducted on the species (Appendix 2.2). Current projects are also yielding successful results (Appendix 2.5). Considering the aesthetic, cultural and medicinal values species are providing, supplementations in the current sites and additional potential translocations are present out with the native range e. g. the north (Appendix 2.2) may be considered after obtainment of the necessary licences.

Saxifraga cespitosa

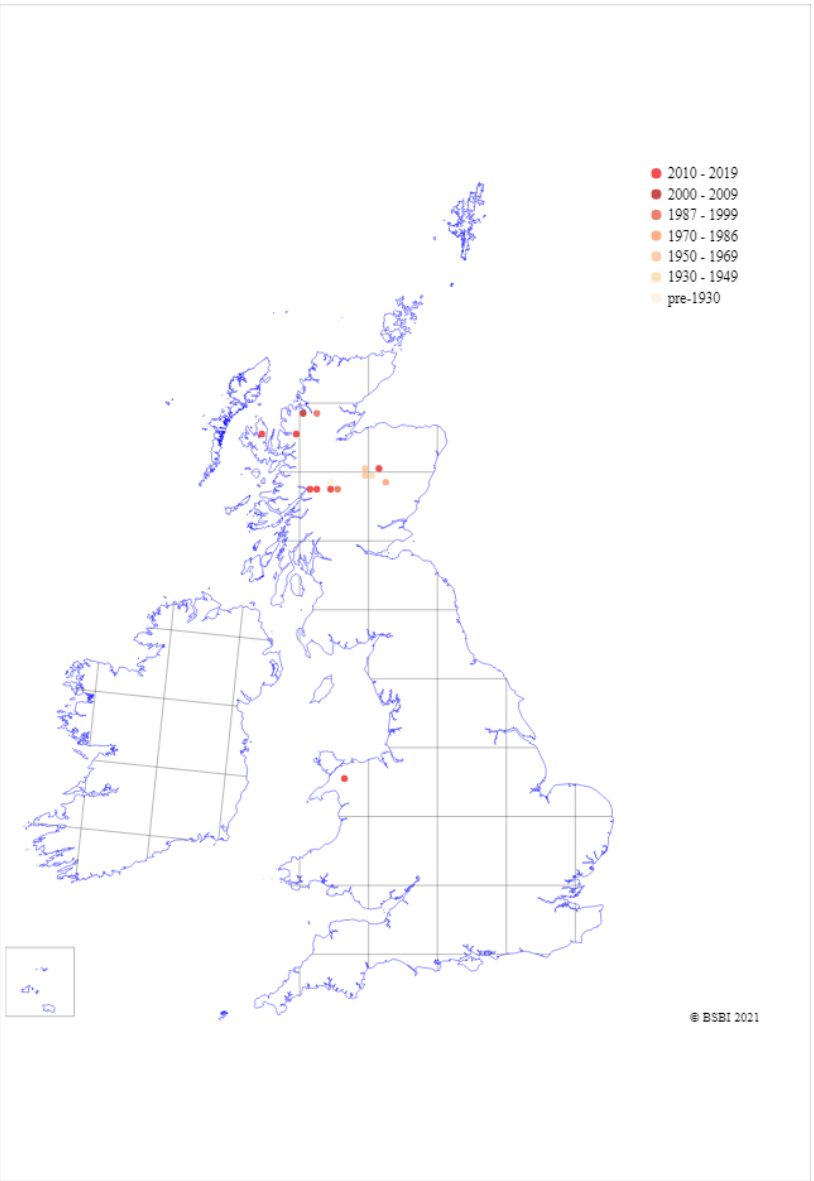

Figure 26: Distribution map of *Saxifraga cespitosa* in the UK.

Score: 12

IUCN-based threat category: EN

Growth form: perennial herb

Habitat: arctic-montane

Advice/ Comments / Recommendations :

It requires very cold, well-drained alkaline rock and is susceptible to drought (Appendix 2.8) (BRC, 2021). There are no risks and, no benefit besides the safeguarding of the species,

predicted (Appendix 2.8). Translocation of the species was planned by Nature Scot but was cancelled as it is on the best sites possible and may inevitably lack future suitable habitat (Appendix 2.8) (Figure 26). *S. cespitosa* is already grown and being cultivated in the RBGE *ex-situ* collection (Barnard, 2014). The ongoing *ex-situ* cultivation project may be supported or a new one started as a conservation measure.

Scleranthus annuus

Score: 11

IUCN-based threat category: EN

Growth form: biennial herb

Habitat: grassland

Advice/ Comments / Recommendations :

A drought-tolerant herb found in lowlands (BRC, 2021). No studies could be found on the ecology and the conservation of the species. It is possibly a part of meadow community. After the risk assessments are conducted, it can be incorporated to wild flower seed mixes within its native range and grown *in-situ* as a conservation action (Scotia Seeds, 2021).

Sorbus spp.

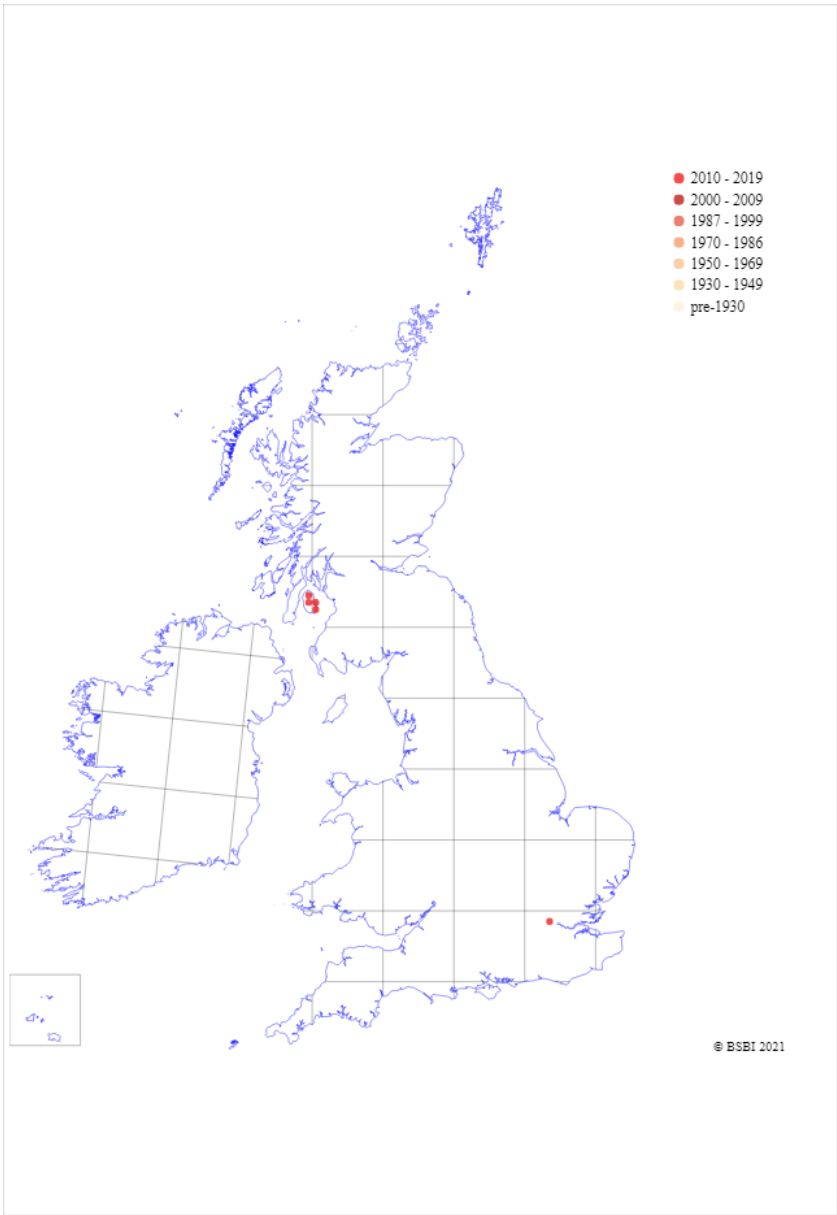

Figure 27: Distribution map of *Sorbus arranensis* in the UK.

Sorbus arranensis, Sorbus pseudomeinichii, Sorbus pseudofennica

Score: 25.5

IUCN-based threat category: CR (*S. pseudomeinichii* and *S. pseudofennica*), EN (*S. arranensis*)

Growth form: tree

Habitat: lowland

Advice/ Comments / Recommendations :

All three species are endemic apomictic taxa grow exclusively in the Isle of Arran (Figure 27). They are originally derived from two parent species *S. rupicola* and *S. aucuparia* with multiple origins (Appendix 2.2). The populations have been mostly stable since 1970 (BRC, 2021). However, there are reports of declining habitat quality and grazing pressure affecting reproductive success (SSAG, 2021). They occur very close to each other and are suffering from grazing pressure. Successful propagation of the taxa has been achieved in RBGE in the past and are grown in conservation collections (McHaffie, Frachon and Robertson, 2011). Parts of the *Sorbus* trees have antioxidant properties that may hold pharmaceutical potential (Raudonis *et al.*, 2014; Raudonė *et al.*, 2015). As tree species, they may be able to support other taxa, like *Melampyrum sylvaticum* if the species can be licensed and co-translocated with Arran *Sorbus*. No risks were associated with the translocation. Fencing and, propagation by grafting and seeds were unrecommended practices. Control of grazing is strongly recommended. Recreation of habitat, including *S. aucuparia* and *S. rupicola*, that gave rise to the three hybrids can be the ideal approach for a conservation project as the species are the products of multiple and ongoing evolutionary events (Robertson, Newton and Ennos, 2004) (Annex 2.2).

Woodsia spp.

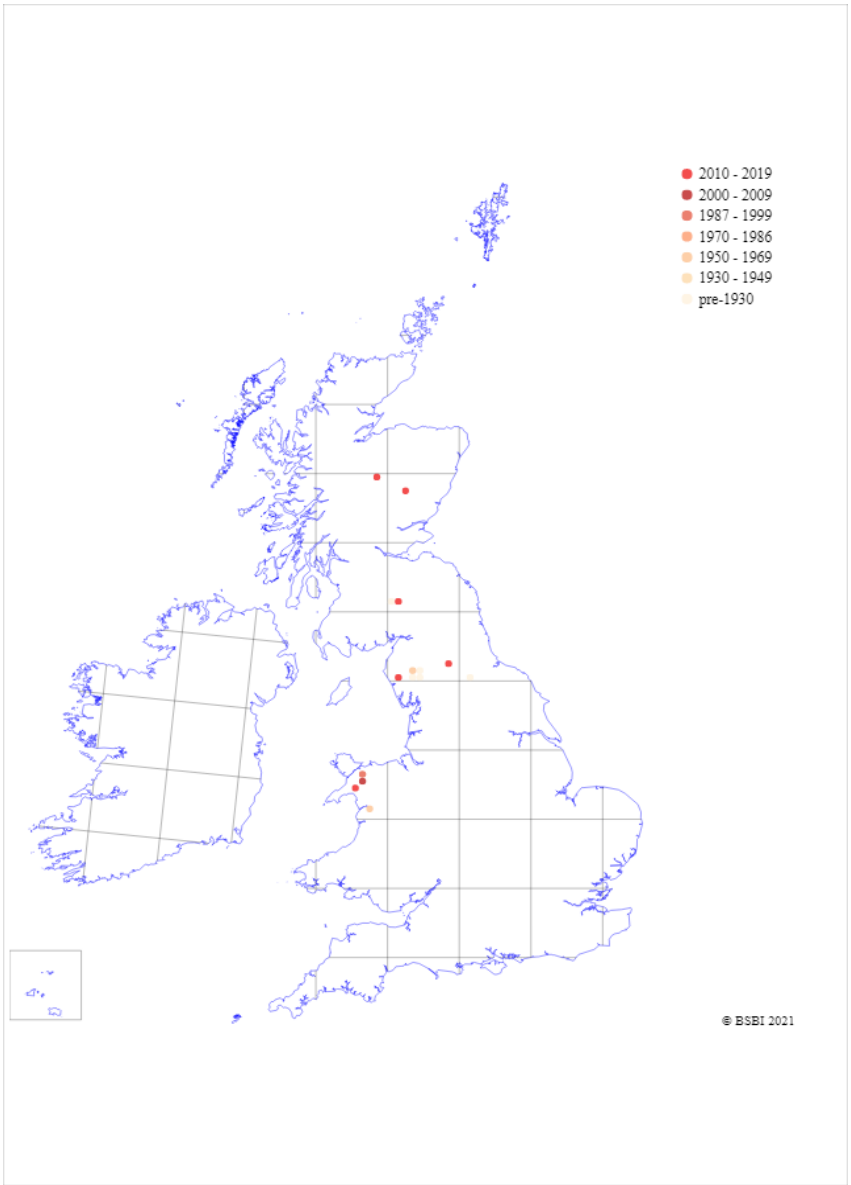

Figure 28: Distribution map of *W. ilvensis* in the UK.

Woodsia ilvensis

Score: 15

IUCN-based threat category: EN

Growth form: perennial herbaceous (pteridophyte)

Habitat: upland

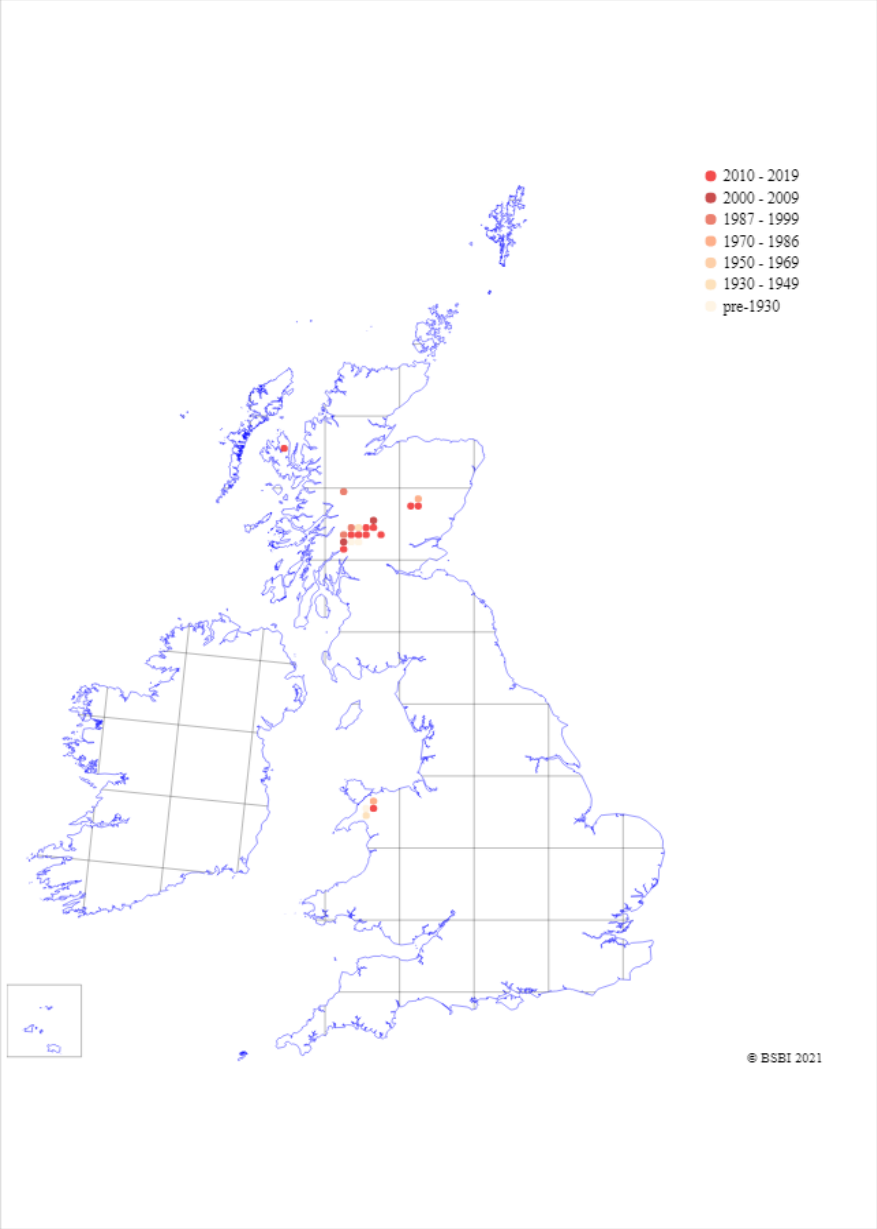

Figure 29: Distribution map of *Woodsia alpina* in the UK.

Woodsia alpina

Score: 13

IUCN-based threat category: VU

Growth form: perennial herbaceous (pteridophyte)

Habitat: upland

Advice/ Comments / Recommendations :

Both fern species were treated the same for translocation purposes due to habitat similarity i. e. 300 m altitude (in Scotland), damp free-draining rock crevices with little competition (Annex 2.2) (BRC, 2021). *W. ilvensis* prefers drier niches whereas *W. alpina* requires some water running down over, which is essential in terms of aspect of the hills they grow in (Annex 2.2). Current British sites for Woodsia are thought to be the relics of from more widespread populations in post-glacial times (BRC, 2021). They were presumed to be originally rare, and they suffered from the 19th century Victorian fern collecting frenzy (Annex 2.2) (BRC, 2021). Populations of *W. alpina* seem relatively stable and are less threatened (SSGA, 2021; BRC, 2021), yet, both species are anticipated to be suffering from climate change and the grazing pressure (Annex 2.2). Although the species are not particularly palatable to the grazing animals, the 'nibbling' is a major factor affecting their survival (Annex 2.2). Some older records e. g. in Cumberland, England, may be erroneous due to surveying efforts, to the identification the number of clumps/individuals and to the time of the year that the survey was done (Annex 2.2) (BRC, 2021). No benefits or risks for the translocation were predicted (Annex 2.2). There have been many projects on *W. ilvensis* with different degrees of success (Annex 2.2) Regeneration from the soil spore banks (Dyer, 1994) and from the fertile fronds in *ex-situ* cultivation were also tested for both species and, good results were obtained by the horticulturist experts (Annex 2.2). No translocations were conducted for *W. alpina* but, a significant amount of understanding was obtained on its ecology as well (Annex 2.2). Management of the site is necessary in case of translocation i. e. high grazing control (Annex 2.2). The re-introductions of *W. ilvensis* in Scotland and Teesdale are not mapped (BRC, 2021) (Figure 28). Nevertheless, new translocation projects for the taxa would be the ideal approach, depending on the monitoring report.

Zostera noltei

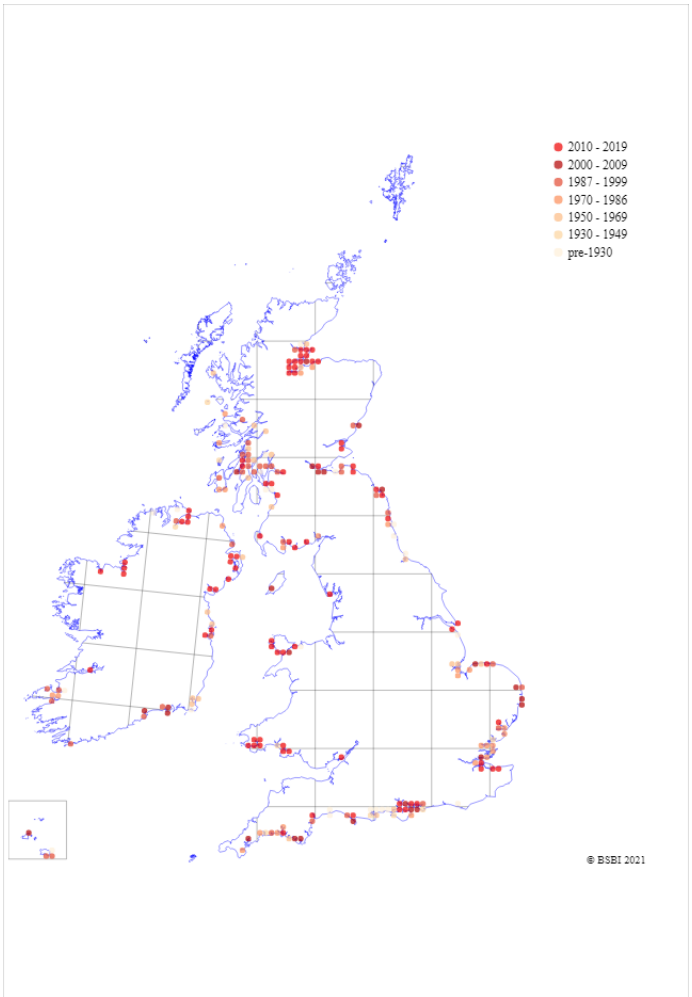

Figure 30: Distribution map of *Zostera noltei* in the UK.

