Small Cow-wheat

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Summary

- **Small cow-wheat is a nationally scarce annual** – the UK distribution consists of only 19 sites, mostly in Scotland, and only five populations have more than 500 individuals.
- **Habitat consists of fragmented upland deciduous woodland** – sites are typically cool and wet, close to water bodies and have an open canopy.
- **The Species Action Framework (SAF) project sought to address population status and reinstate interactions with wood ants** – the overall aim was to increase the number and size of Scottish small cow-wheat populations, and improve seed dispersal by wood ants.
- **Population expansion trials have shown initial success** – attempts to create entirely new populations are not so encouraging.
- **Cultivation trials** – protocols for the successful cultivation of small cow-wheat have been developed to allow seed to be grown for future restoration work.
- **Wood ants** – despite careful searching in several areas of Highland Scotland, only one site has been found that supports wood ants and small cow-wheat.
- **Habitat management** – this is now being attempted in order to increase the quality and extent of small cow-wheat habitat. This approach is recommended as the first course of action in the protection of all small cow-wheat populations.
- **Detailed monitoring guidance has been developed** – this should be used to monitor the status of small cow-wheat populations and the effectiveness of attempted management.

Introduction

Species background

Small cow-wheat (*Melampyrum sylvaticum*) is a hemi-parasitic annual herb with bright yellow, nodding flowers in pairs up the main stem and side branches (Fig. 1). It is found in remnants of upland broadleaved woodland where birches (*Betula* spp.) are typically the dominant tree species.

Fig 1. Small cow-wheat.

Why was this species on the SAF list?

This species met criterion 1a of the SAF, as a species for conservation action, because it had declined substantially in the UK, and Scotland is now a stronghold. Recent research had improved our understanding of the species so that targeted actions could be undertaken to instigate recovery. These actions could also benefit other species such as insects in the same habitat. Small cow-wheat was listed as a UK Biodiversity Action Plan Priority Species and is included on the Scottish Biodiversity List.

Habitat and distribution

Once widespread in Britain and Ireland (c. 110 sites; Rich *et al.*, 1998) small cow-wheat is now restricted to only 19 sites, mostly in Scotland north of the Highland Boundary Fault. Of these, only five sites support more than 500 plants and seven sites support populations of 100 individuals or fewer.

These small populations typically persist in isolated remnants or small fragments of upland woodland along river gullies, in steep-sided ravines or high up on rock ledges. At lower altitudes this species occupies high humidity sites - close to water, north-facing and under a closed canopy. At higher altitudes the climate is cool enough to maintain adequate moisture levels without a dense canopy, although the shorter growing season constrains plant size (Dalrymple, 2007).

Extant sites have all been undisturbed for more than a century, indicating that the species has a requirement for stable conditions. However, many sites are experiencing incremental habitat deterioration resulting in decreasing densities of plants even where the extent of habitat has remained roughly the same over centuries. The small size of the remaining populations puts them at risk of extinction from random population fluctuations and one-off events such as flooding, landslips or human damage.

General ecology

Small cow-wheat is a hemiparasite and therefore gains additional water, nutrients and organic compounds from the roots of host plants. Research has demonstrated that small cow-wheat plants attempt to attach to the roots of a range of species including blaeberry (*Vaccinium myrtillus*), various grasses, and herbs such as devil's bit scabious (*Succisa pratensis*). However, cultivation trials have shown that many of these species cannot support small cow-wheat plants. Good hosts are birch, rowan and various vetches.

This 'summer annual' flowers from June to early August and sets seed from late July to early September. The seeds are exceptionally large for an annual and are adapted for dispersal by wood ants as they have a small body on them called an elaiosome (Fig. 2), rich in fat and protein, which provides a reward for ants that carry the seeds back to their nests. The ants remove the elaiosomes, then take the seeds from the nest and deposit them intact as refuse. It has been hypothesised that this relationship with ants is important for the dispersal of seed to favourable microsites for germination and establishment, such as gaps in the forest canopy where ants build their nests. However, this mechanism appears not to be operating at remaining sites for small cow-wheat in Scotland because of the local absence of wood ants. As a consequence, seed dispersal is severely limited.

Fig 2. Small cow-wheat seeds with elaiosome adapted for ant dispersal.