Score: 10

IUCN-based threat category: VU

Growth form: perennial aquatic herb (marine)

Habitat: coastal marine (down to -3 m)

Advice/ Comments / Recommendations :

The seagrasses play major role in the maintaining of the biodiversity by building habitats for many marine species, as well as food source for seabirds (Appendix 2.6) (Berov *et al*., 2015). They occupy 0.1% of the seafloor and sequester 11% of the carbon in the ocean which is, along with mangroves and coastal meadows, much higher than that of tropical forests (Project Seagrass, 2021) (Appendix 2.6). The distribution of the species appears to be stable even in the polluted habitats like Thames estuary (BRC, 2021), however, as much as 92% of the UK's seagrass has been lost (Project Seagrass, 2021). It supports marine fauna of different compositions and different life stages (Guidetti and Bussotti, 2000; Blanchet et al., 2004). The decline of the species is related to the pollution by waste water (Sousa et al., 2019) (Appendix 2.6). *Z. noltei* growth and photosynthetic capacity was found to be adversely affected by high water temperature (+20 °C), in combination with the toxic elements emanating from pesticide run-off (Gamain et al., 2018). No correlation between the water treatment and the vegetation recovery was found in another study (Calleja et al., 2017). It has an antioxidant potential for anticancer drugs as the sister taxon *Z. marina* (Custódio et al., 2016). No risks are associated with the translocation (Appendix 2.6). Translocation of the species is fairly easy and the restoration of the habitats are expected to support 50 species of fish in the UK (Project Seagrass, 2021).. Projects are already in motion for the species conservation (Project Seagrass, 2021). (Appendix 2.6). The support for the future conservation projects and management strategies s be taken into consideration.

Additional expert-suggested species:

- *Athyrium distentifolium* var. *flexile*
- *Linnaea borealis (LC)*
- *Minuartia rubella (Sabulina rubella)* (NT)
- *Omalotheca norvegica (Gnaphalium norvegicum)* (LC)
- *Oxytropis helleri* (LC)
- *Platanthera bifolia* (VU)
- *Polygonatum verticillatum* (VU)
- *Primula scotica* (LC)
- *Pyrola media* (VU)
- *Sagina nivalis* (VU)
- *Saxifraga hirculus* (VU)
- *Zostera marina* (NT)

Discussion

The optimisation of conservation translocations

The IUCN Red List criteria were proved to be very conservative in assigning the species to threat categories. Red listing threat statuses at regional assessment were expected to result in possibly different than that of the globally assessed ones (IUCN, 2021). For example, *Cicerbita alpina*, unassessed globally, had appeared VU in the UK region as it is both in decline and it is on the western edge of its distribution in Scotland (IUCN, 2021) (Appendix 2.6). However, the differences in categories were too significant in several cases that the sole dependence on the IUCN threat categories would be useless for the purposes of conservation translocation. This can be attributed to several causes.

No criterion in the IUCN Red List assessment takes population genetics into account. Although this aspect may be subtly reflected through criteria A, B and C which assess the reduction in population size, the geographic range of the species and the number of individuals respectively, it had certainly been missed in one case. *Linnaea borealis*, a vegetatively propagating perennial herbaceous species that was widely distributed and recently well-recorded in Scotland was assessed as LC according to SSAG (2021) (Figure 3). However, *L. borealis* is a highly self-incompatible species that requires very short distances for pollination to occur (Scobie, 2009) (Appendix 2.9). The IUCN assessment was possibly done using 10-km^2 grids, where the taxon seems abundant in Scotland. In Mar Lodge Estate, the species was reported to have only eight patches with single individuals which were very far from each other for pollination to happen (Appendix 2.8). The current isolation will possibly drive the species to extinction due to loss of genetic fitness and the lack of action even though the species has been investigated for a long time (Long and Scott, 2003) (Appendix 2.6).

Skewed data in the distribution and IUCN categorisation was another driver of this effect. The red listing of the species on the SSAG list was applied to the whole of Great Britain instead of Scotland only. This problem in the scale caused a species with a stable distribution in Scotland like *Astragalus danicus* to show up on the list as EN which was due to the

reduction in the population size criterion (SSAG, 2021; IUCN, 2012) that has been occurring only in England (BRC, 2021). The misidentification of the species e. g. *S. saginoides* (Appendix 2.11), or the poor surveying efforts and wrong records e. g. *L. inundata, S. saginoides* and *P. flexuosa* (Appendices 2.10; 2.11), or even possibly an attempt to decrease the IUCN threat status based on the increase in the number of individuals following the recent translocation transplants e. g. *W. ilvensis* (Appendix 2.2) were other contributors affecting the IUCN threat status. Even though the last possibility which could have been the case for *W. ilvensis* was eliminated from the distribution maps (BRC, 2021), the survey data must have skewed the status outcome.

Endemism is not explicitly used as a criterion in IUCN red listing. It is in fact implicitly assessed under the criterion B (IUCN, 2012). Yet, the same criterion would boost the locally rare species which would potentially be prioritised over the endemics, thus risking their survival. For instance, if the endemism was not treated as a factor *A. sciura* would have been pushed behind *C. maritima* in the scoring table even though it is restricted to a single site (Table 3). Therefore, the IUCN threat statuses cannot be fully trusted for the translocation conservation.

In addition to endemism, consideration of genetics and future habitat suitability due to climate change, the feasibility of the translocation and the habitat building capacity factors in the decision making was a completely different approach which are not evaluated by the IUCN red listing. Nonetheless, the marking scheme developed for the priority assessment had a very high level of subjectivity and it is possible for the final scores to be inaccurate (Table 1). The resources that were used to assign credit values for the factors were restricted and biased. For example, no number of individuals were present for the majority of the species per the site. This information would crucially account for the 'small population size' sub-factor within the Distribution. Yet, the marking of this sub-factor was mainly done through the expert opinions. Nevertheless, the subjectivity stemming from both the reporter and the experts could be overcome by using reliable data, altering the credits per factors, increasing the maximum number of credits in the table, including more sub-factors to increase the accuracy and by incorporating negative marking in cases of unfeasibility of the translocation. Past or ongoing translocation projects may be taken into account like *Z. noltei* to score more

confidently (Seagrass Project, 2021). Thus, this method can also be used as a multi-access scoring table for different translocation purposes. An example would be augmenting over all numerical value and further sub-dividing the factors within the habitat building capacity to make a priority list for the ecosystem species.

Besides subjectivity in the scoring, it may be argued that the IUCN threat status and distribution factors, highlighted in red in Table 1, may be duplicating each other. For this reason, a new red listing factors or criteria may be necessary for the assessment of the species in Scotland exclusively on which the geographic range of the species would be assessed only once. Though even if the two factors were merged, it is likely that there would be species which would not benefit from the translocation like *S. cespitosa* to end up higher than more threatened species like *C. alpina* on the list. Had it not been for the expert opinion, many species that would be unrecommended for translocation, as the ones highlighted in gray in Table 1 could be prioritised over the focal species which are in more urgent need. This way, the relatively higher weight that is inevitably given to some factors may be compensated. If a discussion panel can be organised for the scoring by the consensus decision of the specialists, the personal biases influencing the assessment could also be minimised.

Modelling may be an efficient and objective tool for the decision making in both the feasibility of the translocation prioritisations and the conservation strategy. If the modelling approaches that can be efficient in predicting the future conditions of the translocation sites, as in the case of the climate change, single large reserves may be opted for the in-situ conservation of species like *Primula scotica* that occur in relatively narrow areas for short-term protections (BRC, 2021) (Appendix 2.8). Nevertheless, the uncertainty of the climate projection models make the conservation of immobile species within a single site very risky (Brooker *et al.*, 2018; Met Office, 2021). Therefore, the conservation of several small sites for most species, those that occur in a single site in particular, should be opted as the conservation translocation strategy considering the level of habitat fragmentation that impacted Scotland (Sydes, 2008; Bunce *et al.*, 2014b).

Why and how to save focal species?

The Scottish focal species that are assessed in this report form only a fraction of the species that are threatened in the country. Some of these species are apomictic endemic genera like *Hieracium* and *Taraxacum* that were not yet assessed (SSAG, 2021). There were also data deficient taxa and species like *Pinguicula alpina* that had questionable native status (BRC, 2021; SSAG, 2021). Even though there were suitable habitats in Scotland, these taxa could not be assessed in the priority list. Therefore, the future assessment of priority for conservation translocation might wish to consider such species when further information is available. Additionally, small changes in the legislation and licensing for genera like *Woodsia* and *Salix* to be translocated in the northern suitable sites that are out with their native range may be considered as an option (Appendix 2.2) (Act, 2011). Strong cases can be made for EN English taxa that have significant proximity to the Scottish border as well.

The public perception factor was not considered in the assessment of the prioritisation and some of the species on the list may not be the most charismatic. There has been an effort to include additional benefits of the focal species in fields such as biomedicine as incentives for their conservation (Results). Furthermore, some focal species may have ecosystem engineering roles that are unknown. However, if our aim is to benefit the species themselves, our approach as the society should be to support the moral and ethical position that all species have an inherent right to exist (Butcher and Baillie, 2012). It is the human activities that drove many of these species and it should be our responsibility to rectify our impact.

To put this renewed outlook into practice and to derive benefits from it may depend on a few adjustments that would be applied to several disciplines. For instance, overgrazing was the major concern for the species on the priority list according to many experts (Appendix 2). This did not mean that the grazing should be ceased Scotland. Evans *et al.* (2015) reported that the lower plant biomass as a result of higher grazing intensities had a negative cascading effect across trophic levels and, decreasing grazing would increase species abundance and overall biomass across trophic levels that included insects, birds, mammals and predators. Experts had also suggested that the grazing should be moderated (Appendix 2). Overgrazing of *Thymus* spp. in England had resulted in the regional extinction of a butterfly species in the past (Thomas, Simcox and Clarke, 2009). Some of the species on the list like *Salix* spp. were ultimately declining because of overgrazing of both wild and livestock herbivores (Appendices 2.2; 2.5 and 2.6). It was also stated that the current habitat of *Salix* spp. and of

many woodland-associated herbaceous taxa in the overseas were refugia where they escaped grazing rather than their optimal niches (Appendices 2.2; 2.5; 2.6 and 2.8). Yet, some species like *L. inundata* and *Euphrasia* spp., were favouring high grazing pressure (Appendices 2.4 and 2.10). The diversion of livestock grazing into the translocation sites of the grazing-favouring species where possible could be a good solution. For the wildlife herbivores like deers, current practices that are successful in the site management may be continued to be implemented or through the education of the public, the missing trophic levels in the Scottish landscape may be compensated in the future as it had yielded in Yellowstone Park (Beschta and Ripple, 2016). Trials conducted by GPS-tagged of a few individuals of the same sex within a closed reserve may be a feasible project for a start.

Once the grazing is managed optimally, the restoring of the ecosystem that gave birth to the endemic apomictic *Sorbus* spp. by transplanting the regionally extinct parent may also woodland establishment using the published guidelines and researches (Nature Scot, 2021; Ennos *et al.*, 2012). Missing tree lines may be restored (Appendix 2.6). Also, single species may do little restoration and multiple can reinforce communities. Having invested in the translocation project, there may be simultaneous or non-simultaneous transplanting of groups of species may be an ideal solution for prioritising. Many planted woodlands in Scotland have little understorey cover which provides ideal niches for many herbaceous species (Appendix 2.8). Translocations of the prioritised focal species may be conducted with their companion plants following thorough assessments (Appendix 2). Botanical gardens may be given weight in the *ex-situ* conservation and the genetic preservation of the translocation-unrecommended species and, ‘living walls’ that can easily host many species may be encouraged (*Living Wall & Green Roof Design Specialists*, 2021). Once the collaboration of the government and the aspiration of the public is obtained, we would have less decisions to make for prioritisation.

References

1. Adamec, L. and Lev, J. (1999) 'The introduction of the aquatic carnivorous plantAldrovanda vesiculosa to new potential sites in the Czech Republic: A five-year investigation', *Folia Geobotanica*, 34(3), p. 299. doi: 10.1007/BF02912816.

2. Barañano, C., Fernández, E. and Méndez, G. (2018) 'Clam harvesting decreases the sedimentary carbon stock of a Zostera marina meadow', *Aquatic Botany*, 146, pp. 48–57. doi: 10.1016/j.aquabot.2017.12.002.

3. Barnard, K. (2014) 'Monitoring Populations of Saxifraga cespitosa in Scotland', *Sibbaldia: The International Journal of Botanic Garden Horticulture*, (12), pp. 99–110.

4. Barry, J. M. *et al.* (2019) 'Pumas as ecosystem engineers: ungulate carcasses support beetle assemblages in the Greater Yellowstone Ecosystem', *Oecologia*, 189(3), pp. 577–586. doi: 10.1007/s00442-018-4315-z.

5. Beatty, G. E. and Provan, J. (2011a) 'High clonal diversity in threatened peripheral populations of the yellow bird's nest (Hypopitys monotropa; syn. Monotropa hypopitys)', *Annals of Botany*, 107(4), pp. 663–670. doi: 10.1093/aob/mcr003.

6. Beatty, G. E. and Provan, J. (2011b) 'Phylogeographic analysis of North American populations of the parasitic herbaceous plant Monotropa hypopitys L. reveals a complex history of range expansion from multiple late glacial refugia', *Journal of Biogeography*, 38(8), pp. 1585–1599. doi: 10.1111/j.1365-2699.2011.02513.x.

7. Berov, D. *et al.* (2015) *Distribution, structure and state of seagrass habitats in the SW Black Sea (Burgas Bay, Bulgaria)*. e1391. PeerJ Inc. doi: 10.7287/peerj.preprints.1141v1.

8. Beschta, R. L. and Ripple, W. J. (2016) 'Riparian vegetation recovery in Yellowstone: The first two decades after wolf reintroduction', *Biological Conservation*, 198, pp. 93–103. doi: 10.1016/j.biocon.2016.03.031.

9. Blanchet, H. *et al.* (2004) 'Heterogeneity of macrozoobenthic assemblages within a Zostera noltii seagrass bed: diversity, abundance, biomass and structuring factors', *Estuarine, Coastal and Shelf Science*, 61(1), pp. 111–123. doi: 10.1016/j.ecss.2004.04.008.

10. BRC (2021). Available at: www.brc.ac.uk/plantatlas/ (Accessed: 9 August 2021).

11. Britton, A. J. *et al.* (2009) 'Biodiversity gains and losses: Evidence for homogenisation of Scottish alpine vegetation', *Biological Conservation*, 142(8), pp. 1728–1739. doi: 10.1016/j.biocon.2009.03.010.

12. Brooker, R. W. *et al.* (2018) 'Tiny niches and translocations: The challenge of identifying suitable recipient sites for small and immobile species', *Journal of Applied Ecology*, 55(2), pp. 621–630. doi: 10.1111/1365-2664.13008.

13. Bubac, C. M. *et al.* (2019) 'Conservation translocations and post-release monitoring: Identifying trends in failures, biases, and challenges from around the world', *Biological Conservation*, 238, p. 108239. doi: 10.1016/j.biocon.2019.108239.

14. Bunce, R. G. H. *et al.* (2014a) 'The landscape ecological impact of afforestation on the British uplands and some initiatives to restore native woodland cover', *Journal of Landscape Ecology*, 7(2), pp. 5–24. doi: 10.2478/jlecol-2014-0013.

15. Bunce, R. G. H. *et al.* (2014b) 'The Landscape Ecological Impact of Afforestation on the British Uplands and Some Initiatives to Restore Native Woodland Cover', *Journal of Landscape Ecology*, 7(2), pp. 5–24. doi: 10.2478/jlecol-2014-0013.

16. Burlakova, L. E. *et al.* (2011) ‘Endemic species: Contribution to community uniqueness, effect of habitat alteration, and conservation priorities’, *Biological Conservation*, 144(1), pp. 155–165. doi: 10.1016/j.biocon.2010.08.010.

17. Butcher, R. E. and Baillie, E. M. J. (2012) ‘Priceless or Worthless? The world’s most threatened species’. Available at: http://copa.acguanacaste.ac.cr:8080/handle/11606/655 (Accessed: 13 August 2021).

18. Cannone, N. *et al.* (2008) ‘Accelerating Climate Change Impacts on Alpine Glacier Forefield Ecosystems in the European Alps’, *Ecological Applications*, 18(3), pp. 637–648. doi: 10.1890/07-1188.1.

19. Nature Scot (2019) *NatureScot*. Available at: https://www.nature.scot/climate-change/climate-change-impacts-scotland (Accessed: 9 August 2021).

20. Highland Titles (2021). Available at: https://www.highlandtitles.com/conservation-in-scotland/ (Accessed: 23 August 2021).

21. Custódio, L. *et al.* (2016) ‘A comparative evaluation of biological activities and bioactive compounds of the seagrasses Zostera marina and Zostera noltei from southern Portugal’, *Natural Product Research*, 30(6), pp. 724–728. doi: 10.1080/14786419.2015.1040791.

22. Dalrymple, S. E. (2007) ‘Biological Flora of the British Isles: Melampyrum sylvaticum L.’, *Journal of Ecology*, 95(3), pp. 583–597. doi: 10.1111/j.1365-2745.2007.01234.x.

23. Dalrymple, S. E. and Broome, A. (2010) ‘The importance of donor population identity and habitat type when creating new populations of small Melampyrum sylvaticum from seed in Perthshire, Scotland’, *Conservation Evidence*, 7, pp. 1–8.

24. Dennis, P. *et al.* (2005) ‘Effects of grazing management on upland bird populations: disentangling habitat structure and arthropod food supply at appropriate spatial scales (GRUB)’.

25. Duwe, V. K. *et al.* (2018) ‘Genetic structure and genetic diversity of the endangered grassland plant Crepis mollis (Jacq.) Asch. as a basis for conservation management in Germany’, *Conservation Genetics*, 19(3), pp. 527–543. doi: 10.1007/s10592-017-1025-8.

26. Dyer, A. F. (1994) ‘Natural soil spore banks — can they be used to retrieve lost ferns?’, *Biodiversity & Conservation*, 3(2), pp. 160–175. doi: 10.1007/BF02291886.

27. Ennos, R. A. *et al.* (2012) ‘Process-Based Species Action Plans: an approach to conserve contemporary evolutionary processes that sustain diversity in taxonomically complex groups’, *Botanical Journal of the Linnean Society*, 168(2), pp. 194–203. doi: 10.1111/j.1095-8339.2011.01206.x.

28. Evans, D. M. *et al.* (2015) ‘The cascading impacts of livestock grazing in upland ecosystems: a 10-year experiment’, *Ecosphere*, 6(3), p. art42. doi: 10.1890/ES14-00316.1.

29. Evans, D. M., Pocock, M. J. O. and Memmott, J. (2013) ‘The robustness of a network of ecological networks to habitat loss’, *Ecology Letters*, 16(7), pp. 844–852. doi: 10.1111/ele.12117.

30. Fenton, E. W. (1940) ‘The Influence of Rabbits on the Vegetation of Certain Hill-Grazing Districts of Scotland’, *Journal of Ecology*, 28(2), pp. 438–449. doi: 10.2307/2256238.

31. Fiedler, P. L., and R. D. Laven. (1996). Selecting reintroduction sites. In *Restoring Diversity: Strategies for Reintroduction of Endangered Plants*, edited by D. A. Falk, C. I. Millar, and M. Olwell, 157–170. Washington, DC: Island Press.

32. Flather, C. H. *et al.* (2011) ‘Minimum viable populations: is there a “magic number” for conservation practitioners?’, *Trends in Ecology & Evolution*, 26(6), pp. 307–316. doi: 10.1016/j.tree.2011.03.001.

33. Fusani, P. and Zidorn, C. (2010) ‘Phenolics and a sesquiterpene lactone in the edible shoots of Cicerbita alpina (L.) Wallroth’, *Journal of Food Composition and Analysis*, 23(6), pp. 658–663. doi: 10.1016/j.jfca.2009.08.014.

34. Gamain, P. *et al.* (2018) ‘Can pesticides, copper and seasonal water temperature explain the seagrass Zostera noltei decline in the Arcachon bay?’, *Marine Pollution Bulletin*, 134, pp. 66–74. doi: 10.1016/j.marpolbul.2017.10.024.

35. Gardner, S. M. *et al.* (1997) ‘Carabid communities on heather moorlands in northeast Scotland: The consequences of grazing pressure for community diversity’, *Biological Conservation*, 81(3), pp. 275–286. doi: 10.1016/S0006-3207(96)00148-6.

36. Gibby, M. (2003) ‘Overview of Scottish plant conservation: Problems, research needs and policy issues’. doi: 10.1080/03746600308685043.

37. Gruzdev, E. V. *et al.* (2016) ‘The complete chloroplast genome of parasitic flowering plant Monotropa hypopitys: extensive gene losses and size reduction’, *Mitochondrial DNA Part B*, 1(1), pp. 212–213. doi: 10.1080/23802359.2016.1155090.

38. Guidetti, P. and Bussotti, S. (2000) ‘Fish fauna of a mixed meadow composed by the seagrasses Cymodocea nodosa and Zostera noltii in the Western Mediterranean’, *Oceanologica Acta*, 23(7), pp. 759–770. doi: 10.1016/S0399-1784(00)01117-8.

39. IUCN. (2012). IUCN Red List Categories and Criteria: Version 3.1. Second edition. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32pp.

40. Hobbs, R. (2009) ‘Woodland restoration in Scotland: Ecology, history, culture, economics, politics and change’, *Journal of Environmental Management*, 90(9), pp. 2857–2865. doi: 10.1016/j.jenvman.2007.10.014.

41. Hodder, K. H. and Bullock, J. M. (1997) ‘Translocations of Native Species in the UK: Implications for Biodiversity’, *Journal of Applied Ecology*, 34(3), pp. 547–565. doi: 10.2307/2404906.

42. Humphrey, J. W. and Patterson, G. S. (2000) ‘Effects of late summer cattle grazing on the diversity of riparian pasture vegetation in an upland conifer forest’, *Journal of Applied Ecology*, 37(6), pp. 986–996. doi: 10.1046/j.1365-2664.2000.00550.x.

43. Imms, A. D. (1941) ‘The Prickly–Pear Problem in Australia’, *Nature*, 148(3750), pp. 303–305. doi: 10.1038/148303a0.

44. Jusaitis, M. (2005) ‘Translocation trials confirm specific factors affecting the establishment of three endangered plant species’, *Ecological Management & Restoration*, 6(1), pp. 61–67. doi: 10.1111/j.1442-8903.2005.00220.x.

45. Karban, R. and Strauss, S. Y. (1993) ‘Effects of Herbivores on Growth and Reproduction of their Perennial Host, Erigeron Glaucus’, *Ecology*, 74(1), pp. 39–46. doi: 10.2307/1939499.

46. SWT (2021). Available at: https://scottishwildlifetrust.org.uk/scotlands-wildlife/key-threats-to-wildlife/ (Accessed: 23 August 2021).

47. Kier, G. *et al.* (2009) ‘A global assessment of endemism and species richness across island and mainland regions’, *Proceedings of the National Academy of Sciences*, 106(23), pp. 9322–9327. doi: 10.1073/pnas.0810306106.

48. Kuzovkina, Y. A. and Volk, T. A. (2009) ‘The characterization of willow (Salix L.) varieties for use in ecological engineering applications: Co-ordination of structure, function and autecology’, *Ecological Engineering*, 35(8), pp. 1178–1189. doi: 10.1016/j.ecoleng.2009.03.010.

49. Leake, J. R. *et al.* (2004) ‘Symbiotic germination and development of the myco-heterotroph Monotropa hypopitys in nature and its requirement for locally distributed Tricholoma spp.’, *New Phytologist*, 163(2), pp. 405–423. doi: 10.1111/j.1469-8137.2004.01115.x.

50. Leimu, R. *et al.* (2006) ‘How general are positive relationships between plant population size, fitness and genetic variation?’, *Journal of Ecology*, 94(5), pp. 942–952. doi: 10.1111/j.1365-2745.2006.01150.x.

51. Leroux, S. J. and Schmiegelow, F. K. A. (2007) ‘Biodiversity Concordance and the Importance of Endemism’, *Conservation Biology*, 21(1), pp. 266–268. doi: 10.1111/j.1523-1739.2006.00628.x.

52. *Living Wall & Green Roof Design Specialists* (2021) *ANS Global*. Available at: https://www.ansgroupglobal.com (Accessed: 27 August 2021).

53. Long, D. and Scott, M. (2003) ‘Action for biodiversity priority species in Scotland’, *Botanical Journal of Scotland*, 55(1), pp. 65–76. doi: 10.1080/03746600308685049.

54. Lynes, M. (2019) ‘Alchemilla sciura (Rosaceae), a new species of Lady’s-mantle’, *British & Irish Botany*, 1(4), pp. 335–341. doi: 10.33928/bib.2019.01.335.

55. MacRoberts, M. H. *et al.* (2002) ‘Endemism In The West Gulf Coastal Plain: Importance Of Xeric Habitats’, *SIDA, Contributions to Botany*, 20(2), pp. 767–780.

56. Manes, S. *et al.* (2021) ‘Endemism increases species’ climate change risk in areas of global biodiversity importance’, *Biological Conservation*, 257, p. 109070. doi: 10.1016/j.biocon.2021.109070.

57. Mardon, D. K. (1990) ‘Conservation of montane willow scrub in Scotland’, *Transactions of the Botanical Society of Edinburgh*, 45(5), pp. 427–436. doi: 10.1080/03746609008684981.

58. Mardon, D. K. and Watts, S. H. (2019) ‘Population dynamics and life history of the rare arctic-alpine plant Sagina nivalis (Caryophyllaceae) on the Ben Lawers range, Scotland, UK’, *British & Irish Botany*, 1(1), pp. 50–69. doi: 10.33928/bib.2019.01.050.

59. Matthews, W. S., Wyk, A. E. van and Rooyen, N. van (1999) ‘Vegetation of the Sileza Nature Reserve and neighbouring areas, South Africa, and its importance in conserving the woody grasslands of the Maputaland Centre of Endemism’, *Bothalia*, 29(1), pp. 151–167. doi: 10.4102/abc.v29i1.586.

60. McHaffie, H., Frachon, N. and Robertson, A. (2011) ‘Starting a conservation collection of Sorbus pseudomeinichii: the Catacol Whitebeam’, *Sibbaldia: The International Journal of Botanic Garden Horticulture*, (9), pp. 171–178.

61. Met Office (2021).lea *Met Office*. Available at: https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/land-projection-maps (Accessed: 26 August 2021).

62. Moseley, D. D., Ray, D. and Bryce, J. (2005) ‘A forest habitat network for the Atlantic Oakwoods in Highland region, Scotland’, *Botanical Journal of Scotland*, 57(1–2), pp. 197–209. doi: 10.1080/03746600508685098.

63. Novy, P. *et al.* (2015) ‘Composition and Antimicrobial Activity of Euphrasia rostkoviana Hayne Essential Oil’, *Evidence-Based Complementary and Alternative Medicine*, 2015, p. e734101. doi: 10.1155/2015/734101.

64. NSRF (2014). The Scottish Code for Conservation Translocations. Scottish Natural Heritage. National Species Reintroduction Forum (2014). Best Practice Guidelines for Conservation Translocations in Scotland Version 1.1. Scottish Natural Heritage

65. Paduch, R. *et al.* (2015) ‘Aqueous Extracts of Selected Potentilla Species Modulate Biological Activity of Human Normal Colon Cells’, *Current Drug Targets*, 16(13), pp. 1495–1502.

66. Peterken, G. F. (2001) ‘Ecological effects of introduced tree species in Britain’, *Forest Ecology and Management*, 141(1), pp. 31–42. doi: 10.1016/S0378-1127(00)00487-4.

67. Pimm, S. L. *et al.* (1995) ‘The Future of Biodiversity’, *Science*, 269(5222), pp. 347–350. doi: 10.1126/science.269.5222.347.

68. Project Seagrass (2021). *Project Seagrass | Advancing the conservation of seagrass through education, influence, research and action*. Available at: https://www.projectseagrass.org/research/ (Accessed: 23 August 2021).

69. Raudonė, L. *et al.* (2015) ‘Phytochemical and antioxidant profiles of leaves from different Sorbus L. species’, *Natural Product Research*, 29(3), pp. 281–285. doi: 10.1080/14786419.2014.950577.

70. Raudonis, R. *et al.* (2014) ‘Phenolic and antioxidant profiles of rowan (Sorbus L.) fruits’, *Natural Product Research*, 28(16), pp. 1231–1240. doi: 10.1080/14786419.2014.895727.

71. Ren, H. *et al.* (2016) ‘The use of grafted seedlings increases the success of conservation translocations of Manglietia longipedunculata (Magnoliaceae), a Critically Endangered tree’, *Oryx*, 50(3), pp. 437–445. doi: 10.1017/S0030605315000423.

72. Ricciardi, A. and Simberloff, D. (2009) ‘Assisted colonization is not a viable conservation strategy’, *Trends in Ecology & Evolution*, 24(5), pp. 248–253. doi: 10.1016/j.tree.2008.12.006.

73. Rich, T. C. G., Fitzgerald, R. and Sydes, C. (1998) ‘Distribution and ecology of small cow-wheat (Melampyrum sylvaticum L.; Scrophulariaceae) in the British Isles’, *Botanical Journal of Scotland*, 50(1), pp. 29–46. doi: 10.1080/03746609808684901.

74. Robertson, A., Newton, A. C. and Ennos, R. A. (2004) ‘Breeding systems and continuing evolution in the endemic Sorbus taxa on Arran’, *Heredity*, 93(5), pp. 487–495. doi: 10.1038/sj.hdy.6800528.

75. Rueda, J. L. *et al.* (2009) ‘A highly diverse molluscan assemblage associated with eelgrass beds (*Zostera marina* L.) in the Alboran Sea: Micro-habitat preference, feeding guilds and biogeographical distribution’, *Scientia Marina*, 73(4), pp. 679–700. doi: 10.3989/scimar.2009.73n4679.

76. Scobie, A. R. (2009) *Understanding the causes of reproductive failure in two rare Scottish plants, Linnaea borealis L. and Spiranthes romanzoffiana Cham. and the implications for future conservation management*. Ph.D. University of Aberdeen. Available at: https://abdn.alma.exlibrisgroup.com/discovery/delivery/44ABE_INST:44ABE_VU1/12152747010005941 (Accessed: 26 August 2021).

77. Scotia Seeds (2021). Available at: https://www.scotiaseeds.co.uk/ (Accessed: 23 August 2021).

78. Seddon, P. J. (2010) ‘From Reintroduction to Assisted Colonization: Moving along the Conservation Translocation Spectrum’, *Restoration Ecology*, 18(6), pp. 796–802. doi: 10.1111/j.1526-100X.2010.00724.x.

79. Seel, W. E. and Press, M. C. (1994) ‘Influence of the host on three sub-Arctic annual facultative root hemiparasites’, *New Phytologist*, 127(1), pp. 37–44. doi: 10.1111/j.1469-8137.1994.tb04257.x.

80. Shrivastava, R. and John, G. W. (2006) ‘Treatment of Aphthous Stomatitis with Topical Alchemilla vulgaris in Glycerine’, *Clinical Drug Investigation*, 26(10), pp. 567–573. doi: 10.2165/00044011-200626100-00003.

81. Silcock, J. L. *et al.* (2019) ‘Threatened plant translocation in Australia: A review’, *Biological Conservation*, 236, pp. 211–222. doi: 10.1016/j.biocon.2019.05.002.

82. SSAG (2021). *The Great Britain Red List of Vascular plants* (19.02.2021). Species Status Assessment Group.

83. Sousa, A. I. *et al.* (2019) 'Blue Carbon stock in Zostera noltei meadows at Ria de Aveiro coastal lagoon (Portugal) over a decade', *Scientific Reports*, 9(1), p. 14387. doi: 10.1038/s41598-019-50425-4.

84. Spangenberg, J. H. (2007) 'Integrated scenarios for assessing biodiversity risks', *Sustainable Development*, 15(6), pp. 343–356. doi: 10.1002/sd.320.

85. Sticher, O. and Salama, O. (1981) 'Iridoid Glucosides from Euphrasia rostkoviana', *Planta Medica*, 42(6), pp. 122–123. doi: 10.1055/s-2007-971584.

86. Sydes, C. (2008) 'Can we protect threatened Scottish arctic-alpine higher plants?', *Plant Ecology & Diversity*, 1(2), pp. 339–349. doi: 10.1080/17550870802349179.

87. Sylvie, B. R. *et al.* (2009) 'Effects of phytohormones and macro- and microelements on growth and alkaloid accumulation in Lycopodiella inundata (L.) holub plant cell cultures', *New Biotechnology*, 25, p. S295. doi: 10.1016/j.nbt.2009.06.672.

88. Teixeira, R. and Silva, L. R. (2013) 'Bioactive compounds and in vitro biological activity of Euphrasia rostkoviana Hayne extracts', *Industrial Crops and Products*, 50, pp. 680–689. doi: 10.1016/j.indcrop.2013.08.035.

89. Thomas, C. D. (2011) 'Translocation of species, climate change, and the end of trying to recreate past ecological communities', *Trends in Ecology & Evolution*, 26(5), pp. 216–221. doi: 10.1016/j.tree.2011.02.006.

90. Thomas, J. A., Simcox, D. J. and Clarke, R. T. (2009) 'Successful Conservation of a Threatened Maculinea Butterfly', *Science*, 325(5936), pp. 80–83. doi: 10.1126/science.1175726.

91. Tomczyk, M., Leszczyńska, K. and Jakoniuk, P. (2008) 'Antimicrobial activity of Potentilla species', *Fitoterapia*, 79(7), pp. 592–594. doi: 10.1016/j.fitote.2008.06.006.

92. Trendafilova, A. *et al.* (2011) 'Flavonoid Constituents and Free Radical Scavenging Activity of Alchemilla mollis', *Natural Product Communications*, 6(12), p. 1934578X1100601216. doi: 10.1177/1934578X1100601216.

93. Trofast, J. (1978) 'Chloromycorrhizinol A, A furochroman from an isolate of the roots of Monotropa hypopitys', *Phytochemistry*, 17(8), pp. 1359–1361. doi: 10.1016/S0031-9422(00)94589-8.

94. Trofast, J. and Wickberg, B. (1977) 'Mycorrhizin a and chloromycorrhizin a, two antibiotics from a mycorrhizal fungus of monotropa hypopitys L.', *Tetrahedron*, 33(8), pp. 875–879. doi: 10.1016/0040-4020(77)80038-0.

95. Van Zuidam, J. P. and Peeters, E. T. H. M. (2012) 'Cutting affects growth of Potamogeton lucens L. and Potamogeton compressus L', *Aquatic Botany*, 100, pp. 51–55. doi: 10.1016/j.aquabot.2012.02.005.

96. Warren, M. A. *et al.* (2010) 'Increasing density of juvenile Atlantic (Gadus morhua) and Greenland cod (G. ogac) in association with spatial expansion and recovery of eelgrass (Zostera marina) in a coastal nursery habitat', *Journal of Experimental Marine Biology and Ecology*, 394(1), pp. 154–160. doi: 10.1016/j.jembe.2010.08.011.

97. Wilson, K. L. and Lotze, H. K. (2019) 'Climate change projections reveal range shifts of eelgrass Zostera marina in the Northwest Atlantic', *Marine Ecology Progress Series*, 620, pp. 47–62. doi: 10.3354/meps12973.

98. Wildlife and Natural Environment (Scotland) Act 2011 (2011). Available at: legislation.gov.uk (Accessed: 9 August 2021).

99. Yackulic, C. B. *et al.* (no date) ‘Assessing the population impacts and cost-effectiveness of a conservation translocation’, *Journal of Applied Ecology*, n/a(n/a). doi: 10.1111/1365-2664.13908.

100. Zopfi, H.-J. (1998) ‘The genetic basis of ecotypic variants of Euphrasia rostkoviana Hayne (Scrophulariaceae) in relation to grassland management’, *Flora*, 193(1), pp. 41–58. doi: 10.1016/S0367-2530(17)30814-9.

Appendix 1: List of experts and species interviewed

1. Prof Mary Gibby – *Dryopteris pseudodisjuncta, Dryopteris pseudocomplexa*
2. Dr Heather McHaffie – *Sorbus arranensis, Sorbus pseudomeinichii, Sorbus pseudofennica, Melampyrum sylvaticum, Woodsia ilvensis, Woodsia alpina, Salix myrsinites, Salix lapponum, Salix lanata*
3. Michael Scott – *Arabis alpina*
4. Dr. Alex Twyford – *Euphrasia montana, Euphrasia rotundifolia, Euphrasia frigida, Euphrasia marshallii*
5. Shaila Rao - *Salix myrsinites, Salix lapponum*
6. Dr Aline Finger – *Cicerbita alpina, Zostera noltei*
7. Sarah Smyth – *Carex maritima, Calamagrostis scotica*
8. Iain MacDonald – *Phyllodoce caerulea, Alchemilla wichurae, Alchemilla sciura, Potentilla rupestris, Saxifraga cespitosa*
9. Ian Strachan – *Poa flexuosa, Lycopodiella inundata*
10. Robin Payne – *Monotropa hypopytis*
11. Dan Watson – *Sagina saginoides*

Appendix 2: The replies to the interviews

Appendix 2.1 – Mary Gibby

Dryopteris pseudocomplexa and *pseudodisjuncta*

Which sort of habitat/environment does the species tolerate and thrive in your experienc

-Both species grow in small woodland, at low altitude. There's not a lot I can add – I have only seen it once, it's a bit difficult to say where it might be likely to grow elsewhere. The locality where it grows is typical for related apomictic species of *Dryopteris*. The distribution of *D. pseudocomplexa* is not thoroughly studied - few people other than one or two experts can identify it . It is recorded in Europe as well.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-When translocating one of the most important things is not to introduce other plants into the site that you've chosen. It is really important to make sure you haven't got anything else with it, a weed, a contaminant etc. Otherwise, you would be introducing something you haven't done any sort of risk assessment for. Then you might be introducing something entirely inappropriate for the habitat. It's easy to get greenhouse weeds being transplanted into the wild, or disease, and so that's one of the dangers of translocations. One of the reasons for translocation may be that it has been lost. Perhaps we knew it had grown there in the past, and so may wish to re-introduce it. But even then, you don't want inadvertently to introduce anything else at the same time.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-At the moment, I don't consider any sites appropriate because we don't know enough about their current distribution. Experts need to look in detail in the field to map their distributions. Even then it would be very easy to overlook it as apomictic *Dryopteris* are hard to identify. There are two or three people I know of who I would send into the field to try to do a survey. I wouldn't have the confidence to do it myself.

What sort of benefits of translocation can you predict for the recipient site?

-The benefit of translocation is that if one site was devastated, they would be lost all together. But I think better strategy rather than translocating it would be to have some plants in conservation in the botanical gardens, and then you have the potential to plant it out somewhere else if that site was lost. But I wouldn't suggest translocating. I just suggest saving it in the gardens. When you've got such a small population as that because you're more likely to keep the population alive if you can keep an eye on it. It is also where you could mimic the natural conditions the best. We've got three botanic gardens to choose from. The challenge will be just to raise the plants, and this is where somebody with the skills of raising plants and spores will be able to do it. Then holding the plants in case, you need to do a translocation. I think that's the most sensible approach.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-No invasive potential. I don't think a big problem from competition. These are not plants that are going to spread very easily. You don't have fertilisation going on because it's apomictic, so they will be genetically similar to the mother plants .They're almost like clones.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-You want to collect the spores to grow plants. You need to be there in July or early August. It's quite important to wash the frond to make sure that you are collecting from that plant and not others' blown from the neighbouring. You don't need the whole frond because you don't need thousands of spores. You want is supposed to be as clean as possible and not contaminated with other species. Cut off the fronds and if there is a stream nearby you can actually wash it in the stream. Thus, any surplus spores will be washed off and the others will still be within the sporangia. You then dry it and then when the spores are ripe, they will fall out.

Are there particular practices to do in the recipient site management for successful establishment?

-If we are talking about *ex-situ*, yes, the experience. We've got some really good horticulturists in the RBGE like Andy. If he planted things, the plants tended to survive, and if people without a lot of experience of growing plants planted them, they weren't put in the

ground so well. They just didn't actually thrive as well. You can see in the records that if you're putting out 60 plants and after one year only 30 of survive when non-experienced people planted them. It can suggest that you're planting technique wasn't good. If Andy planted them, you were guessing 59 surviving. If you were to translocate them into the world you need experience of the people growing the plants to know how and where to plant them. It's partly about choosing the site and locality ideal for them to grow in. Imitate the nature. And, you've got to do your annual monitoring. After several years, you don't necessarily have to do it manually, but you do have to do regular monitoring that that's important for any translocation. I would apply the same procedures to both of them.

Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

-*Athyrium distentifolium* var. *flexile*. It's not a species. It doesn't get onto the list because it's not a species, it's just a variety. It is unique to Scotland. It doesn't grow anywhere else. And it's a recessive. But it has a lot of features that make it worthy. It's selected for in its habitat because it can grow better than *A. distentifolium* under certain conditions. It's one of the things that might be lost. Due to climate change and global warming because it relies on snow patches in winter. You need to conserve the population from which they arise. That's what you've got to do. They have been reintroduced back into the site where they already grow. There weren't many plants there, so it's a great example.

Appendix 2.2 – Heather McHaffie

Crepis mollis

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-*Crepis mollis* has suffered a lot because it grows in grassland. People have this thing about growing trees and planting trees, they say we ought to have more trees. They plant trees and quite a few sites have suffered because of well-meaning local groups planting trees on top of *C. mollis*. Now this was a lack of knowledge for the tree planters. *C. mollis* really wants just a good bit of open grassland. We grew some plants of *C. mollis* and gave them to a local group and they planted them. Obviously, you want to make sure that the other species are not just taking over the habitat. And another group without telling them, and I don't know how it happened, planted trees on top of where they put their plants, which is just incredible. Another snag about reintroductions is that people do need to monitor them. They need to look very carefully about how they're doing it, because some people think once you put the plants in, that's it, you're finished.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-No.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-Any grassland site in Scotland, like Cairngorms Highlands would be a good site. You do need to be careful that you are keeping within its historic range in Scotland. Sites within that area. I cannot give you specific sites at the moment. But this is something where you do need to be careful. It sounds a good idea: “Oh yes, let's just plant some more.” But actually, it's very complicated because there will not be very many suitable sites.

What sort of benefits of translocation can you predict for the recipient site?