Recent genetic research has demonstrated that most Scottish small cow-wheat populations are highly inbreeding, exhibit very low levels of genetic diversity and are highly differentiated from one another (Crichton, 2012). A potential consequence of inbreeding and isolation from gene flow is that remaining populations can become highly adapted to the particular site conditions where they occur. This 'local adaptation' (if it is occurring) combined with low levels of genetic diversity may severely limit the potential of these small, isolated populations to adapt to future climate change.

A full description of the ecology of small cow-wheat can be found in Dalrymple (2007). Scottish sites that support small cow-wheat can be summarised as follows:

- Often in principally deciduous upland woodland communities (National Vegetation Classification W11 or W17) or in some cases, the community is similar in composition to the understory vegetation of these communities but tree canopy is absent.
- Tree canopy cover (or shading created by local topography) of > 30% and showing a negative correlation between canopy cover and altitude, i.e. with increasing elevation, the coverage from a tree canopy reduces.
- A broadly northerly aspect.
- Distance to water bodies (lochs, rivers or streams) usually < 20 m.
- Altitude of 110–640 m above sea level.
- According to the Forestry Commission's Ecological Site Classification system, an accumulated day-degrees > 5°C (AT5) within the range of 441–1207, and a moisture deficit within the range of 0-106 (White *et al.*, 2000).

- The probability of disturbance is low to medium: sites are often at the edge of steep gullies or in marginal woodland and may be disturbed by, for example, deer moving through the population, but more extensive disturbance is very rare.
- Suitable host plants are usually trees such as birch, but may also include legumes, and whilst small cow-wheat will attach to shrubs such as blaeberry, cultivation trials suggest that this is not a good host plant.

History of decline, contributory factors and current threats

A key cause of the historical decline of small cow-wheat has been the loss and fragmentation of its woodland habitats due to extensive felling of woods for timber, conversion of woodland to agricultural land, and unrestricted heavy grazing of upland habitats by deer and domestic livestock. In addition to the direct loss of woodland habitat, unfavourable management, such as overgrazing, fencing to exclude grazing animals, planting of dense conifer stands, and fertiliser run-off from nearby farmland, has further degraded the habitat quality of remaining sites where this species occurs.

The small size, isolation, low levels of genetic diversity and lack of dispersal capacity leaves the remaining populations of small cow-wheat highly vulnerable to extinction. The breakdown of the mutually beneficial relationship as a result of the loss of wood ants reveals the parallel loss of species composition that is evidently occurring in the isolated and degraded fragments or 'refuges' where there the populations remain.

This species shows a requirement for cool, humid sites in the UK, and is likely to be susceptible to climate change. It is conceivable that gradual warming of the climate since the end of the last glacial period has contributed to the current restricted distribution of this species. Predicted future climate change almost certainly poses a threat to the long-term survival of this boreal-montane species in Britain.

Aims

Aims for 2007-2012

The main aims were to:

- Enlarge existing small and isolated populations.
- Reintroduce wood ants to mobilise seed at remaining sites.
- Establish new populations with high genetic diversity in surviving wood ant areas.
- Establish new populations of small cow-wheat with high genetic diversity and wood ants in newly established pine or birch woods.

Additionally, the aims of a PhD research project which ran concurrently with the SAF project were to:

- Understand the diversity and distribution of genetic and phenotypic diversity of the species.
- Develop horticultural protocols to enable conservation translocations and *ex situ* collections to be carried out with greater rates of success.

Management Action

Summary of the main actions carried out

- **Local population expansion trials** were carried out in 2010 at Glen Tilt by the Cairngorms Rare Plants Project as a pilot for wider implementation at other sites. Following signs of initial success, this was followed up with additional plots at Glen Tilt and similar work is now underway at a further two sites – the Birks of Aberfeldy and Keltneyburn.
- **Cultivation techniques** were developed for small cow-wheat creating an 'insurance' *ex situ* collection, and producing seed for restoration work.
- **Creation of new populations** in unoccupied but potentially suitable habitat was implemented in 2005 by the University of Aberdeen and Forest Research and continued throughout the SAF period with mixed success.
- **Genetics research** was undertaken at the Royal Botanic Garden Edinburgh (RBGE) and University of Aberdeen in 2008-2012 to study

the effects of fragmentation on genetic diversity and inform future conservation work on this species.

- **The feasibility of introducing small cow-wheat to sites supporting wood ants** was explored but the habitat requirements of each species were found to be too different to warrant further action, with the exception of one site.
- **Habitat management** including small-scale targeted actions, such as bracken and canopy management, and larger-scale actions, such as woodland restoration, has been implemented or is currently being taken forward as part of long-term management plans at five key sites for this plant.