-Yes, it definitely would. It's a quite good plant for pollen and nectar, so that would definitely enhance the biodiversity.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-I don't think you should worry about it being invasive. From our limited experience of it, which might not be correct. But I doubt if it's going to compete with other things. It's more likely that it would struggle to survive in the grassland. No potential of becoming an arable weed or anything.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-Seeds are always the best. You get more genetic diversity, because hopefully there's been some cross-pollination. For vegetative propagation of *C. mollis*, you would have to dig it up and divide it, but I suspect the plants might not be very long-lived and by digging it up and splitting it you might just kill it. The divided plants might not survive anyway, whereas if they're grown from seed, you start off with nice healthy young plants. You probably want to clear it a little space when its planted so that it's not got other plants competing. You would need to possibly experiment with which size is good to plant, whether you want young plants in their first year, which will require less water as they establish or big plants that might survive for longer. We have also found it's much better to plant in the autumn rather than in the spring because we get very dry springs now. It often doesn't rain for months, and this is again a climate change factor. While an established plant can tolerate that, it's pretty difficult if you've just planted something and mostly don't go back and water it. It's usually quite a long time from starting to think about the translocation because you have to find your sites. You have to arrange to collect the seeds. You can use local people to help with that so that you get the seed just when it's ripe. You might even find that the first time you plant things something happens to them, so you might need to do a second lot of planting, so there there's a lot to experiment with there. The only trouble is finding sites because I know there has been interest in this in the past.

Are there particular practices to do in the recipient site management for successful establishment?

-Monitor them. We might find the flowers are always grazed off and that's obviously going to make it difficult because it will never manage to release seed to perpetuate itself. You can plant plants and they might survive. But I would only say it's very successful when they themselves can produce seeds and you get more plants from them. If all you do is plant the plants out and they just sit there, that that's almost like gardening. What you want is a dynamic population with a turnover that can produce seed and perpetuate itself. When we plant, we keep careful records or where we put the transplants. We either have a map that shows how many plants are in a given area and or we will have some photographs marked to show where actual individual plants are put. For something like C. mollis, I think you probably plan that a given area has got, say, 60 plants in. That would be a good sized number

for a population, but quite reasonable to count. If you put too many plants, it’s harder to count accurately. So, it's better to have a closer group of something like 60 and then a gap, and then perhaps another group somewhere else. We've found it's easier to monitor if you cluster the plants. We do things like put little flags in beside each one when monitoring so you know which ones you've found and which ones you've counted. To begin with, you're monitoring establishment and you also see if it's got flowers. Through time you would be looking for seed production. And for the plants not to be eaten and grazed too much. You would also be looking for new seedlings. And it's when you get new young plants, which would be much smaller than the ones that you put in, or perhaps appearing in a different area. Then you would feel that it was being successful.

What makes me think about grazing is that if this species were to be translocated, it will be an open habitat. If the deer numbers were properly controlled as in some areas, they are, you do see a big difference. You want some grazing, obviously because it's got to be grassland. We were not allowed to do one of the willow reintroductions until the deer numbers have been reduced, but they've just been building up again. I don't think it's being addressed properly, and I think without proper control of grazing, a lot of what people do could just be an absolute waste of time.

This is a species that has been declining a lot, and when you look at what you're going to do in the way of conservation, you always want to look and see why something is disappearing. Just planting something in an area where it's disappeared without knowing why it has disappeared is of no use. If it's something you can't do anything about, like climate change, then you can’t really do much. Unless you could plant like higher up the hill or further north or something like that. You still need to be a bit careful that it is within the native range.

Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

-It's not as easy to make a list as you might think because things keep changing. The criteria change. People find more populations and conservation lists are changing all the time, but you've got a good list here I must say. There are some species you think it would be good to do something about. When you look at the map, if it's a 10-kilometre square distribution, you do have to remember that you can have a small population or several bigger populations, and it's just one dot on the map. Don't assume that there's a lot there just because you seem to have quite a few dots. Each dot might be a widely spaced population, or a very small barely viable population. And when you start experimenting you do find it's not as simple as it seems. We have looked at the species that have been on the conservation lists and have tried growing them to find out how easy they are to grow. Some things are actually quite a nuisance in cultivation and would spread invasively into the pots of other species, but they don’t spread like that in the wild. Why not? Probably because of grazing!

Woodsia spp.

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-*W. ilvensis* likes it a bit dryer. But I think it must have its roots way, way, way down into the rock. Whereas *W. alpina* will grow on rocks. It needs some water running down over it. So that's quite a marked difference in their habitat. *W. ilvensis* is usually south facing. Something that grows in dry rock faces, which it's a very hard thing for planting. There was a site in Teesdale, England where we have done reintroductions. We used a mixture of all the British plants, which was the first time that happened. One site was almost north facing, but it was on a gentle slope. So, it did get quite a lot of sun. In the summer, that one did quite well to begin with. But the other site, south facing, exactly where the original plants had been. It was so sad to go there and find less and less every time. The plants, to begin with did look quite good. But we do get long, long dry springs and I don't think, it likes that very much. It would be alright for a month or two, but by the time it's four or five months, that's probably just a bit too much. We think probably it was a rare species that meant they wanted it more and collected an awful lot of it. This made it even more rare. Probably, it contributed a lot to why it has declined so much. Having said that, I think there's a climate change element, especially now, but that might well have been affecting it even when it was being collected. It's a plant that at one time we reckon there was something like 96 individuals, plants or clumps. It's hard when you get a clump. Quite a good sized lump of it it's two plants side by side or if it's just the same one that's got bigger and bigger. We're continuing to monitor some sites plant by plant.

W. alpina, that's more east. It is roughly the same but this one likes to be in just a bit damper place. Probably more facing in slightly different directions. The ones I can think of, funnily enough, or even north. Because *W. alpina* likes it more damp, more shaded, I would say. Most of the snow in Scotland would lie against the North Slope. That might be keeping it damp. It gets very wet in those conditions so, it doesn't mind it being a bit too damp either. Somebody has told me that some of the populations natural wild populations did suffer when we had extended droughts.

Both are fern species have roughly the same habitat. I'd say about 300 metres. They are not the highest things. Our hills are not very high anyway. Although some of them do grow quite low down. You will find a few other things that grow with it, but actually not very much because it's not going to like a lot of competition. I don't think they will disperse very far either. Someone did a study on woodland ferns and found that most of the fern spores were deposited quite close to the mother plants.

Somebody I know said that he saw *W. ilvensis* covered with ice once. The water had run and was frozen on top of it. That would have protected it from grazing. Actually, it wouldn't mind that at all. Although where it grows is often quite dry really. Some plants, if you keep them sitting in their pots and you have a very cold winter, it will kill them. I've not seen that with

W. ilvensis. I had some that I was given that were sitting outside and I didn't plant them in my garden until the spring.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-I don't think either of them want to have associated companion plants or anything. And there's nothing about pollinating obviously.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-Well, certainly for planting we find that screes are much easier. The ones that survive the previous translocations the best tended to be in cracks in rocks, and that goes for both the species. What we saw in some cases that there were lots of rocks with nothing much growing there. Which is good because you don't want competition and we took the compost that these plants were grown in the nursery, lifted out some rocks, put some compost in, put the plants in and put the rocks back and, that gave them somewhere to grow to begin with. Then later on, we would hope they would put the roots right down to find more what's there. The trouble with that is you would come back and find some other plant that had the seeds are blowing in and they were growing very well within the composts. There was one year that had a really, really bad drought. I thought it would be interesting to see how the *W. ilvensis* was growing. Some of them had died but a lot of them looked very good, but the flowering plants had died. They mustn't have had the roots way down. They were just living in this compost that we had put in. So, in that sense, W.ilvensis is much better adapted, and I presume it must have long, long roots. We haven't planted *W. alpina,* but it must have its roots way back to. It depends on the root establishment. It needs to not have too many dry years while they were first growing at.

Another debate we've had is whether we should go further north from where they're growing now, because we would anticipate climate change. And this has been talked about for other flowering plant species. But since you're not supposed to be planting something outside its current range, there would need to be a change in our laws and our legislation in Scotland. If that was something that people seriously wanted to do, I think it would have to be thought about. It's just that there are these laws not to plant alien species out of their native range, so you're not supposed to go planting things in the wild. Which is all right, if it's going to be invasive, but we'd be lucky if these things grow at all, of course.

A site in England is just a single one in the Lake District, and that is the biggest population in Britain. People kept visiting it and the plants did quite well. I think that was a west facing site. We've only been there once and there was a dense mist. It's a very, very, very steep site. The rocks keep moving when you stand on them, a proper scree. There's been a student recently who took a day off and he went to a nearby site that was unrecommended by his institution. That shows how dangerous this site is and he found that there were lots more new young plants and that was an amazing discovery. If you have the right habitat, it is surprising how ferns will grow up. We've collected soil from underneath the fern. And if you grow that in cultivation, you do get young plants. Yet they don't seem to grow where they are, unless slugs eat them or something.

I think it might help if we had a very wet year, or perhaps several wet years. Because they're not going to like drying out too much in a long, long dry spring again. Especially as the prothalli are quite tender. I do think climate change has a lot to do with this one. And by the time you've got very small populations because of collecting and not much genetic variation, I just think you've got a bad combination of things. The ones growing in Glen Fishy. I think there were about 3 clumps when they first found it. That's got smaller and smaller and smaller. We were asked if we would plant some more in that area, not in the exact place but nearby. That was what we call the supplementation. We collected spores from the original plants and sowed them about a kilometre away and they've been monitored a bit as well. They did very well to begin with. But we realised that when you have lots of deer walking around, they trample the vegetation, and they knock the moss off the stones. The moss was going right over the top of our little plants. Some of them were big enough to grow through, but a lot of them would find the rock where we planted them and round about that. We knew there were so many plants. But now it was just surrounded by moss. They've declined a lot. So, the trampling is another factor that goes with grazing. It can be quite helpful too as it keeps a habitat open. As long as it is balanced. If it just damages one part of it, it can grow back again, obviously. But I think the covering of moss is just going to be hopeless because the most are thick, big mosses.

You can even go and water them. You could. We'd them you could keep the plants sitting there if you tried hard enough, but that's not what happens in the wild. Also, again, it's not just the plants surviving. It's the plants surviving and producing more new young plants that would be our measure of success. And if you don't get new young plants then I would say it's not successful. If there was a big grass or something trying to grow where we'd planted them, we might pull it out gently, but really, you can't go around weeding things. We are always trying to make sure that we're not gardening. Yes, you can plant things out. You can look after them but there should be minimum intervention.

What sort of benefits of translocation can you predict for the recipient site?

-No benefits of translocation. I honestly don't know how it helps the site to have these tiny little Woodsia plants. In some cases, it might help to hold the scree together if you had big enough clumps, but you don't really have that big populations.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-Well, it's certainly not invasive. It's not competing with anything. I don't think it's going to ruin the economy.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-Starting from spores for both Woodsia. I did some experimental work with sowing spores, and I found that *W. ilvensis* does like to outcross. But if you only have one or two individuals left, perhaps they're not establishing so well. For a project in the botanical garden, it took a bit of preparation. Just trying to find out how to grow the spores. Obviously, they are collected when they're ripe, usually sewn quite quickly. Sometimes you might delay sowing until the spring, but at the garden they've got growth rooms and they can get a controlled amount of light. Using that, I know that Andy, our person who grows the ferns. He's very good. He had plants with spores from about five months for *W. ilvensis*. You would never get that in the wild because it would have spores one year, perhaps tiny little plants the next year. I'm sure the plants would take several years to get big enough to produce spores, but we can hurry things along in cultivation. With artificial day lengths and just feeding them all the time. If you plant them, it's best to plant them in the autumn. The other thing we found was the first reintroduction that I was involved with. I don't think we even had Andy with us, and we got volunteers to help. To carry the plants up the hill and planting. And we let the volunteers choose where to plant them. It was hopeless. They didn't even properly remember where they put them, and they scattered them all over the place. But we learned anyway. After that we always got Andy to plant them, and Andy does it beautifully. So, we all had to stand around and watch. The ones that Andy planted have done better than any others. So, the more recent reintroductions did do better. But then of course you might argue that there are more plants surviving because it's more recent and they haven't had as long to die. Though they aren't going down as before now.

Another debate for any species is how big do you want it to be when you plant it out? The bigger the plant I think the better it will survive actually. Because if you've got a bigger lump of soil around the roots it will take longer to dry out. It is a difficult one. Also, the bigger the

plant, the heavier it is to carry up the hill. So will be the pots bigger. We keep them in their pots to keep the soil damp, but you don't want to water them too soon before you carry them. Because it makes them heavier. It means they're a bit dry over the time you get them to where you're taking them. Then they'll get planted as deeply as possible. The other thing the volunteers was that they didn't put them in deep enough. They had some of the soil sticking out, which of course dries off faster. So don't use volunteers or if you do, give them a very good training.

There is also the acclimatisation period. They don't do well many times. There should be what we call hardening off. They're not coming straight out of a glasshouse or anything, but we were going up 300 metres or so. And they've been in a hot car to get there. It's not ideal. I suppose you might be better to take them to this near the site and leave them there for a few weeks and then plant them perhaps. But we've tended just to take them and put them out. I think it's more that the weather year on, year after year when you get these long, dry springs. That's what's worrying them. And this is *W. ilvensis*, because we've not planted any *W. alpina* at all.

For *W. alpina*, about I think it was five months after we gave him the spores, and that is incredibly quick. Artificial day length was again the reason. We were looking at a population of *W. ilvensis* near another lot of *W. alpina* and there were plants. We knew the plants personally. One clump was very soggy. The water had been running right down over the top of it. Some old fronds very wet hanging down, and when we took them, you could see that they'd had spores. Andy took them back, dried it off, got some spores. Just a little private experiment that Andy did. It was very interesting when we went back next year. The plant that we thought was dead because it was so wet and water running over it was alive. The water changed its direction a little bit and was no longer running over it, coming down the cliff and the plant had come up again. It wasn't dead at all. It's interesting so Alpena will come and go a lot more and we found that if you go to a site, you think it's not there, you come back another time and it is there. If you look at the numbers for when we were monitoring the numbers, go up and down. The reason is sometimes somebody different monitoring couldn't find them. Or it might be that you could not see the plant because it had just dropped its fronds. It may have finished growing for the season. So just because you don't find something one year you perhaps don't need to worry too much because it might be there another time. After a year, if it's been there for 10 years. If it disappears for five years, you know that it is dead.

Are there particular practices to do in the recipient site management for successful establishment?

-Grazing. You see, we come back to grazing and I have seen them munched off, and they do get eaten. Well, it's not so much eaten. I think the animal bites it, doesn't like it and drops it

again. But of course, if you get enough animals doing that, it doesn't really help. They are just nipped off and dropped. Sometimes you just find them dried up and you can see where they've been eaten off. Very, very rarely does anything eat them. I once went up a hillside and I ate bits of all the different fronds that I found. Just chewed it up for a bit and spat it out to see what they tasted like. Some ferns are dreadful. *Dryopteris* is not bad. I can eat that but not very nicec. Which is good. Putting a fence around the sites might be better to begin with. But you might get a bush that grows that never got to grow before, and then that starts to shade. And if you get too much shading, they don't like it. Here's me talking about grazing again. I'm always going on about grazing. You don't want too much. You don't want too little. Certainly, the sort of site management we did. We were fussing around a bit rearranging the rocks to try and make it harder for sheep to get their face down into where the plant was. So, it was growing in a very narrow bit of rocks. Things like that rabbits or birds building nest around is also possible but that is not something you can do much about really.

We also discussed whether we should feed them to encourage them to grow bigger and get their roots down more. We did a little bit to begin with, but it's a very difficult. It is supposed to grow by itself.

Also, the criteria change. It is endangered one minute and then it's not. I know when we planted so many, and somebody wanted to change the status of W. ilvensis because they said there were a lot more plants. There are only the plants that we've planted. They're not wild.

Melampyrum sylvaticum

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-It grows in woodlands, and it needs a very high humidity. So, it usually grows near a waterfall where you would have that spray of water. Very humid atmosphere. But, if you cut down all the trees, it disappears. This is a strange one because it is an annual and has a big seed that is distributed by ants. On the seed there's a little oil body that the ants want. They take the seed to get the oil and the seed kind of gets planted by the ants. The seed germinates over winter. It's also hemiparasitic because it produces this haustorium, a root-like thing that grows into the root of a host plant. It must have a host. If it doesn't have a host plant, it can't grow at all. So, it is an unusual requirement. I haven't seen very many populations. It doesn't tend to be a very big part of the vegetation.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-You would need the ants. It will have any host plant. It's very unfussy. We've used vetches and *Sorbus aucuparia.*

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-Somebody did a project in the Cairngorms area of Scotland, and this was one of the species. He was very keen to re-introduce it, but he just couldn't find a suitable site at all. It's very hard to find appropriate sites. Just because the landscape has been so much changed.

What sort of benefits of translocation can you predict for the recipient site?

-It will add to the biodiversity. Any increase in species diversity will have effects that carry over to other species. They will be more flower shapes for pollinators and that has other benefits for predators and associated species. As it is hemiparisitic, it will slightly stunt the species it grows on, and this always has a beneficial effect in encouraging species diversity as vigour is reduced in the common host plants.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-There's almost no invasive potential. With such a specialised habitat and life cycle it is difficult to get it to establish at all.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-An awful lot of techniques for this one. Very complicated. You would establish this one from seeds and they would need to go out in the autumn. Because they have to start to grow over winter. And they have to find their host plant. They do need the host plant and in cultivation trees were easier to use than other herbaceous plants. But in the wild they will most likely be growing on herbaceous plants or small shrubs like *Vaccinium myrtillis*.

Are there particular practices to do in the recipient site management for successful establishment?

-I've never seen it being eaten or grazed. You would need the humidity, the woodland shade and the ants and quite a lot of sites have just been lost. A student doing her PhD looked at the

genetic variation and she collected lots of seeds from different sites. Originally, there was to have been re-introductions to old sites in Scotland, but we found it very hard to find old sites that are suitable. It was just decided that you couldn't go to these sites because they would not have been any good. It would have been a waste. The idea was to have a new site. A completely new site within the native range where it just doesn't seem to be growing at all. But again, you see it's a very specific requirement. Not the easiest thing to grow, and that's often what makes these things difficult to work with. And that's why it's probably declining in the first place anyway, really.

Salix lanata, Salix lapponum and Salix myrsinites

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-These willows are alpine species that like a winter snow cover. They are dioecious, separate male and female plants. We centred what we did around *S. lanata*. I'm thinking also about other willows that grow at these higher altitudes and they also lack winter snow cover. They need the snow, although they are hardy plants, quite tough plants. But if there's anything out of the snow, animals come along and eat the twigs. And I've seen plants where there must have been the twigs sticking up above the snow, and they'll be just cut off as if they've been trimmed off. If it is the mountain hares that eat it, then they have a nice neat little nibble, so you know that they've been eating it. If it's been deer, they pull it and tug it, and it's all sort of draggled and untidy. Montane Willows are very susceptible to grazing, especially towards the end of the winter when there's not enough to eat and willow twigs taste good. It means a lot of the willows have had to grow up on steep little ledges, rocky places where the animals can't get to them, and people tend to think that these willows like to grow up on the cliffs. In fact, they'd be much happier down on the ground. It's just that they've been pushed out of those spaces. There was a thorough research for the willow project. Some students had looked at the DNA and other people looked at pollinators. There've been different PhD students working on all sorts of different things. When you look at the map on what we call the 10 kilometre square basis, a smallish map of Scotland, for example, you'll get one dot if there's any willow in that 10 kilometre square. But that dot doesn't tell you if there's three populations or one population. And for S. lanata, there are, if I'm right in remembering, only about 13 populations in Scotland. Only about 3 populations are considered big enough with more than 100 plants, which we felt is a self-sustaining population. Many populations are probably a lot smaller than they used to be and some of these populations are one plant. If you have a female all by herself in the middle of nowhere, there aren't going to be seeds. *S. lanata* was also selected for addition funding under the Species Action Framework initiative which funded our reintroduction work.

S. lanata likes to have soil or rocks that have some lime. Calcium carbonate. And that is quite unusual in Scotland because most of our rocks are quite acid. So, there are not all that many habitats in the first place that are suitable for it. There are other interesting species there as well, and so we were restricted. It grows at 800 or so metres altitude. And also, it tends to

grow on a north facing aspect or northeast because that's where the snow blows in, and that's where it lies longest. A lot of these alpines depend on snow cover. When the snows cover them, if you do have a milder spell, and not enough to melt the snow, it stops them from starting to grow too soon, because if they start to grow too quickly, and then it goes cold again, the new growth just gets killed and that could be very damaging. What you need is snow from about October right through till the end of May. That's ideal, and that's what a lot of these sites used to get.

S. myrsinites is more widespread I would say, but they're very small populations in my observation, so when people record a species, it is useful to have an indication of the numbers present . Some plants get so rare you start talking about how many individuals they are and that makes it a bit clearer. Although if you've got an expanse of willow spread out sideways it's not always easy to tell whether you're looking at one big bush or three.

S. myrsinites in my experience grows on ledges. Does it want to grow on ledges? Probably not. It's the only safe place to grow. All the alpines are potentially threatened. (Although some alpines in the far north of Scotland will grow at sea level where it's so windy that plants that you would get up in the hills in the middle of Scotland come right down to sea level. It's colder further north and windier and it's the wind that gives exposure). There may have been a more significant decline of myrsinites lately that could have given it a higher threat level. That sounds quite likely. The other snag here is if you're comparing older recording and more recent recording, it might just be that people haven't recorded it, and it doesn't mean to say it's not there. That's another problem as well. People are not as good at identifying willows as they might be. Recording can be a quite an issue. Some uncommon things, if you look at an Atlas for the distribution, you're seeing the distribution of the people that record them as much as the distribution of the species. So, there's a whole lot of factors coming in here. But certainly, if something appears to have had a big decline, that will give it an elevated status. The other thing that might confuse the conservation status is that we have a UK-wide red data list, but we really should have a Scottish one because there's some species that are special to us, but you get a lot in the north of England, so that means it's not very important and it works the other way around. We want to look after the species that are special to us. We are less interested if there's some in the north of England, we want to conserve our species. I've only seen S. myrsinites quite high up, just when we were walking past on the way to and from other sites. It was east facing I'm sure a lot of these species should have been down on the valley floor instead of which they were just up on the side of the cliffs. And I think probably they would grow at lower altitude quite easily if they were not being eaten. The same applies to *S. lapponum*. These alpine willows will have adaptations that allow them to survive at high altitudes when they have long since suffered from too much competition at the lowest altitudes.

Willows root easily from cuttings. I'm quite sure that they will do what's called layering. If a part of the branches touches the ground, it's going to send out roots. It's a technique that we've used quite a lot with plants, especially if they don't have any seed like *Sorbus*. I would guess many hundreds of years' old individuals, who knows, had long branches growing along, leaning on the ground. It could root into the ground and just keep growing, and

growing, and dying off behind itself. So, what you're looking at is something that's been growing continuously. With too much grazing the flowers or seeds would get eaten, but the willows can spread vegetatively. Slowly, just by the branches lying literally in the moss, on the ground and sprawling out sideways. It doesn't grow up like a tree in this case, it's just a sort of sideways spreading. And of course, we've always been looking for seedlings, and as far as I know, they've not found any seedlings yet.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-I think most of the species that grow with S. lanata obviously are little low herbaceous ones. I don't think they need actual companion plants. I think you'll find references to pollinators and there should be a description of the other plant present. The appropriate plants are probably already growing in the selected sites. It's just the willows that have been grazed out

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-You've got to go into the right habitat and of course, because you must have some lime in the soil. There were some planted some on a nature reserve where it wasn't the right sort of soil, and they just didn't do very well at all. And although the wild plants are OK, if there is a shortage of snow cover year after year, the plants suffer. All Alpine plants are similarly affected. It's just not good for them. When you have snow higher up, it melts and releases water slowly. So even if you have a dry spring, it doesn't matter because you've got the meltwater seeping down. It can keep the plants warm in the winter, although that doesn't matter much for willows because they're quite tough. But it keeps the grazing animals off. Snow is such a good thing, and we're just not getting enough of it.

There's a very steep planting site near Glen Feshie. There was also the one in Corrie Sharroch which had a fence round it. The trouble with Corrie Sharroch is that if you have very deep snow building up, the deer just walk in over the top of the fence. And then they stay there when the snows melts. Or sheep also. It was demolished by a little avalanche once. So actually, the fence isn't there all the time. There are other potential sites that belong to National Trust for Scotland. We have had people that are rewilding areas and planting lots of different common species. Some of them would be very keen to add *S. lanata* in. But again, you've got the same circular argument that if it's not native in that area, you shouldn't be planting it. There're also not very many places you can plant because *S. lanata* it needs some lime in the rocks. And also, often the area is quite special for other alpines because lots of

species like lime. There is a limit to what you can plant, like we were only allowed to plant something like 10% of the chosen site in Corrie Sharroch because it had other interesting species.

What sort of benefits of translocation can you predict for the recipient site?

-In fact, *S. lanata* is a quite popular species. People like to see it. It's a pretty thing in the spring it's got great big yellow catkins, if it's a male plant. It's the sort of thing when people go up into the hills to look at plants, they like to see it. This is in terms of tourism. We had a local member of Parliament. He came up the hill with us to see what we were doing. Though you don't want lots of people doing is going up on the ledges, trampling, where the original plants are. They can cause damage with trampling, but there is always the argument for planting things where people can see them. It's a good garden plant too.

Willows are part of the biodiversity and would attract invertebrates. They provide different shapes of bushes with different kinds of habitat and cover available. By the time you're talking about having a small wood with lots of small bushes and trees, that's certainly enhancing the nesting opportunities. If the whole area has the grazing reduced, it's amazing how many other species come up and get to flower, too. It's quite wonderful and it makes you realise how you just don't see it.

I think willows must be quite significant in this respect. I don't know how many invertebrates, moths etc. They might be specific species. The habitat has become very fragmented. Very, very small populations. So, it's good if you can have more continuous areas. Because once you get this fragmentation, if you have tiny populations, they're very vulnerable. For all the different species living in there, if the population is too small and it's too far to the next population if anything happens, landslides or a series of exceptional dry years, some species will probably not recolonise. So, you want a decent sized population. I think there are benefits with willow definitely, and it is something a lot of things eat, which is part of its problem for being grazed. But it's good if there are all different things munching away. Don't mind small things eating it.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-I'm pretty sure it wouldn't invade. We'd be quite pleased if it did invade. But, In Corrie Sharroch, there was competition risk with the other lime-loving flora which is very special in terms of the type of vegetation growing down the hill, I was told. I believe there was Nardus stricta with Saxifraga oppositifolia and other species giving an uncommon association in Scotland. It was a bit unusual to see the Nardus and S oppositifolia growing together because usually N. stricta is in areas where it's more acid and the other species liked alkaline soils. It was very unusual, and it was a very special habitat. So, somebody from Nature Scot came to approve because we were planting into protected areas. He said that only the 10% of that area

could be planted. Although it's a huge area and what we planted was a tiny bit of it. So, we don't want to go and plant right on top of something really uncommon.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-We did collect some cuttings, but mostly we did it from seed, which is by far the better way to do it. Cuttings would be easier because you just stick them straight in and they root very fast. Seed is ideal because of the genetic variation. The seed is green and because it's a green seed, it's only ripe for a very short period. So, if you go to collect the seed too soon, you'll find it still white, and you can't collect it then because it's not ripe. Because it's up in the hills, we had to make special arrangements to get there and to drive up private roads. We would go all the way there and find the seed was not ripe so we couldn't collect. If you came back two weeks later, the seed might have ripened up, and it's all gone. So, this was when got help from a local teacher to collect seeds for us in his spare time. Ideally, we felt we should be introducing plants from at least 30 individuals. It was all very carefully labelled. We had to know exactly where the plants came from and exactly which parents. We didn't want to mix up populations. We wanted to put plants back either in the nearest place to the population or to create a deliberate mix in in some cases.

Willow seeds are fluffy. They've got a little ring of hairs round the seeds and another ring of hairs as a parachute. When you plant the seed, you put it on the surface of the compost because it's green and it's photosynthetic. It's going to grow almost instantly, but you don't want the fluffy bit since it can go mouldy. You can have all sorts of problems. Natasha from the horticultural team came up with a solution and now we know how to remove the fluff. This is very labour intensive because first of all the seed has to lose its fluff. Then the seedlings have to be pricked out individually into root trainers. Then they were grown on for about 18 months. You can't plant them out at the end of the first summer because they're too small, so you grow them on until the next summer, and then they're ready to plant. We grew three species so that we were planting a community. We selected sites to plant and had them approved. The week before planting we stuck flags in the approved sites where we wanted each species to go, and each colour of flag corresponded to a different species. The planting volunteers were meant to put six plants round each flag, but they weren't to put them in a circle, just to plant within two metres of the flag. That way we could plan where the plants were growing approximately. We knew exactly which parent they'd come from. We had three groups of people planting on different altitudinal levels. I had people who were planting at the lowest level, and it was mostly S. myrsinifolia and S. lapponum. Other people were planting S. lanata and the other two species a little bit higher up among some big boulders, big rocks. And then other people went really high up and they planted just S. lanata and S. lapponum. All the planting sites were very carefully planned. This involved planting in September. It is good because it's still warm enough for the plants roots to grow a little bit. It's going to be wet because it usually rains about that time of the year. In either case, whether you collect the cuttings or seeds, they're taken to the nursery. The advantage of the nursery is that there's a lot of staff there and that takes care of watering and the care that the plants need for at least 18 months.

A student was doing work on observing bees pollinating. And obviously if you have male and female plants they mustn't be too far apart. That was a problem in one of the sites because you had 30 plants scattered across a huge area. It was too far for a bee to be likely to fly from one plant to another to pollinate. So, we found that even though there were male and female plants, the females never had any seed. In that particular site, which was near Glen Feshie, it was decided to put in extra willows and as there was only S lanata growing at that site we only planted the one species there , but using seed-grown plants from other sites, for more genetic diversity. The other planting that we did in Corrie Sharroch was to put in two other species of willow. One of them was S. lapponum. The other was S. myrsinifolia (not S. myrsinites), a fairly common willow, but it's one that goes from lower altitudes, right up to higher altitudes. And we thought by planting other willows, it's possible that if there was grazing damage, the grazers might eat the other willows or be distracted by them. So, there's less chance or risk of them eating the special ones. To some extent, there is a risk of hybridisation but that's what you get in a natural population. Another problem can be collecting cuttings of naturally occurring hybrids this but can be overcome by good record-keeping and not collecting much for any bush. We kept very, very careful records, of the parent bush we collected from. We didn't collect much seed from any bush because you want to collect a little bit of seed from lots of bushes. We knew exactly which parent plant we had collected from. Willows are quite notorious for hybridising, but another study found that there were not as many were hybrids as people thought, and that the wild plants had a bigger range of variation than people realised.

We also had to make sure the plants to go out for planting didn't have weeds because you don't want to introduce any nursery weeds. There are some horrible persistent weeds. Also, we took off dead leaves and checked under theliving leaves because willows get quite a lot of diseases and they get rust, the little fungus. They planted *Juniper* cuttings in England once. And they've introduced *Phytophtora,* and it's killed off the original plants. You can do things like that by mistake, which is terrible. That would be just so awful that it would put you off reintroductions for the rest of your life, I should think.

Are there particular practices to do in the recipient site management for successful establishment?

-Changing climate. Too much grazing. It's the same story, the same things.

It's no use putting plants where they're just going to be grazed. They were very, very good at controlling their deer in Glen Feshie so that was a good site;

There had been some S. lanata work by somebody else at the Botanic Garden. He'd gone to one site where there was just a single plant and he'd planted out a lot of other plants that were

from nearby sites. Sort of nearby, but none of them were very near. I think the plants were grown from cuttings. And he planted them out on the ledges around this single plant. We found the original single plant even smaller than it was when he used to see it. There were about 30 of the little plants that were planted around it. They were mostly surviving, but they were very small and grazed. The ledges were too accessible. We could walk onto them and if we could walk onto them, so could the sheep and the deer. Other single plants are growing on cliffs and there's nowhere else to plant extra plants. We ended up selecting three areas that we did plant into. One of them that we spent a lot of our time on was actually the second biggest montane Willow population in Scotland, Corrie Sharroch. We thought it was better to supplement it and have a really good sized population. That area had been fenced for quite a while. In this area, the willows are all up on the cliffs and we were going to plant down on the flatter ground. But there was no regeneration at all, because as soon as you put a fence, all the grass and other vegetation grows up and even if the willow seed falls near the ground, they aren't even able to touch the ground because of all the long vegetation, too much for the seeds to get through. Really, no bare soil of any sort. So that was why we planted Corrie Sharroch. We also planted a third site once the deer had theoretically been reduced. That site only had S lanata. Monitoring continues except the site near Glen Feshie had been accessed and planted using ropes and is hard to revisit.

Sorbus spp.

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-I'm treating the three *Sorbus* species as the same thing because they do grow pretty much together, and they're mixed up with common *Sorbus aucuparia*. The thing is they are derived from hybridisation between the apomictic *Sorbus rupicola* and *the sexual S. aucuparia.* This is continued to some extent in the hybridisation that followed to that the hybrids become species, or micro-species that can exactly reproduce. At one time in the past, on the island of Arran, there have been the two parents. But now there's only the one parent (*S. aucuparia*) and there's none left of *S. rupicola*, which was the other parent. *S. rupicola* is not very common anywhere in Scotland either. The trouble with these *Sorbus* on Arran is that they are not spreading much. You hardly ever see a young tree at all, or a young plant. There is too much grazing which is the same problem everywhere in Scotland or nearly everywhere.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-No need for companion taxa? I don't think so. They grow on rocky moorland with *Calluna vulgaris* and other ordinary species

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-I have to say Arran *Sorbus* has been planted quite a lot on the mainland of Scotland, not on the island. Only in small groups. We've given people a set of the plants, the two parents and the three hybrid species. They are obviously not in big populations. What you need to do is to conserve the habitat rather than try to start new sites elsewhere. That is a much bigger problem than just going planting trees. People think, oh well, we'll just plant some more, but that's never the solution. You need to plant them somewhere where they would be safe, but you do have to look at the whole habitat. What we find is that the plants that we are trying to conserve are the first ones to go if anything gets eaten. You might think if they were mixed up with other things then only some would get eaten and some of the other plants would get eaten. But usually for the plants that we are interested in, they seem to taste better. They're the ones that get eaten more, and this is the whole problem. You'll see a field of orchids and all the rare ones get eaten first, but that tells you something you see. That's probably why it's having more problems than the other commoner species. At the headquarters of Nature Scot in Inverness. They planted a group of Arran *Sorbus* one day. We were going to have a sort of grand opening the next day. And overnight some deer came and ate the rarest one. It's very interesting. They just chose that one and not the others. But, if you were going to do some translocations, you would just go for similar sites to where the *Sorbus* grew in the first place. The thing is, they come from an apomictic parent. And theoretically, the same crossing could

happen again. You could get the same combinations happening. The conditions that gave rise to them appearing in the first place are no longer there. What we're doing is just perpetuating the clones as they arose hundreds of years ago, probably. I have to say I'm a wee bit cynical about a lot of conservation things because there's so much effort gone into them. At the end of the day, you often think what have the conservation efforts actually achieved. Bringing back the dynamic system that gave rise to all this hybridisation and the microspecies in the first place rather than trying to conserve would be an interesting project. I think it would be better again to be restoring the whole habitat.

What sort of benefits of translocation can you predict for the recipient site?

-No benefits for the site? The presence of more species would enhance the biodiversity, introducing a shrub layer which offers more variety, more nesting sites, more flowers for invertebrates and invertebrates for nesting birds and so on up the food chain.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-I'm quite sure that it won't be invasive.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-With the seeds, we did find problems in germination. It was very, very slow and seven years later, I do know they were still germinating That's kind of difficult for a project. If you want to get a decent number of plants you don't want to wait too long. Also, one of the species the rarest one, (*S. pseudomeinichii*?? Yes) has only about two individuals in the wild. There were two, one got lost, but now I think another one has been found, so we're back to two again. There's a good big tree of it. One single, solitary tree. The first time we collected seeds, we found that the seeds had got little holes going into the middle, and there was something eating away in there (biodiversity!) The seeds were collected again on another occasion, and they found the same thing. So, that's another interesting thing that you need to consider if it is getting eaten by some sort of invertebrate. If you take lots and lots of cuttings you will get a limited number of plants and like 20 cuttings will give you one plant. It was about that sort of ratio when somebody in the nursery was experimenting. If you take 200 you get 10 or so. Is that right? We did a lot of grafting too, but the trouble with grafting is that they'll be growing on the roots of the common *Sorbus*. It could look very similar to the parent plant and I can imagine the thing growing away from its roots and nobody noticing. So, grafted material is of no use for re-introductions. Plants grown from cuttings are all that we've we really wanted to use for *S. pseudomeinichii*. We did have success in laying the grafted trees on their side and persuading the grafted twigs to root. This gave more plants of all three species on their own roots. Growing it has been a massive exercise actually. I don't think they have done any big

planting in the wild. But, we've got the techniques now and that was a lot of what our work was about. The time of year would just be the autumn, which is always because there will be rain over winter and that helps the plants to establish.

Are there particular practices to do in the recipient site management for successful establishment?

-Just controlling the grazing, isn't it? You'd think on an island like Arran, the grazing would be better controlled. People like shooting deer and you'd think that would keep the numbers down. But they need to have a lot to choose from for shooting so there is a good chance of finding them. You just have far too many deer.

Fencing is a solution but the trouble with when they put fences around some of the populations was that it just got so dense. Mostly all you had were the trees and mosses underneath, and you still weren't getting any new young trees. I know the problem really is that you've got so much grazing. You've got a limited species diversity, which is not very good in itself. It's not what you would reintroduce. It all comes back to grazing. Whatever you talk about, it's overgrazing. You would either have to have predators or you would just have to have very heavy culling of the deer. In the areas like Abernethy, they have been very carefully controlling the deer. In another estate called Glen Feshie they have also culled a lot of the deer. And when you go there, you see lots of young trees of fairly common species. But in most parts of Scotland you just do not see a lot of seedlings. You tend to see old woody plants. Introducing predators can be done but it's quite labour intensive and has many implications. It's not very popular with farmers or the public are worried about, you know wolves eating their sheep and children. It's quite controversial. We're very far from being a natural country. We're not a very big area and a lot of people go walking. So, it's no use pretending that we're restoring something that is actually very natural, because what is natural? I think we've come a long, long way from anything that we might imagine the country was like, say, 5000 years ago. I don't know if you can go back because there's been so many changes. I think you just have to decide what you want to do now and how you're going to do it, which species you prioritise. I think plants don't figure very highly on people's priorities. I remember when they were culling the deer, killing them, shooting them in one of the areas that we wanted to plant willows, and somebody phoned up and was really angry with me on the phone. I wasn't even really connected with it, but I knew it was happening and he said they were shooting all these lovely deer 'just because they eat a few plants' as he put it. There's a lot of public perception to be got round. People will think that invasive aliens look really pretty, and what a shame that they're taking them out. At one time in the past, on Arran, there have been the two *Sorbus* parents. But now there's only the one parent (*S. aucuparia*) and there's none left of *S. rupicola*, which was the other parent. It's not very common anywhere in Scotland either.

Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

-Where do you stop? Animal translocations attract big funding, plants much less so.

Appendix 2.3 – Michael Scott

Arabis alpina

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-I should make clear that it's a species I have never actually seen in Scotland, although as Peter Marren records in his book, *Chasing the Ghost*, we did try to find it together, but I do know it from both the Arctic and the Alps – and we grow it successfully in our garden. So I have gone looking for it, and got very close to its best-known site, so I am very aware of its habitat. And I've talked to people who have seen it, in the context of writing my book about mountain flowers in the UK.

I have a section about *Arabis alpina* in my book, and I have seen it in my travels and it just confuses me in Scotland completely. I've seen it in in the Alps, in Norway as well. In glacial moraines just below active glaciers are its typical kind of habitat in both the Arctic and in the Alps. It also seems to be very freely seeding into any disturbed ground in Arctic Sweden around ski developments. Wherever there's building work going on, that creates a moraine-like, gravelly habitat it seems to establish and grow quite happily. In the airport at Kirkenes in the far north of Norway, where you just walk from the plane to the terminal, I noticed that the gravelly area by the runway was just completely covered in *A. alpina*. And the other places like Nuuk, the capital of Greenland, I have seen masses of *A. Alpina* in very disturbed ground disturbed by people walking over it. Clearly, they were able to cope with some extent, at least with being trampled on. The other most amazing place where I found it, which I really didn't expect all was in a mountain on the island of Madeira.

It seems like a very adaptable plant yet none of that seems kind of consistent with what we see in Scotland. It's found in just three sites, very high up in the Cuillin Hills. Around 800 meters is a pretty good estimate for its altitude. The other two sites in the UK, shown in the *BSBI Atlas*, are introduced sites. The only place where it is presumed to be native is those sites on the Isle of Skye, all within one quite small area, I think probably within the same five kilometre square, probably South-facing aspects if I remember rightly. They're very, very difficult place to get to, on remote rock ledges – the sort of place that you could imagine in very severe weather, very heavy wind.

Very strong winds bring driving rain on Skye, and I wonder if these are the sorts of places where deer might find their way into that gulley to get a bit of shelter from the worst of the weather. And they would be having a nibble. I'm sure there is some grazing pressure, but it doesn't look like it's that extreme. I suspect a lot of the input of water is from cloud rather than from rain, so the plants are sort of bathed in cloud and can extract water from that because other people have described it as being in a very dry site. When they go and look at it, and it looks dry. That is kind of consistent with glacial moraines because they tend to be

very rapidly draining. So, they probably are in areas that get a reasonable amount of rainfall, but the water drains away fairly quickly. The plant probably has to be pretty good at taking in water when it's available and coping with dry conditions. When that water is drained away, perhaps those shady ledges remain just a little damper.

And it apparently isn't seeding to other places, and I do not understand why it's not commoner than it is because there are a lot of apparently suitable ledges around in the Cuillin hills where it's not being recorded it. It's a very localised area where it's found. They must be survivors from immediately after the last Ice Age. As plants decline after the ice age, there's always going to be a stage where there's only one site left. Chance events have eliminated plants from the other sites. You know, a rockfall can be enough to eliminate it from site A. A Hungry red deer finding it can be enough to eliminate it from site B. Then you've only got site C left. It's just sheer luck. There's one side left for it and the other sites of all gone, but it doesn't quite make sense to me with A. alpina. It seems to be fairly free seeding in our garden. It seems to regenerate quite well from seed. It seems to be good at moving into the open disturbed ground. But, I don't understand why it's not producing enough seed in the Cuillin Hills. Plants are however, successful in cultivation, showing vigorous growth and abundant flowering and seed set. So in our garden, we have plants growing from seed from the Scottish Rock Garden Club. It seeds itself quite freely around the garden and turns up in other parts in the garden. And we're about 20 meters above sea level on the northwest coast of Scotland. It seems to be almost invasive in our garden, although, admittedly, that relies on us having open ground for it to move into .