Local population expansion

The aim of local population expansion work is to increase the extent of small cow-wheat populations, thereby reducing the risk from localised threats such as brash dumping following forestry activities, landslides and vehicle damage, all of which have reduced the size of Scottish small cow-wheat populations in the last decade. At sites where the number of plants is large, seed production is plentiful and dispersal limitation is evident, there is clearly a case to intervene and assist the plant to reach nearby areas of suitable habitat. The following sections describe a trial to establish small cow-wheat in areas of suitable unoccupied habitat in close proximity to an existing population in Glen Tilt. This population achieves the highest densities of any Scottish small cow-wheat population and therefore made an ideal candidate for local population expansion.

Location of work

One of the largest small cow-wheat populations in Scotland occupies a site on the east side of the River Tilt (NN8869). Although the extent of the population is limited by the valley side to the west and a track to the east, there is potentially suitable unoccupied habitat immediately to the south and across the track to the east.

Methods

Five planting plots of 2 x 2 m were established in carefully selected areas of habitat to the east and south of the natural population (Fig. 3) and marked at the corners with wooden pegs to permit future monitoring. Seeds were collected from the natural population on 26 September 2010 and sown into the five plots the following day. 300 seeds were planted in each plot by scattering them over the entire area. Plots were monitored in 2011 and 2012 when counts were made of small cow-wheat plants inside and around the plots. Plants were also assigned to two health classes, and the relative proportions in each class recorded: (i) large plants (15-25 cm tall) with regular branching and many flowers = healthy, (ii) small plants (<10 cm) with no side branches and few or no flowers = poor.

Fig 3. Location of small cow-wheat population expansion plots established at Glen Tilt in 2010 and 2012.

Results

Small cow-wheat plants were recorded in all five planting plots in 2011 and 2012. However, there was considerable variation in the number of plants per plot and the relative proportions of plants in each health class (Table 1). Plot 1 was least successful with 95 plants in 2011 and only three plants in 2012. This plot was situated at the upper edge of the woodland, furthest away from the river, and had a much higher cover of tall grasses compared to the other plots. In the four remaining plots, the number of plants increased between 2011 and 2012. Plots 3, 4 and 5 contained between 192 and 425 in 2012 and the vast majority of them were classed as healthy. Some unexpected movement of seeds had taken place since planting in 2010. Groups of plants had established outside plots 3, 4 and 5 (but within only 1–2 m of them) suggesting that some very local dispersal of seed had taken place.

Table 1. Monitoring data for small cow-wheat population expansion plots established at Glen Tilt in 2010.

Plot no.	No. seeds sown	Vegetation description	SCW plants 2011[1]	Plant health 2011	SCW plants 2012[2]	Plant health 2012
1	300	Height: 30-50 cm Graminoids: 80-85% Forbs: 10% Open/mossy: 5%	95 [31.5%]	25% 15-25 cm tall, regular branching, many pairs of flowers. 75% of plants <10 cm tall, no branching, few or no flowers.	3 [↓97%]	All plants <10 cm tall, no branching, few or no flowers.
2	300	Height: 20-40 cm Graminoids: 50-60% Forbs: 20-25% Open/mossy: 20-25%	98 [32.5%]	65% 15-25 cm tall, regular branching, many pairs of flowers. 35% of plants <10 cm tall, no branching, few or no flowers.	129 [↑31.5%]	50% 15-25 cm tall, regular branching, many pairs of flowers. 50% of plants <10 cm tall, no branching, few or no flowers.
3	300	Height: 15-35 cm Graminoids: 20-25% Forbs: 35-40% Open/mossy: 35-40%	253 [84%]	80% 15-25 cm tall, regular branching, many pairs of flowers. 20% of plants <10 cm tall, no branching, few or no flowers.	425 [↑68%]	85% 15-25 cm tall, regular branching, many pairs of flowers. 15% of plants <10 cm tall, no branching, few or no flowers.
4	300	Height: 15-35 cm Graminoids: 10-15% Forbs: 30-35% Open/mossy: 40-50%	124 [41%]	90% 15-25 cm tall, regular branching, many pairs of flowers. 10% of plants <10 cm tall, no branching, few or no flowers.	192 [↑55%]	90% 15-25 cm tall, regular branching, many pairs of flowers. 10% of plants <10 cm tall, no branching, few or no flowers.
5	300	Height: 20-40 cm Graminoids: 10-15% Forbs: 50-60% Open/mossy: 30-35%	229 [76%]	90% 15-25 cm tall, regular branching, many pairs of flowers. 10% of plants <10 cm tall, no branching, few or no flowers.	315 [↑37.5%]	90% 15-25 cm tall, regular branching, many pairs of flowers. 10% of plants <10 cm tall, no branching, few or no flowers.