Actually, when I have visited its habitat, I was fascinated that we couldn't see any deer there. We couldn't spot any sheep there on the hillside either. I'd always thought that they were part the problem. Maybe the plant was seeding freely onto gravel scree slopes, but the deer and the sheep may be finding it and munching away very quickly. Grazing is a regular issue in many other mountain areas, but I'm still not sure if they are making a very major contribution to the restriction in the range of the species, from what I've seen.

From the public perception point of view, crucifers are not the most appealing of species either. But the estimated Skye population of 83 plants aren't enough to sustain a population. We need to value it more, as possibly one of the most arctic-montane species and a specialist associated with glaciers – a Scottish survivor with links to the Arctic and the Alps. There is something rather special about it, rather evocative about having it in Scotland.

Its main site has recently become rather more accessible. The approach into the corrie where it grows passed a tourist attraction called the Fairy Pools. About five years ago, the Forestry Commission established a new footpath to the waterfalls there. This attracted lots more visitors and the nearby road got completely blocked off by parked cars in them. Emergency vehicles couldn't get through if there was an emergency, so they have now built a 100-car car park and further improved the path. So, it's much easier now to get there because there is this big car park. The vast majority of people that visit there don't go beyond the waterfalls and

you need to go well beyond the waterfalls to get into the area where the plant is. But it's much easier now to get there, much safer apart from anything else, to get there so it's more feasible to do work there than it was a few years ago. Having it in those hills in Skye and its sites happening to be near the tourist attraction of the Fairy Pools. I mean, that's just kind of amazing in itself.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-I have no particular information on the associated species. Not that I've heard of. The only one I can mention is *Arabis petraea*. It has roughly similar habitat preference, so it grows in similar places and is always recorded as growing near the *Arabis* in the Cuillins.. I don't think I've ever seen any insects associated with it. Also, they're probably mostly self-pollinated.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-The first stage would be just to try and understand its existing locations in the Cuillin Hills a little better. Still, I can’t see any harm in scattering some seeds at the same time and speeding up the process by doing two different things at once. There are very few people that have visited the site. Recently, a new population was found by a botanist called Lynn Youngs, not far from the existing sites, but in a cave high on Sgurr a Ghreadaidh, which is one of the most difficult mountains to climb – and, if it’s there, perhaps there are other sites to discover too. There were 20+ plants and they were either in full flower or almost flowering and it looked like a very healthy population.

What sort of benefits of translocation can you predict for the recipient site?

-I can't imagine there's any kind of insect species or anything like that that relies on it, because it's such a small population that. Any reliant insect would have died out by now.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-It actually looks like a weedy species. That's the strange thing about it. Here we allow it to become established. In our garden, we have to weed it out in some areas, because it is sort of taking over the garden completely. But this is unlikely to happen in the wild.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-You have to get seeds first of all, I guess, from the Scottish plants. Catriona Murray, a previous botanical recorder for Skye, actually had it growing in her garden from Scottish seeds. She's long since dead and had no idea what happened with her garden. But it would be worth checking that if it is available as a local seed source. Certainly, you would need to bulk it up, presumably in the RBGE or whatever. Scatter a few seeds on a few suitable looking ledges and monitor what happens. At the moment, with our state of knowledge, that might be more successful than transplanting seedlings. If you're scattering 100 seeds, there's a chance that one of them will land up in a suitable habitat, whereas if you're planting 10 plants, you would struggle to know what the right places to plant them, but it will be a learning process. The appropriate site would be sort of trial and error thing.

What I would really like is for a good ecologist, like Dr Aline Finger, to go, find the existing sites and work out what is special about the places where it is managed to hang on. Because we are talking about it being on inaccessible damp ledges. It might be a particular altitude that doesn't get too cold in winter, doesn't get too frozen in winter, but that is frequently bathed in cloud and summer. Are there any different outcropping rocks nearby? What's the pH on those ledges?

For transplanting, late spring-early summer would be the time to do to give them as long as possible in summer to get established because I would assume that the winter is a significant crunch point for the survival of the plant. It is very typical for the high peaks of the Cuillin Hills to be in cloud. When we were last there, I think it was in July. It was still sunny there, but you could just see the cloud hanging over and so I think that is what will do the watering of the plant. And yes, the summers are changing. We're here in the Northwest Highlands. We are really grateful. It's actually raining today, because it's the first time it's rained in three weeks. Stick to the Cuillin Hills, but don't stick to one peak. Given how little we know about its ecological requirements, I think it makes sense to concentrate our efforts, at least initially, on places where every reason to believe the ecological conditions are broadly similar. Still, I don't think, there's anywhere quite like the Cuillins elsewhere. Other hills in the northwest of Scotland might be worth trying in the future, once we know more about the species' requirements, but I think sticking to the Black Cuillins is better for now. There will be other places in the Black Cuillins that would be possible, not just the one corrie. But then it would be down to the logistics.

I guess maybe a bit slightly overhung, but to be honest, we know so little about it. I wouldn't see any harm in just trying to spread the seeds or plant out seedlings on other inaccessible ledges in the area where it grows.

Are there particular practices to do in the recipient site management for successful establishment?

-Choosing a site for good monitoring. You would have to have the capacity to go back and check regularly whether the seeds were germinating or the seedlings were surviving. It's not an insignificant commitment of time and energy for somebody to do that. It would be a major, you know, that would be a kind of a PhD project in itself. There would need to be a guaranteed capacity to follow up for a good length of time after you do any work like that to make sure that it is succeeding. That then becomes incredibly important for the future conservation of the plant.

In summary, I think I'm suggesting that the main purpose for translocations of *Arabis alpina* plants or scattering of seeds on suitable rock ledges would be more about getting a greater understanding of the ecological requirements of the species rather than it actually being about reinforcing the existing, extremely limited population in the first stages (although hopefully it would do both). If we were able to get plants established in some trial sites, then I think the second stage would be to draw up a plan specifically aimed at improving the conservation status of the species through carefully sited translocations, but the first stage has to be a better understanding of its specific ecological requirements

Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

-None that I can think of.

Appendix 2.4 – Alex Twyford

Euphrasia spp.

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-Before considering habitat, it's worth stating that *Euphrasia* are extremely taxonomically complex, and this has implications for translocations. The species are finely taxonomically divided and hard to tell apart, and some are unlikely to prove 'real' when investigated with genetics. They hybridise extensively making the sourcing of 'pure' seeds very difficult. They are mixed mating or selfing, and this means many species have low genetic diversity and there is strong geographic population genetic structure, meaning it may be unwise to mix different populations.

In terms of your specific question, *Euphrasia* are found in a wide variety of habitats, from coasts to mountains. *E. frigida* is very much associated with damp or wet, basic cliff edges at high elevation, typically 400+ meters. Further north in Shetland they grow at slightly lower elevation (200+ meters).

E. marshalii is a UK endemic. It is found on the North Coast of Scotland and the isles of Lewis, Skye, Orkney and Shetland. It grows at low elevation, up to 60 meters, in coastal environments, on rocky cliffs. It is often associated with *Calluna vulgaris* and *Plantago maritima*.

E. montana predominantly grows in hay meadows and is a species that likes moist but sunny conditions. In the South of England it typically grows at up to 50 meter elevation, though it is reported at up to 430 meters elevation. It's widespread in England and Wales, but rare and predominantly southwestern in Scotland.

E. rotundifolia is exceptionally rare. It's endemic to Scotland, and it's found only in a few sites in Sutherland, Caithness and Shetlands. Its taxonomic status is doubtful and it may well prove to be a local variety of hybrid.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-Critical for all these species is the collection of associated taxa that may act as hosts. *Euphrasia* are hemiparasites that are green and photosynthesise, but derive some nutrients from a plant host. Translocations should aim to match local hosts where possible. In general legumes are the best hosts, though *Plantago* and many herbs are also good, too.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-In general I would say that translocating *Euphrasia* is rather premature, and more research on the nature of species differences would be an important first step to identify discrete taxa, and only then should translocations be attempted. However, if this was attempted, I would aim to match habitats with the source site, bearing in mind many *Euphrasia* species are extremely specialised in their ecological preferences.

What sort of benefits of translocation can you predict for the recipient site?

-As hemiparasites they can act as ecosystem engineers, reducing the vigour of dominant vegetation such as many grasses, and encouraging the growth of small herbaceous plants that would otherwise be outcompeted. This may subsequently have indirect impacts on the local community, such as fostering conditions for pollinators.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-*Euphrasia* tend not to be so competitive so they’re unlikely to cause major damage to natural systems. I think the only issue to be aware of is that species barriers are highly permeable and all *Euphrasia* species can inter-cross, so any translocated populations may hybridise with species present at local sites.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-We've tested all of these growth strategies with various different success rates. If you're planting seeds, they require a period of cold seed stratification over the winter before they germinate in the spring. Seeds are obviously good because they are easy to transport, easy to work with etc., but the downside is that it seed germination rates are low, and its hard or impossible to distinguish introduced seedlings from local plants.

Working with small plants germinated off-site may be more successful but comes with its own set of challenges establishing the plants with a suitable host and subsequently moving them en mass.

Either approach would require careful monitoring to ensure the plants that are introduced prove to be the species expected.

Are there particular practices to do in the recipient site management for successful establishment?

-Grazing or mowing is essential for establishment. They don't compete well with surrounding vegetation and so need to have low vegetation to enable them to establish.

For *E. frigida*, this is probably easier because it lives in high elevation environments, above 400 meters. There they could be growing above the tree line in alpine environments where there's less competition from shrubby and woody plants.

Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

Appendix 2.5 – Shaila Rao

Salix lapponum and *myrsinites*

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-They are quite similar. *S. myrsinites* probably prefers a bit more base richness and S. lapponum pretty damp or wettish at least. They're both high altitudes like mountain. Montane willow species. it's quite interesting because we are they grow now is probably a refuge habitat, so it's not necessarily the optimum habitat for them. It's where they've managed to survive outwith the reach of grazing animals. it's hard to tell any differences in terms of altitudinal preference because there's so little of them in Scotland. But in my understanding from Norway, *S. lapponum* can be a bit wider, ranging in altitude compared to *S. myrsinites*. You know it from 500-700 meters. There are a few sites lower than that in Scotland, and I know for sure in Norway and such, like it grows, it can grow at lower altitudes as well.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-I mean I'm not sure about that. I think the approach that we've taken is rather than try and transplant other companion species in with the willows is just to make sure that we're planting willows in habitat that is suitable, a site that has the associated species. If you know what I mean. We've looked at the species around the willows that are already growing in the existing populations. We've looked at the other species growing alongside. And our choice of selection of sites to translocate and plant willows into sites that are similar to those where it's already growing. We're trying to match that up. But again, as I said before and I think is often the case in Scotland with some of these rare plants is that they're very much growing in a refuge habitat here, and so it's not necessarily reflective of the optimum habitat for them. I'm always slightly cautious on basing where you put the species necessarily, entirely on where you're finding them now. I think we need to look more widely and other places where there are these plants are thriving. And to see what communities are occurring with them, like in Norway.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-In Scotland, it's better to try some new sites and there are more akin to where it's growing in Scandinavia. What we've done here in Mar Lodge is that we've tried a range of altitudes, in a range of sites, so that we would have a mixture of things. In sites very similar to the existing populations, and in fact, quite close to them. But we've also taken the step of creating some new populations. From 600m right up to 850 meters but based on habitats where you see it growing in Scandinavia, where it should be able to grow.

What sort of benefits of translocation can you predict for the recipient site?

-I think there are benefits for the populations that we've put in beside existing populations. Obviously we're hoping to create bigger populations that are going to be more genetically diverse and more capable of reproducing in the future and being self-sustaining and expanding. I guess there's wider sort of potential biodiversity benefits in terms of providing habitat for wild willows in particular as they are quite good for a number of vertebrate species. And then, in the longer term, we can create a much better tree line. We can create habitat that could even have benefits for bird species and possibly even encourage some species have been almost lost in the UK back things like blue throat. lapland, bunting etc. to recolonise. Some will undoubtedly benefit, which we already have here. These translocations of the willows are the first steps into creating the missing tree line, woodland habitat in Scotland. It is like a missing piece of our landscape, almost entirely gone.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-I think one clear risk is about taking plants that have been grown on in our nursery to introduce pathogens into the wild. We take as many steps as possible to ensure it doesn’t. That's a limited risk. There are also discussions and some concerns in putting these willows into calcareous grassland areas. People are afraid that the willows might outcompete the local flora. That could put them at risk, but I have to say I don’t necessarily agree with that. Some of the existing populations of all those are in those habitats already, and it strikes me that the two can occur together.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-Growing from seeds in the nursery is the best option. If you were to just scatter seeds like that, the survival would be really poor. The best successes from growing on the seed and actually then planting the trees out. We've been collecting seeds here and giving it to a nursery to grow them. And then we've been taking those plants and planting them out in spring. When just under two years old. We've chosen to do it in the springtime because it gives the plant a chance to have a growing season straight away. It's not just sort of sitting dormant when you put it in the ground . There is a risk that you get a dry spell the trees could suffer from drought if you plant them. But, for these particular willow species we are

choosing quite damp sites. In areas with sort of flushing or snowmelt. it's quite unlikely that they're going to get too dry for the plants over the summer. So yeah, practically, spring is just a better time to be at these altitudes, planting trees than in autumn. All within the native range at Mar Lodge, but we've also been involved in giving some of that material to Abernethy, which is on the other side of the Cairngorms. We've also taken some material from them as well. So, there's some exchange going on because they're doing similar work on their estate. They also have very small and fragile populations of both species. To enhance the genetic diversity, we're swapping material so that we have some material from their site, and they have some from ours. Aline did some genetic analysis for us across the whole Cairngorms and suggested that there has been historic gene flow between these populations, which are now very isolated. But in the past, they were probably much more closely connected. So, to reduce the risk of inbreeding and loss of fitness in these small populations, the recommendation is that we mix material between the populations and try to improve their genetic fitness.

Are there particular practices to do in the recipient site management for successful establishment?

-No. Absolutely nothing. We just plant the tree in. You don't have a grazing problem here in Mar Lodge. We have reduced the risk significantly. We're hopeful that it won't be sort of to the level would really restrict the growth of the plants. We've selected sites where we know the grazing pressure is low. We're not doing any sort of site preparation or tubing or protecting the trees. We are picking the niches where we put them quite carefully though, so trying to pick areas where they will be less vulnerable to herbivores . In Cairngorms, you usually plant them in the ground. Not necessarily rocky, where herbivores cannot access them. It could fail. Of course, there is that risk, but we've decided or taking the approach that we think the grazing pressure is low enough so we're not putting them just on ledges or out of reach of browsers. The grazing pressure here is less than one deer per square kilometre, so, we're reasonably confident that will be OK. With extensive culling, so we've reduced the deer population maybe from about 20 deer per square kilometre to less than 1 in the last 15 years. Since where you are planting limit quite high altitudes, there's no sort of dense thick ground vegetation as in lower altitudes. It's not quite as competitive. I think the plants are very much restricted due to the growth conditions and the climate. There is undoubtedly some competition, but I don't think it's anything like that you get at lower altitudes.

Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

-*Linnaea borealis.* We have, for example, 8 patches of it here. Small patches and each patch is just one single plant. Each patch has limited genetic diversity. It's one clone. And it also has limited capabilities of expansion because when these self-pollinate, the seedset is very poor. They don't reproduce successfully when self-pollinating. There's a number of people working on creating new populations of twinflower with multiple plants. To create a genetically diverse patches are able to reproduce successfully and expand. But in most cases,

it's growing in just a single. Plants are quite isolated from others, further apart than the pollinators to fly basically. So, there's quite a lot of work ongoing in the Cairngorms.

Appendix 2.6 – Aline Finger

Zostera noltei

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-It is a seagrass, an underwater flowering plant. I'm not a super expert on this species, but I think the conditions must be related to the degree of pollution in the water. Below the water, it needs to be clear enough to be visible. If the water is too muddy, for example, it can't live in there. It has all to do with pollution. That's also the reason why it's declined in the past. Because of the water quality. It descends to depths of about four meters. Definitely along the coast. I think they've found mainly in Europe, but again, you better look this up. I'm not 100% sure, mainly in Europe and along the shores. It's quite common in Atlantic. I don't know about the temperature range. They grow in much warmer, certainly further southern waters. They may be able to tolerate a bit of temperature differences, but I don't know the exact range.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-I don't think it needs another species. This one is a habitat builder which is why it's a great species for translocations, and it often occurs with the other species like *Z. marina*. But, they don't need to be together so it can be translocated by itself. It's quite happy by itself.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-There are already some translocation projects on the way. There's an organisation called Project Seagrass. They do a lot of work on seagrass restoration and they have a site along the north of Edinburgh. I think anywhere where the pollution has gone down, where you've got some protected bay areas, where is a bit protected from the currents and where they're constantly underwater, it is suitable for translocation. I mean, I think they can tolerate to be a

bit out of water in the intertidal areas, but they still need to have some sort of protection. There was a lot of pollution in the water and because of that a lot of seagrass habitats have been lost. Now, the water quality has increased and because of that there's a much higher chance that the translocations are going to be successful. So many organizations are working together to do some restoration, some seagrass restoration because the water quality has increased. If the water quality isn't good enough, then there's nothing you can do about it. I could imagine in the past everything just went into the sea. You know, from big factories or whatever, everything that all the muddy stuff, all the chemicals or whatever would just go into the sea. I think they've stopped doing that. They now have to properly treat the water before it can be released somewhere. Sometimes you walk along the coast and you have these big pipes and water is coming out of them, right into the sea. That used to pollute the water really, really, really. I suspect the regulations have changed but the water runoff from agriculture is playing a big role. Since they're putting a lot of chemicals on the fields and then it rains. The water runs off and eventually it reaches the ocean.

What sort of benefits of translocation can you predict for the recipient site?

-The benefits are that once we have restored sites a lot of space and habitat will be formed for other species. I think there's something like 50 different species of fish you see cross as a habitat, either in the very early life stages, or when they're young to protect themselves, or to feeding on Zostera. Many different bird species feed on seagrass as well. They also are amazing for carbon sequestration. Much more than any forest would do so in terms of climate change. That is like a really, really good nature-based solution for climate change, apparently, compared to planting trees. You're much better off planting seagrass. Plenty of benefits and because you know it is also good for fisheries and for commercial fishing. You increase the habitat for the fish, which means you get higher yield.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-None that I'm aware of.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-As far as I know what they do is collecting seed from *Z. noltei*. They put it in little bags, Hessian bags, that have plenty of holes in them. They put a little weight on it. Then they just drop these bags onto the sea floor. They germinate and they grow into plants. That seems to be a very easy, successful and well-working method. It's been quite a lot of time and effort has gone into developing this ideal process. If I had to do it myself, I would just follow this method. The seeds are ready in August-September, depending on where you are in the

country. In Scotland, it's probably more end of August and September when they are ripe. I believe you can just use the seeds immediately. You can also store them.

Are there particular practices to do in the recipient site management for successful establishment?

-A problem would be the seeds or seedlings drifting away if it's too stormy, if the tides are too strong. So, choosing a good window for the translocation would be good. Other than that, not much. I don't think anything except for monitoring. Just to make sure that what you've sown is actually growing. I don't think it needs any additional protection. Well, you wouldn't want people with boots walking around or any ships to just put anchors in. Make sure that it's not polluted. You make sure that the water quality is OK, and that's it.

Cicerbita alpina

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-In Scotland, it's found on very steep ledges and cliffs. But that is just to avoid grazing because it's very palatable. Lot of species like eating, including deer, sheep, bugs, slugs, pretty much anything. And because of that, they've been pushed up onto these ledges to escape grazing. In the UK, we've only got 4 populations and they're all in Scotland. If we look in other countries where grazing pressures lower, they have wider habitat range. In Scandinavia, which is geographically the closest comparison and also climatically very similar, they actually grow in forests. They grow all the way down to the coast, so it's not even high elevations. They like some shade. They tend to grow within dappled shade in the forest, birch and pine woodland particularly. Montane birch and pine woodland has been lost in Scotland. We assume that this is where they would love to grow if they had a chance and if they weren't eaten. Scotland is the western edge of its distribution, which is why it's really rare. Most likely down to grazing. They would be quite happy to grow at lower altitudes. Just need moist but not waterlogged grounds. They like not too acidic, but actually not really alkaline either. Neutral to slightly acidic, I think.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-It is a good question. They don't really need other species, so you don't have to translocate other species with them. At the moment, where they grow in Scotland is on the ledges. I'm actually not sure whether a pollinator would find them. It is a quite a steep area so there are not many of them. So, whether any pollinator would be attracted by a tiny little patch of them, I doubt it. It could be an issue if you don't plant enough of them. In a single location, or if they're too far apart, as you say, that pollinators may either not really find it because it's too small, or they may not be able to fly in between the different patches. There's definitely

something about needing the right amount of plants for within the translocation site just to attract pollinators. But also, the right amount of distance. Either the distance to your natural population or distance between two reintroduced populations just to make sure that there is pollination. Scottish populations are associated with other tall herb ledge community. I think that is specific to Scotland. We're not quite sure whether that is just the typical. I don't think they need to be with other tall herb ledge plants.They can happily grow in in a forest somewhere in the right conditions. Seeds are wind dispersed with a fluff on them. Quite often they are dropped, but they have the potential to be blown quite far, especially in the Scottish winds.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

- It's not a habitat builder. It might be possible that they attract many invertebrates. If you have enough of them. They have these really pretty blue flowers. At least in the nursery, they're full of hoverflies and bumblebees and things that come into the nurse region. I mean it's amazing. This year there were plenty of flies as well, of many kinds. They just loved these flowers. Maybe they could attract quite a lot of pollinators. But again, I think you need to have something that is visible for an insect that flies across the landscape. Maybe 50 or so flowering plants. If they all flower at the same time, we've got a blue patch. The insects would probably be quite drawn to that. It also comes to the genetic diversity. I mean, you'd want to have hundreds of individuals. 100 different genetic individuals. Just to make sure that there's no inbreeding in the next generation. Then that's tricky because you need to find an area where you can plant hundreds of individuals. Quite often the sites that we find that quite small.

What sort of benefits of translocation can you predict for the recipient site?

-It's tricky. You have to have the right conditions. Grazing levels have to be low. Plus, ideally you have a defense. You need to protect them from further grazing from smaller mammals. Soil acidity might be a problem. I guess you don't want to plant them right next to heather. Competition is another thing they don't like. As a typical alpine. They're very limited areas that are actually suitable, unless you have them in a garden somewhere. Then you can grow them easily, but that is because there's a lot of work involved. For example, in RBGE they grow happily. Horticulture team looking after them and weeding the area. There are probably not that many areas left where you could actually plant them, except for very steep ledges. As we said earlier, where they escape grazing. We're planning a translocation project in autumn this year. We're still looking for the right places. We know an area, the Corrie Fee National Nature Reserve. One area where we found the absolutely perfect site. We are struggling to find another side that is similar. Because it's so difficult to find the exact perfect conditions. Another site is managed by NatureScot. It's got a deer fence around and it gives it a certain level of protection. It's just a great area for plants generally. Lots of rare things growing there. Another translocation site is Mar Lodge. Any deer that comes to the state pretty much gets

shot. So again, it gives us the extra protection and they've got some woodlands restored. They've planted quite a lot of woodlands. We planted *C. alpina* within these newly planted woodlands. That was semi-successful. About half of the translocated plants survived. It's not great, but it's OK. And they flower, so that's the other thing that's great. The last location was Morrone Birkwood Nature Reserve. Nothing survived there. That was absolutely a wrong location because the soils were too wet, waterlogged. I don't think it's so much the temperature in itself that is a problem for the Alpine plants. It's more that with a higher temperature, you've got more competing vegetation. And usually, the Alpine plants are not very good competitors. They're happy to grow in warmer temperatures, but they can't cope with the other vegetation. In Edinburgh, where it's much warmer, they don't struggle too much with the temperature itself.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-No risks. I mean, they don't. They produce clonally. You just need to release a few sheep and they're going to get rid of them or, you can pull them up again. It's nothing bad could happen really. And also, they are edible. In other countries like France, for example, they are called ‘la laitue des Alps’, the Alpine lettuce. That is because they eat them as lettuce in France or in Italy. I think they use the roots and cook them. In Scandinavia, I think they cook them in milk or something. So, the worst case you can also just eat them yourself. So, very little risk and they don't have any diseases or anything associated with them.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-Different things work. Germination rate for the seeds is very low. You may have to collect lots of seeds. Otherwise, you can also take rootstock like you see in the nursery. For example, every year we can divide the plants. Every year we can twice the number of plants before. This is another technique that works really well. You can get to large number very quickly when you double your numbers every year. It would take a few years to get there, but yeah, within a few years you can have like hundreds of individuals. The problem with that, obviously, is that you're not increasing the genetic diversity. So, you have to be a bit careful with that. Growing them from seeds is probably the better option in that respect as you get higher genetic diversity. In our case, the first rootstock ever collected at RBGE was in 1999. It was three different plants they had over three rootstocks. Since then, they've divided the plants every year. So, we ended up having hundreds of plants. But, still it’s just the three genotypes, which obviously isn't great for a translocation. We then use these plans to do some trial translocations. 15 years later, we planted them up. You could do it more quickly. it's still going to be quite a time. You know, everything is time consuming with plants. If you want to go get a certain number, you are going to have to spend a few years just growing them. When we sow the seeds in the nursery that is in perfect conditions in the nursery, we got 2-3% germination rate. So, for growing seeds in the wild, we're not sure what we need to do,

whether we need to open up the ground. I agree that it may be cheaper and quicker just to use seeds but I am not sure how successful that would be. August-September to collect seeds and then, you can use them straight away. Release in autumn to protect them from drying out.

Are there particular practices to do in the recipient site management for successful establishment?

-What we are doing now is planting in an area that is fenced or heavily managed like in Mar Lodge. We're choosing areas that are not too accessible to grazing animals. Cages around each individual plant to further protect them from voles and snails as well. Some wire mesh. We put it around the plants because it also helps with the snails. We've decided to do that for the first few years, and then we'll take the cages way at some point, hoping that is the end of the management. Once they grow and build one big patch. It will be better able to cope with the occasional grazing event.

8. Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

-*Linnaea borealis.* If they self, they don't reproduce. They don't produce seeds. They have to outbreed. The problem is that only single individuals are left and they are too far apart from each other. Fragmentation is too strong and they're now too far apart. They're stuck and they can't reproduce. So, once these individuals die and there will be no seed from them. They would be just gone. They are actually living dead if you like, unless you do translocations. Especially the ones in Cairngorms National Park. The ones that Shaila mentioned. They have done some translocations to bring a few more individuals in so that at least they have a chance to outbreed and to produce seed. And then you know to create the next generation. It's probably the case that there are some areas where there's enough of them. So, they don't have an issue there. Definitely in some areas, they are very rare. More like colonies in some areas, but they are endangered in other sites like Cairngorms. If once you get to that tipping point where you don't have enough left, all of a sudden, the species will go extinct there.

Saxifraga hirculus. So there the problem is as well. They are reproducing clonally, they have a lot of rhizomal growth. Because of that, it is almost impossible to tell how many individuals you have left in a population. We did some genetic studies. I haven't published it, so you won't find that online. But basically the genetic data showed that some of these populations just consist of one or two individuals, which isn't great. They can self, so they can still produce seed. But the quality of the seed is going to be much lower It means that in the long run every time they self, there will be reduced genetic diversity. It will reduce their fitness. That in itself is a threat as well. I think in Scotland there are only like 7 areas left where *S. hirculus* grows. It's a bit more widespread in England, but the problem is that the number of individuals is quite low. It's a European protected species and it's already gone extinct in other countries. I would put this on the list as well.

Z. marina. Just because of similar reasons. Because the seagrass seems to form such an important habitat. It is bigger and another habitat builder. But I think it's still important for the ecology.

Oxytropis halleri, Sagina nivalis, Sabulina rubella and *Polygonatum verticilatum* may be also worth keep an eye on. They are all declining or not reproducing, but it's been fairly recent, I think. Uh, I'm not sure whether that is reflected in the IUCN.

Also, some of the tree species in the UK and across Europe have had quite some issues with diseases, like for example Ash Dieback. Dutch Elm disease is one we are currently looking at possibly doing a project. To look at the genetics behind that. To see how survivors have a different genetic makeup compared to the ones that have been badly affected by the disease. I'm not sure whether as this project is ever going to happen. These are fairly common tree species that have been massively reduced in numbers. I wonder how the IUCN is going to handle that data, because one of the things. Are they going to shoot up on the list? All of a sudden, they may all be vulnerable even though they are fairly common.

Appendix 2.7 – Sarah Smyth*

*Please note that amendments are to be made by the expert

Calamagrostis scotica

This species is only known from one site in Scotland. It's on a wetland site, of fen meadow kind, up in the far north and I think the water levels are quite critical for the species. It's kind of found on tussocks within the wetland area. Though I don't think we know enough. It can withstand fluctuations in water level but it wouldn't grow in a dry habitat. It must be in somewhere up north.

It needs this tussocky habitat, but I'm not sure if it's a specific grass or if it's just anything that's kind of raising it slightly from the water level. I suppose we haven't done enough work on it to have all the answers, but I would say no, there's no symbiotic relationship or anything like that. So no, not in that sense.

Colder, wetter oceanic climate compared to *C. stricta* that has much wider distribution in the South. There's been a big debate with *C. scotica* and *C. stricta*. Some people say that they are not separate species, and some people say they are and, I suppose so. We've gone down the route that it is a distinct species. I guess any other location where *C. stricta* was thriving would be a good location for *C. scotica*. But then you would want to run the risk if they would hybridise which would result in dilution. I would say any site that *C. stricta* thrives but we just don't know the genetics, the work is not being done if they will hybridise or not.

I suppose not so much for the recipient site that it would. It would just be for the robustness of the population. There's been discussions in the past on the canal running through the middle site. Would it be dredged? Would it be dammed? In that case, the hydrology of the whole area would change and we would possibly lose *C. scotica* from the site. So, it would be more of an insurance having it growing elsewhere.

I don't think so, no. It doesn't seem to be thriving. It's not moved out of this site, so it doesn't seem to have any of that potential at all. Perhaps, hybridisation with *C. stricta*. We almost got some genetic work done on this site and then for some reason, it didn't happen. So, we don't know what the genetics of this population is like. Is it just one population? In that case, that wouldn't make any difference if there is. If they are mixing. Given that is just one very small

population that one very small site. I would assume it's fairly limited in its genetic diversity. Mostly vegetatively growing plant anyways.

Seeds would be easier and cheaper as a first approach, and if that worked go from there I suppose. Seed growing offsite, perhaps in the beginning to try and figure out about the germination rate and all would be OK. It's easier in terms of collection, less damaging to the one the single population. I think that would be my preferred approach, but working with a few rhizomes and growing from seeds just to see which approach works better. If we were to use seeds, I guess we would just collect it in the autumn, since it may need a blast of cold to germinate. I would go for offsite propagation, grow them on, see what the success level is and then plant out seedlings or young plants the following year.

If we were going to a new site then getting the grazing levels right, getting consistent water levels and ensuring there's not too much competition would be ideal. It's not going to be outcompeted with *Phragmites* or something like that but we're a little hazy. We only know it from this one site. We don't know what these optimum conditions are. Still, it may be good to ensure that it's not going to get completely overshadowed and outcompeted.

Carex maritima

1. It likes bare ground, long coastal saltmarsh, sandy areas. It doesn't do well with competition. It prefers newly exposed habitat. It nears freshwater streams trickling down into the sea. So, I think it likes, not waterlogging, not so wet, but I think it likes that freshwater influence in very low coastal area.

2. No, it likes bare ground. No one else around it, no competition.

3. Sometimes you may find it in freshly eroded environments. I knew it from a site we used to monitor. It was a bombing range and sort of the newly created craters were ideal for it. Then, it would establish long edges of those. In terms of climate, it's more of northern distribution. It's up the East Coast up around Orkney, along the North Coast. It's not found down the West Coast at all.

4. I suppose in the long term it would. The bare areas would be stabilised, which would then allow other species to colonise. Though, it would not be a kind of big, functional change. Again, it would just be simply increasing with distribution of the species.

5. I can't think of any, no.

6. Seed collection seems to be effective. I'm not sure if it would need any treatment like cold exposure or maybe even some ocean water. But it seems to get established well.

It can pop up on the coast and manage quite well. It's declined recently but I suspect that's more due to the site management as some development or drainage along the coastal areas. I don't know if there is climate element to it or not. I don't know because it has a quite large global distribution. The UK distribution is contracting, is getting smaller, definitely. I would say it's not thriving. If we stop developing along the coastline and changing the local hydrology then it may do better. Yet, I believe there are sites where there have been no development and no changes and, still it's disappeared from those sites. Possibly, it is marching north. I think it is being lost from the South. But, I think my preferred option is transplanting. Well, that's what I've had most experience. Because you can monitor the success more easily. You know, if you know that you put 30 plants in here, here and here, you can see if they've made it or not.

7. Monitor the site for a good year before hand. You need to see how the hydrology of the site can change in the winter, in the spring and in the summer. To make sure that it doesn't dry out too much or it doesn't get completely inundated. So just to check for 12 months at least to make sure it's suitable. Seeds are quite big but I think they will float when washed along by the sea, by the tide. I think that's the way looking at some of the populations. You could see that the seeds from that population further South must have been carried up shore. It is not wind dispersal, they are carried. A barrier for spreading to new areas would be tidal, if there are, or anything interrupting the natural flow of water.

8. Some species that we work with. We've had a few populations, various things that would seem to be struggling an we've said, oh, you know, it's been a hot, dry summer. That's the reason, and I suppose it's when we get a combination of several hot, dry summers, we're losing the seed sets over a few years. And that would be a problem when it's becoming a distinct trend. It's a bit too early to say. We were worried of grazing about maybe 10-15 years ago, and that seems to have improved. There's been a lot of work on controlling herbivore numbers. Though they are still struggling and that's why we gotta start scratching our heads.

   Minuartia rubella is the species is one of those. I think this one is in trouble. This was picked up through our programme of site condition monitoring SCM – where we take a snapshot of the condition of the features on our designated sites. I think this is a species in trouble as it is relatively slow growing, favours ground prone to erosion and the populations are declining rapidly. Hopefully surveys this year and next will provide more current population figures to inform a decision on intervention / population reinforcement.

Appendix 2.8 – Iain McDonald

Alchemilla spp. (*A. wichurae* and *A. sciurae*)

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-There's nothing particularly different about the habitat from that a number of other *Alchemilla* species grow, so it's quite similar in appearance from the photographs that I've seen to where you might get it. It is growing in upland grassland, sub-alpine grassland quite close to the ski centre in the single site in the United Kingdom. It is an endemic species. Soil is not particularly base rich, and it's not particularly acidic, it's it looks like neutral Alpine grassland. Quite often the local topography and geology makes a difference in terms of the soil conditions, and so it could be quite specific and not in an anticipating that it is though. I would suspect from the other species of *Alchemilla* that it tends to be where there's a slight degree of flushing in the ground. It is possible that it likes slightly greater base enrichment, but that's just my guesstimate without having a look at the habitat. It's probably in excess of 600 meters. But as I said, I've not been to the site. Very cool, high rainfall. In high, prolonged snow cover in the uplands. It also appears to be quite closely related to another *Alchemilla* species like *A. glomerulans.*

wichurae occurs at lower altitudes at particularly further north. It's also a northern upland plant. It would be more susceptible to climate change than many other species, but that would be in the long term. Not even in the medium term. This species would survive because it's got a much more extended distribution in the British Isles. Sure, it'll cope with climate change.

But for the for the purposes of translocation, you can treat them pretty much the same. They're both quite small *Alchemilla* species that tend to occur in the hay meadow grassland, alpine grasslands.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-Associated species? No, no, not really. You tend to get just a high-altitude grass species there. There are quite common.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-I don't think they are particularly suitable for translocation, for the simple reason that they require certain habitat conditions and the habitats themselves are not disappearing particularly fast, so these are certainly case of the commoner species.

What sort of benefits of translocation can you predict for the recipient site?

-The advantage of translocation of *A. sciurae* would be that it would not be only on a single site. We would have an alternative site and therefore, if there were a catastrophic event at its sole global site, we would have it somewhere else. So, it would be for the benefit of the species rather than the site. Many of these *Alchemillas* don't contribute hugely to the composition of the vegetation on a site. Sometimes you get a local cover of the larger leaved sort of fill. They can be quite dominant in aggregates.

Particularly *A. sciurae*, where it's only been recently discovered, it might be ultra-rare. Probably is pretty rare because even *A. glomerulans* is quite uncommon. And therefore, the perception is that we would want to have it somewhere else, if possible, just to safeguard against global extinction.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-No, no, there's no. It's not with either *Alchemilla* species.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-The transplanting nursery-grown plants would be the way to do it. Not collecting seeds and spreading seeds. These are going to be very tiny seeds. The biggest priority would be to get seeds for the Millennium Seed Bank. It's possible that a collection has already taken place. I don't know, but I suspect that the Alchemilla experts would have gone out to collect some seeds, but for translocation it would be from plants grown *ex situ.* I would do it earlier in the year to allow it to become established before the following winter. So, I would say early summer. In areas that might be subject to snow cover.

Are there particular practices to do in the recipient site management for successful establishment?

-That's a good question. Habitats in which these *Alchemillas* grow. It is prone to grazing by sheep, deer and goats. For short term, you could have a control where you've got fencing. Generally, things don't do better when they're being translocated. Unless they've got a degree of protection. Because they always stand out to herbivores if you disturb the ground and you

put something in, herbivores will see it. If you go to the effort of collecting it, growing it on, moving it about you perhaps would want to just plant it in a protected space.

Potentilla rupestris

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-It's a stranger, uncommon in Britain. It occurs in quite dry, south facing, craggy slopes and it occurs where there is very slight base enrichment. It doesn't appear to like neutral medium. These slopes have one or two species growing on the same cliffs that are associated with *Sorbus rupicola, Ajuga pyramidalis.* Open sunny sites. It's quite low, 40 meters at one site and at the other side we're only talking about 15 to 30 meters. It's growing this low because it's on a higher latitude. It was found in a higher altitude site in the northern Cairngorms, but there is a suggestion somebody might have planted it there, but we don't know. On a steep slope. We are just quite suspicious because it's kind of place where people would have seen it before and there is a suspicion that it was translocated there, but nobody knows for sure. It does present lot of problems for us if we don't know if a site is native or not. When botanists decide to translocate species without permission, they are often very good at picking the right habitat. So, they know what habitat this species grows, and so, they'll be looking for things like *Ajuga pyramidalis* growing. That will give them an indication it's possibly the right. I don't know the exact soil chemistry, but it's an indicator that is not particularly acid.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-No. I don't think so.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-The conditions in which it occurs are quite specific i. e. south-facing, low altitude, slight base enrichment. There's not many of these sites in Scotland, because most of our rock is acidic. It's possible that we could find a cliff site. I cannot actually think of many suitable sites. Rocks to the South of Inverness, on conglomerate rock. That would be a potential translocation site. It would mean moving it south ironically, but at higher altitude. That's where the closest site I can think of nearby. I think this species just likes particular conditions.

What sort of benefits of translocation can you predict for the recipient site?

-Benefits will be just increasing biodiversity, as in all of these cases. More for its own species protection. It's a pretty plant, as one of the prettiest Scottish or British rarities.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-The risk would be removing too much material from the existing populations and thereby placing them at risk. I can't see any other risk of translocating; it'd be quite easy to control if it were to become invasive. It's not likely to be invasive.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-The technique would also be transplanting but I would probably mix up the two sites. So, rather than just taking material from one site and plant it somewhere, I would take plants from both sides and plant them together. A bit like what Aline is doing with *C. alpina*. The genetic variation is probably very, very low because of the tiny population. Should be careful of drought though. Because you'll be moving it into a location prone to drought. This is a species where you might want to consider planting later in the year, so maybe from September onwards. If I was doing it, I'd be wary about putting any plant out. If you've disturbed roots and it could result in failure. You would take advice definitely from the horticultural experts. Because quite often with these plants you'd want to keep it well-watered. Translocating out in the wild, it's not possible to just pop in and water it every day. You would have to pick a window of weather as well. Just to be on the safe side. I would imagine it grows quite well, being from Rosaceae. It would be easier to cultivate than some other species.

Are there particular practices to do in the recipient site management for successful establishment?

-You would simply be looking for crevices. Where there's rock outcrops. And caging. The small plant growing in a container, placed in the crevice, trying to avoid damaging the roots. One native site is grazed by goats. But the plant has persisted, which would suggest that is not particularly palatable to goats. The biggest threat at both sites would be encroachment by course shrub species. Shading by other plants is probably a bigger threat than grazing because it grows on extremely steep rocky ground. Not many grazing species go there

Saxifraga cespitosa

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-It's an arctic species. It's not really a true arctic-alpine. This one is one of the few species which I would say is an arctic species clinging onto Scotland. It grows on frozen rock. East facing, north facing aspects. There is one record I can think of that have not been to the site, west facing side. It probably is less specific to aspect. Basically, growing in tiny amount of soil in the crevices. In terms of moisture, it does require an arctic type climate. Very cold, very wet. It is adapted to drying out but I doubt it favours it. It can cope with high wind speeds as well. Not really associated with other vascular plant species at all. The other uncommon saxifrage growing near it on the Isle of Skye is *Saxifraga nivalis*.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-No, no, not really. It's a plant that grows in a very tough environment. Nearby, you don't get many other rare species with one or two exceptions. It was found, strangely enough, on the Isle of Skye quite recently. By far the lowest altitude record in Scotland and where it occurs in Sky, it's slightly base-enriched and occurs in a very damp gulley. It's fairly close to another saxifrage species, which is uncommon, *Saxifraga novalis.* And moss cushions but simply due to similar habitat preference.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-For translocation, I would look for a very high altitude, very cold, very exposed side. A bare rock high up in the mountains, that is not acidic, neither neutral, to having a very slight base-enrichment. I would also be looking for a site that stays fairly damp. Not a lot of light hitting it and drying it out. That's why the east and the north aspect are better. There are not many things that can compete with it because it grows in such inhospitable conditions. There's plenty of pollinators at these altitudes too. There are not many sites that would probably be suitable. Probably Ben Hope would be a potential site. Or Ben Morass. Certainly, southwest of Ben Hope in the north extreme north of Scotland could conceivably host *S. caespitosa*. But we must go and look at the microconditions of the site. one of those threatened by climate change It can't really go any higher in the mountains where it occurs. The mountains get progressively shorter, you don't have high areas over 1000 feet in the North of mainland Scotland. The Shetlands does have one or two arctic-alpine species growing in it. But it is just too low altitude. I think it's too late to put it down to Shetland. You be looking at Ben Hope or something like that on the extreme in the North Coast of Scotland. There are slightly enrich slopes. But the trouble is that they are west facing.