Values given in [] are [1]the % of seeds planted per plot in 2010 which had established as plants in 2011, and [2]the % change between the number of plants per plot in 2012 compared to the number in 2011. Monitoring was conducted on 22/06/2011 and 26/07/2012.

Following the initial success in plots 3 to 5, three additional plots of 5 x 2 m were created to reinforce these areas (Fig. 3) and similar work commenced at the Birks of Aberfeldy and Keltneyburn in 2012. Three plots have been planted at Birks of Aberfeldy, and there are plans for further expansion. At Keltneyburn the small cow-wheat population is very small (<50 plants), so a small number of seeds were collected in 2012, to be germinated and grown at the RBGE with the intention of producing more seed for planting in unoccupied habitat near the existing population (see following section).

Cultivation protocols

Owing to the rarity of small cow-wheat, and the vulnerable state of remaining populations, cultivation protocols have been developed to produce seed for experimental work at the RBGE and the Cruickshank Botanic Garden, Aberdeen. More recently, seed has been 'bulked-up' for local expansion work i.e. seed was grown in favourable *ex situ* conditions where release from competition and herbivory produces greater seeds yields than in the wild. An *ex situ* collection of small cow-wheat is now maintained at the RBGE. The following is a brief summary of the protocols reported by Crichton *et al.* (2012) and findings of research projects conducted at the University of Aberdeen.

Recommended method of cultivation

Seeds can be collected from wild plants or those in cultivation as soon as the seed pods have split, usually from late July. Seed should be transferred quickly and stored in cold (4-6°C), moist, breathable conditions where viability can last for three months, and potentially longer (although this has not been tested).

Seeds break their winter dormancy through prolonged exposure to cold temperatures, including temperatures below freezing. Preferentially sowing seeds that have undergone the first germination by producing a radicle (the emerging root) leads to higher establishment success. Seeds that do not produce a radicle may simply be dormant. Cultivation conditions must meet both the over-wintering requirements of the seed, and the growing season requirements of the plant. During the growing season plants require cool, humid, shaded environments with moist but free-draining soils. This has been achieved by sowing small cow-wheat in pots filled with a mix of compost and sand, using shade fabric and careful watering. As small cow-wheat is hemiparasitic, the roots of a suitable host plant must be near to the seedling to allow parasitism. Host plants successfully used in cultivation include legumes such as tufted- and bush vetch, and saplings of downy birch and rowan. Small cow-wheat is able to set seed without the need for cross-pollination. If seed is to be used for planting back into wild populations, it is important to ensure the pure provenance of the seed by preventing cross-pollination between plants of different populations using net fabric 'cloches'.

Results

Germination of small cow-wheat in cultivation is usually around 40% of the seeds sown (Crichton *et al.*, 2012). This figure is similar to that reported from wild populations but with the benefit that post-germination survival is much improved in cultivation.

Creation of new populations

An attempt to create new populations of small cow-wheat in the Forest Habitat Network in highland Perthshire was initiated in 2005. The aim was to investigate how small cow-wheat survival was affected by i) the identity of the populations from which seed was collected, and ii) the habitat at the sites receiving seeds. The trial was intended to inform any future attempts to create populations on a bigger scale.

Methods

Small cow-wheat seeds were moved to six sites within the extent of its former Scottish range. Seeds were translocated in three phases (2005, 2006 and 2008) to different combinations of the six receptor sites. Each phase of translocation used increasing numbers of seed: approximately 100 seeds per site in 2005, 360 seeds in 2006 and 500 seeds in 2008. The trial used an adaptive management approach in that sites that showed promising survival in phases 1 and 2 received additional seed inputs in phase 3.

Results

Findings suggest that future seed translocation should be to sites that are ecologically similar to the donor population and into sites that fall into the cooler and wetter range of environmental conditions currently supporting Scottish populations of small cow-wheat (for a full report see Dalrymple and Broome, 2010).