What sort of benefits of translocation can you predict for the recipient site?

-It would just be for the species concerned.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-No, absolutely no risks of this one taking off.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-Growing *ex situ* and planting it out. We did consider doing that, but then there wasn't a lot of benefits to doing. The plant will disappear eventually due to climate change, regardless of what we do.

Are there particular practices to do in the recipient site management for successful establishment?

-Have to try and make sure that there's not too much trampling or grazing at high altitude sides, but there's not really a threat from that. It really, really belongs in the Arctic. Scotland is perhaps just too far south and too maritime for the species. But having said that, it did survive warmer conditions in the past. In this interglacial there has been a warmer spell then we have even now. I suspect we lost a few species that still occur in the Faroe Islands. But, all these alpine species somehow survived those spells. So, there is clearly capacity for them to survive. But the reality is, it's better to leave it in place because it is in the best sites for it in the country

Phyllodoce caerulea

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-It's unusual. It likes very long snow lie. Tends to occur in eastern aspects. Steep slopes with snow. Patches lie from about 600 meters altitude.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-I don’t know of any other vascular plant species. Bryophyte species that are associated with snow beds but just because of habitat preference. Just like heather. It doesn’t particularly occur in a rich habitat at all. It's a rather impoverished shrub layer, but the key thing is said that does have a lot of snow cover.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-There is probably potential to grow it. In the Cairngorms, north and east of its existing distribution. Other eastern sites, I don't think, is well suited. It occurs mostly in very far west.

What sort of benefits of translocation can you predict for the recipient site?

-Just adds to the biodiversity. It's just one shrub amongst several. It is another species that could be associated with high altitude willow scrub.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-From the plant itself, no. It's not going to damage other plants.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-The same as the other ones, *ex situ* cultivation and transplanting in mid-summer. You'd probably be planting this species actually in the end of June.

Are there particular practices to do in the recipient site management for successful establishment?

-None that I can think of. It should be quite feasible to translocate this one.

Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

-*Primula scotica* is one that does concern me a little bit. It's a super abundant plant on the North Coast of the mainland of Scotland, and on a few of the Orkney Islands. If the climate changes, it could suffer. It is buffered because of the ocean. It probably won't disappear imminently. Its on a couple of 100 meters off the coast. But, if the climate changes, we could lose an emblematic endemic species. I would look at that one for the simple reason that it's an endemic. We would want to make sure that *P. scotica* has got the potential to move further north. To potentially new islands if necessary, so that we don't lose the species completely. It grows within 100m of the coast. However, it can grow over a km inland at Dunnet Links and there are four inland sites which I have been to.

Omalotheca norvegica is another one. A rare species and is found in high altitude gullies where snow lies into the summer. These areas are sometimes north to east facing which is why the snow seems to lie longer. Snow depth in the gullies can be very deep as it collects and fills the gullies so it takes longer to melt. The options though are fairly limited since it is not super rare and already occurs at high altitude on mountains with suitable geology. I think I said that there might be one or two sites further north which don't have it. In theory it could be translocated there, but the question would be why is not there already?

There are one or two endemic apomictic species which were not on the species status assessment group. They are data deficient and will be added to that spreadsheet later this year. They present particular issues for conservation. Do we want to move them about or not? And that's a big topic really, and I wouldn't confess to know the answer to it either. Because they are the product of speciation. But species also go extinct. So, are we meddling with the natural process of extinction? A philosophical as well as a conservation discussion that one.

Additionally, we may create a habitat at high altitude like the willow scrubs that is lacking in Scotland. Given our climate, should be in Scotland to a greater extent. Trees like *Sorbus rupicola* that are confined to calcareous media. And common herbaceous species like globeflower, *Trollius*. We could plant those out, potentially along with the willows, or after the willow establishment. Nature Scot recently produced guidance on the planting of native flowering species in newly tree planted areas. If you have plantations of trees. You go there after 20 or 30 years, they often don't have very many vascular plant species in them. A very impoverished habitat in terms of biodiversity. So, our guidance, which is preliminary draft guidance, is that people might consider planting out common woodland species of flower as well as tree species. If we were to have extensive areas of willow scrub at high altitude. There is a potential to produce guidance for that high altitude tree canopy area as well. Maybe something for the future. You touched upon it through your discussions about these species about where they might occur. At the moment, some of our rare species are associated with

gulleys and ledges. But if we did have willow scrub it would be worth looking to see if these habitats might also support these species that we call ‘ledge species’. Since in Scandinavia are not just found in ledges.

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Appendix 2.9 - Ian Strachan*

*Please note that amendments are to be made by the expert

Poa flexuosa

1. Stony substrates at high altitude. Fairly fine, gravelly substrates really. It can grow on scree slopes and on stony plateaus as well. In probably 900-1000 m altitude, something like that. The biggest populations are on Ben Nevis, which is just across the valley from me. We had a big project there. On the northern aspect of Ben Nevis we found big, new populations. They were mostly on very high ground. It certainly likes rain. It'll be pretty wet there, but it's not purely western, which you might expect if it was at a very high rainfall requirement. It tends to grow in very open habitat.

2. It's often on its own. You sometimes get a few other montane plants round about it perhaps and things like montane mosses. But, I wouldn't say so for this species. As a grass, it doesn't need pollinators and I am sure it doesn’t like competition, as with quite a few of these montane rarities.

3. This is the question I have a problem with because in general, I don't think translocations are particularly good ideas. I think that the habitat conservation is so much more important. If something had disappeared from a site because of adverse management that's known and if that management has then gone back to good management, then perhaps there's a case for translocation. Otherwise, I'm not so sure. Particularly, these montane species got very few sites and that is what makes them very vulnerable. Also, there is still a lot to be found. I mean, on the survey that we did this week, we found new populations. I think taking conservation effort away from getting habitat management correct isn’t right. We should also understand much more about ecology of the species before. Because translocation takes up a lot of resources. I feel it tends to distract away from other issues too. They can give out the wrong message. It's a sort of thing that gets publicity and then people think “Oh well, it's fine. We can move plants from one place to another. So, it doesn't matter if they disappear from one place. We can just move them.” So many translocations have been unsuccessful, but often that doesn't get publicised. So, that's my thoughts.

4. The benefits would be increasing its population and the number of places occurs. As an entomologist, even though I don't know about anything associated with P. flexuosa but I suppose it would benefit the arthropod taxa. Open screens don't have much on them. I suppose it would increase the structural diversity of those areas.

5. No, no. I think that's very unlikely for this species. There's usually deer and sometimes sheep grazing on it anyways. It's interesting because the grazing has been reduced in recent years on Ben Nevis. Maybe that's helped the populations. We don't know whether it has increased or not, but we certainly found new populations. Quite big population.

6. I would imagine from just from seed on the site. Since it is a very open habitat and you don't have the issue of establishing in the turf. Scattering the seeds in the appropriate habitat in the autumn should be good.

7. Low grazing pressure is the key thing.

Lycopodiella inundata

1. In the West of Scotland. I have seen it in the South of England too. It occurs on mostly on the margins of freshwater lochs. Where the area is inundated in the winter. It comes back to competition. It's has a low competitive ability, and it grows in these areas that the flooding kills off the other species that are unable to tolerate that prolonged inundation. Whereas lycopodium can survive being wet on the edges of lochs. You get a lot of aquatic plant debris washed up and a layer of dead vegetation left. I think that smothers other plants and perhaps creates the bare areas that *L. inundata* is able to grow in. It is quite short-lived. A strange plant really. It needs to be on a peaty substrate. It tends to be on areas where there's a very broken, thin layer of peat on stony substrate. Thus, the peat retains the wetness, I suppose. It's not exclusive to loch margins, but that's its common habitat in Scotland. I know it occurs in wet heathland in England as well. It is certainly associated with areas of disturbance there like vehicle tracks and old peat cuttings. I haven't seen it in that habitat in Scotland necessarily. But, I have seen it at one site in Scotland away from a loch, just in a hollow. Presumably, it has a fluctuating water table. It was not very far from another freshwater loch. It's very easy to miss. I think it's under-recorded because people don't notice it. I found several new sites and where it wasn't known before.

2. It's pretty bare where it grows. It doesn’t like competition. You do get some quite distinctive associates and it's funny. I noticed it in the same habitat with some *Drosera anglica*. But, I think it's the similar conditions suit that species as well.

3. Slightly wet and peaty. Sites with fluctuating water tables, like the lochs.

4. Just adds to the plant diversity in the area. And the structural diversity.

5. No, I don't think that, no.

6. It's a pteridophyte, so it would be spores if you were sow it. But, I think the main spread is via fragments of the plants. As I understand it anyway. After a few years, it starts to break up and the fragments of the plant creates new plants, so I think that's that. Probably, the way to best way to establish it would be to take fragments from existing population. I don't know if there's been any work done on that. I would believe that the existing populations are just large clones

7. I read that high grazing pressure can be beneficial to it. By the poaching, by the animals creating open habitat for it. Like dear trampling at an appropriate level could be beneficial. Well, it's clear that at some of the sites anyway, not particular ones I know, but in other sites that some kind of poaching is useful for maintaining the habitat.

8. As I said, I am not very supportive of translocations. Like in the case of *Calamagrostis scotica.* It may be vulnerable according to the IUCN criteria, but our survey suggests that they populate quite well. There are certainly more than 1000 individuals. The accounts we did were of actual flowering heads so I don't know how that relates the number of actual plants, but yeah, we found a lot more than it was previously recorded.

Appendix 2.10 – Robin Payne

Monotropa hypopytis

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-Most of the records are from the South of England, and it occupies a particular habitat. It grows in woodlands, poor soils in terms of nutrients like that of beech (*Fagus* spp.). It can grow in both calcareous and acid situations. It's a rare plant. The recent findings of this plant in Scotland have been in urban post-industrial sites. I came across it because of casework in a previous job. These sites are being redeveloped for one use or another. In Greater Glasgow, there is a site at New Steveenson. There was a large foundry where they were casting huge metal components that would have been used in the industrial revolution . They were casting this steel and iron in moulds that were made of sand of special mineral type and particle size. Foundry sand is very quartzy and it's very nutrient poor. On this industrial site, once the sand was no longer of use they dumped it. The buildings had long gone from this side, but there were mounds of spent sand around the place covered in scrub. On these mounds of very low nutrient waste, the Monotropa was growing in association with willow (Salix) species. Other rare plants turn up on these post-indusrial sites as well. Those are where the recent records are upcoming. Older records in Scotland relate back to semi-natural habitats including dune slacks and pine woodland. One of them is a place called Culbin on the Aberdeenshire coast where pine as planted post-WW1 on a coastal dune system. What's absolutely crucial in these places is that they are generally very low in nutrients. There's no record of it turning up in places where you've got thick or lush vegetation. It's an opportunist. It's looking for places like pine forests which actually are very open beneath. There's not much growing due to the shading and to the acid regime by the fallen needles. These habitat types and vegetation types which are extremely low in nutrients. Now it seems to have found its way into industrial sites.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-It's associated with mycorrhizae of other plants which are associated with a tree or scrub. When it grows in dune slacks, it grows in association with creeping willow, *Salix repens*. It is also associated with hawthorn, *Crataegus*, and hazel, *Corylus.* At the site where I saw it, it was another willow, *Salix cinerea*. I read somewhere about a research on mycorrhizal associations. The glucose finds its way into the saprophytic plant incredibly quickly. So, this thing grows in an intimate connection with its hosts. But, Monotropa may not be not too choosy about what sort of mycorrhiza they get associated with. Habitat suggests a broad choice of mycorrhizae.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-Ground with poor nutrition. Industrialwaste ground in Scotland may be ideal for this species as long as the habitat is nutrient poor and the vegetation type very open with bare ground.. The shale bings west of Edinburgh are recognised now for their cultural and natural heritage may be suitable . Development agencies flattened and redeveloped many of them but some of those that remain are now preserved. Now, they're being preserved as part of the industrial heritage. They are useful nature conservation sites. So, you've got potential places to move it to, or to just try there. These are interesting post-industrial sites that were disappearing because of their development potential. They would potentially be good translocation sites. Another option would be the coastal pine plantations on large areas of sand at Culbin ot Tenstmuir in Fife where it was previously recorded (if indeed it really is extinct there).

What sort of benefits of translocation can you predict for the recipient site?

-So, if you translocated it to one of these post-industrial sites like the shale bings that already have nature conservation interest , you're adding to it. There's a plant growing on these mounds. An *Epipactis* taxon (youngiana) that isn't seen as a species anymore. It turned out to be just a variant of a much more common helleborine. But you know, suddenly people got very excited about the nature conservation benefit or the uniqueness of bing sides. Other things have turned up on shale bings as well. Lesser butterfly orchid (*Platanthera bifolia*) turns up on these sites too. There will be a number of other ones so, you can add to their biodiversity.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-No, I can't see it. It's such a rare plant and I just don't think it's got that amazing potential.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-I think the information on the Pplantnetwork website is the only guide we have. The seed might be a quite fine seed, but we know little about how it disperses.. I guess how it disperses is analogous to an orchid. They produce really huge amounts of very fine seed that absolutely rely on germinating within a millimetre or so of a of fungal hyphae. I'm guessing that's the same with this, but even if it's producing a lot of it, there aren't many plants to start with to produce this seed. So, it's baffling. I haven't found anything in the literature. How does such a small, apparently small amount of seed find its way around the environment to find these unusual habitats? The plant is doing it somehow because these industrial sites didn't exist 200 years ago. It's found its way in there from somewhere, from semi-natural habitats. If you can collect viable seed from it, this gives an idea as to how you might go about translocating it. When I researched it, it said that the propagation was going to be an

exceedingly difficult. The seed will need to be sown close to its host plant. One way would be to sow it in the leaf litter under established beech or coniferous trees. Or alternatively, you could try sowing the seed in a pot that already contains a potential host plant. If successful, grow the young plant for a couple of years before planting it out. Close to an established beech or coniferous tree. You don't get much ground flowers beneath these trees because of their acidic litter. That opens up an opportunity for species like this that need space So, it's giving a kind of someone's best guess at how you might do it.

Are there particular practices to do in the recipient site management for successful establishment?

-The sites it grows are always subject to serial succession. Eventually they'll produce enough leaf material that you get a humic build-up. You start to get soil building. Then you get plants that fix nitrogen. In the long term, these are going to become richer woodlands. So, there's a balance there between having enough of these host plants, but not so many that they are the standard dominate the side. Certainly with the post industrial sites I think there's an argument there too. The inner-city sites are being developed. At New Stevenson the developers agreed to leave the most significant population on the biggest of the mounds of this foundry sand untouched on the case I worked at. They couldn't build quite as many houses as they wanted to, but they managed to build a whole lot of houses around. The site like that, it's going to get nutrient enrichment. It just happens. You know, people walk their dogs. Dogs urinate and defecate in places. People cut their lawns and throw their lawn-mowings. You get species like gorse (*Ulex* spp.) start growing in there and fixing oxygen. Gradually the nutrient regime of those places increase. I think it is unlikely that the plant would survive in those conditions. When you help to preserve part of the cultural heritage, you might be able to kind of generate interest in a site such that it becomes a local nature reserve. You can curve those activities.

Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

-A lesser butterfly orchid is certainly one. Intermediate wintergreen (*Pyrola media*). A lot of work has been done on lesser butterfly orchid and there is potential for translocation for that. *Linnaea borealis.* A colleague did his PhD on it and he found that all the sites of *L. borealis* which are pollinated by flies were too remote from each other. It would not get proper cross-pollination anymore. So, it's a species ripe for translocation work. It's an interesting one. Enough is known about it.

It's interesting how attitudes to translocation have changed over time. I remember 20-30 years ago. If you went to a botanical meeting and you said “translocation2 it was like saying the word ‘Voldemort’ in the Harry Potter world. Faces recoiled in horror and crucifixes were clutched at the very mention of the ‘T’ word. It was just not the kind of thing you could talk about. But then the things change and you see the success of the work that Heather McHaffie and others have done.

Appendix 2.11 – Dan Watson

Sagina saginoides

Which sort of habitat/environment does the species tolerate and thrive in your experience?

-It's quite widespread on Ben Lawers National Nature Reserve, often in gravelly flushes. It can also occur on sloping rocks that are occasionally damp and on cliff ledges. On Ben Lawers it almost always grows in the same places as both Sagina nivalis and Sabulina rubella. These are two much rarer plants with slightly differing ecological requirements, showing how *Sagina saginoides* has a wider ecological tolerance than either of them. There are a lot of places where it was previously recorded, but there are no recent records. There's a good chance it's still there, just that it hasn't been re-found, probably because it's quite an obscure and small species. It's very easy to miss. There are probably undiscovered populations still to be found in the Scottish Highlands. We recently found a new population in a flush on Sgurr nan Ceathreamhnan above Glen Affric. It usually seems to require open ground, having low tolerance of competition, but here it was growing from a dense but low cover of the moss Philonitis fontana. It is a real mountain plant in Scotland, generally above 600 meters. To my knowledge it is not necessarily restricted to any particular aspect, although it would be interesting to dig a bit deeper to check how aspect and altitude relate to its distribution. Some of some of our alpine plants such as Sagina nivalis are doing less well, disappearing from lower altitudes. If a lower altitude coincides with a south-facing slope, that population is more likely to have disappeared. I don’t know if that would also be the case for *Sagina saginoides*. It is probably best to do a bit more research on it.

Have you observed the species particularly associated with any species? If the species were to be translocated, would you recommend any other taxa to be co-translocated to increase the chances of establishment in the new sites (companion plants, pollinating and seed dispersing fauna)?

-I would say not that is known. Probably unlikely to be necessary.

Which sites do you consider the most appropriate for the translocation of the species in Scotland?

-I wouldn't necessarily think that we would need to carry out translocations at this stage. I see it's more about establishing where it was found and make more effort to re-find the old records to see if it persists. *S. saginoides* might not actually be endangered. It may be widespread and the perceived decline may be related to surveying efforts. I think the first thing to establish, when possible, is whether the records are accurate. There's a potential for plants like this to have been mis-recorded in the past. It's easy to assume that all botanists knew exactly what they were doing in bygone days, but this is not necessarily so. You should take into consideration whether old records are supported with herbarium specimens. Misidentification may well lead to the perception of decline, although in some cases it's impossible to prove.

But if it came to translocations, then, it would probably be best within the core of its range, e. g. the Breadalbane Hills in the central Highlands of Scotland. The most sensible thing would be to identify gravelly flushes within Breadalbane that lacked the species, although I don't see this as really being necessary unless we can prove with greater certainty that it is declining.

What sort of benefits of translocation can you predict for the recipient site?

-Increasing their biodiversity, although only by a small amount.

Are there any risks associated with the translocation i. e. invasive potential or competition with local vulnerable flora or adverse socio-economic consequences?

-No. It's not the kind of plant that would be able to outcompete other things.

What sort of technique would you suggest for the process? Starting seeds, transplanting nursery-growns? What time of year would be the best to start translocation?

-I think would have to experiment a bit because it's never been tried with this species. It could potentially just be a matter of spreading seed in the appropriate habitat. That could be tried and that could be monitored to see how successful it was. Or it could be growing seeds in a nursery and planting them out. It would be a matter of experimentation and see which one works the best. Spreading seeds on the bare ground in autumn is possibly OK, as you say.

Are there particular practices to do in the recipient site management for successful establishment?

-Preserve the bare ground to maximize the chances of success. I should say that I've seen it growing on dense moss. But generally, it would be safest to assume that it needs bare ground with little competition. It can tolerate a range of bryophytes in these habitats, mostly low-growing ones. You'll often see it growing out of bryophytes, but it can't tolerate denser, tall vegetation. Some of these flushes are so high altitude that they wouldn't necessarily require grazing control. Certainly, there is evidence that if the lower altitude flush is un-grazed, they will become more densely vegetated. For a lot of the high altitude flushes it's probably less important. The biggest threat to these high-altitude flushes is climate change. From some of the work we've done on *S. nivalis* rather than *S. saginoides*, in some flushes where it used to occur and no longer does, which are generally lower down in altitude, there are more graminoids and common pleurocarpous mosses. This is most likely to be a result of less prolonged snow cover in the winter. If snow cover continues to decline, *S. saginoides* habitat will potentially get more densely vegetated.

Are there any other species which may not be in the EN status in the Vascular Plant Red List but likely to reach it soon and therefore, should be considered for translocation as well?

-*Sagina novalis* is much rarer in in Britain is only known from Ben Lawers with a small population on Beinn Heasgarnich as well.

Sabulina rubella. The declines in that have only very recently been recognised. That's also quite concerning. It's declining, it's moving uphill. In lower altitude locations, it's disappearing.

At this stage I would be keener on establishing ex-situ populations rather than translocating.