A follow-up project undertaken in 2010 compared the sites used in the original translocation work with four natural populations in terms of climate data, soil nutrient content, slope, distance to the nearest water body and canopy cover. The latter two variables were more influential than climatic factors in explaining the success of attempts to create small cow-wheat populations. Sites that had been selected for the creation of new populations but had failed to support small cow-wheat were associated with greater distances from rivers or streams and had higher canopy cover.

Introduction of small cow-wheat to sites supporting wood ants

In 2008 and 2009 several sites in the Glen Affric area known to support wood ant nests were investigated for their potential to provide suitable habitat for small cow-wheat. Most sites were dismissed because the canopy was too open and the ground flora was unsuitable. Red Burn at Dundreggan Estate was selected as a small cow-wheat introduction site because wood ants were present, the site was close to a waterfall and deciduous woodland was being regenerated in the area. Four hundred seeds were moved from a nearby population in Glen Affric growing in very similar conditions in 2009. The following year, 77 plants had germinated and 69 of these were flowering. This project was part of the Trees for Life ground flora restoration programme and further monitoring was undertaken by them.

Extensive searching for sites supporting wood ants that might also support small cow-wheat was conducted in the Cairngorms National Park, a remaining stronghold for wood ants. Unfortunately,

these searches were without success because of two key factors: (i) the extent of broadleaved woodland suitable for small cow-wheat is very limited within the Park, and (ii) wood ants mainly occur in pinewoods unsuitable for small cow-wheat.

Habitat management recommendations

Generic site management must aim to maintain the conditions that support healthy small cow-wheat populations (see General Ecology section above). Some management interventions are described below:

- Prevent the encroachment of invasive species such as bracken and rhododendron, both of which will shade out small cow-wheat and are unlikely to be suitable host plants.
- Prevent heavy grazing such as that caused by enclosed livestock; but see following point.
- Avoid the understory community developing into 'rank' vegetation by allowing some grazing such as that resulting from sustainable unenclosed deer herds and healthy populations of small mammal herbivores.
- Prevent the abstraction of water from water bodies proximal to small cow-wheat populations where this will have a detrimental effect on ambient humidity levels.
- Restore and extend the extent of suitable broadleaved woodland habitat through regeneration or planting at, or close to, sites where this species remains.
- Maintain or improve the status of wood ant colonies (genus *Formica*) that may contribute to small-scale seed dispersal.

Habitat management has not been attempted with the exception of sites on Atholl Estate, Perthshire, where there is a small but growing small cow-wheat population. Bracken swiping commenced in the summer of 2012. Tree guards were put on 20 naturally occurring tree seedlings in October 2012 to protect them from sheep and deer browsing.

Lessons Learnt, Further Work and Future Recommendations

We make seven points to help with further work:

- **Local population expansion is a feasible option for increasing population extent** – assuming that suitable habitat is available nearby, moving seed from populations which are dispersal-limited is a realistic option for maintaining or enhancing numbers of plants.
- **Ex situ cultivation can be used to bulk-up seed with easily available horticultural equipment** – if seeds from multiple sources are to be cultivated and returned to wild populations, care should be taken to record the identity of the parent populations and isolate them from pollen exchange.
- **Creation of new populations has been largely unsuccessful** – only two of six sites continue to support small cow-wheat plants in very small numbers.
- **The species is highly inbreeding**, and most Scottish populations exhibit very low levels of genetic diversity and are genetically and morphologically differentiated from one another.
- **Avoiding further reductions in the number and size of existing small cow-wheat populations is imperative** to conserve remaining genetic diversity.
- **Local adaptation may be a potential constraint** on the success of translocations of small cow-wheat to new sites – donor and receptor sites should be carefully matched to increase chances of success.
- **Wood ant habitat and small cow-wheat habitat rarely coincide** and where habitat requirements for both species are met, it is uncertain as to whether wood ants can effectively disperse small cow-wheat seeds.

To support the continued survival, and ideally expansion, of small cow-wheat, we recommend that favourable woodland habitat be maintained, restored and expanded where possible. Local population expansion can be effective in carefully selected circumstances but the creation of new populations has not, so far, proved to be a successful strategy for the recovery of small

cow-wheat in Scotland. Guidelines for monitoring small cow-wheat populations can be found in Dalrymple (2015).

New and ongoing work since SAF ended

Work on small cow-wheat since the completion of SAF has focussed on monitoring of attempts at population expansion through small-scale movement of seeds and the further cultivation of plants. The RBGE is now the lead partner in small cow-wheat conservation.

Further Information

- http://www.snh.gov.uk/protecting-scotlands-nature/species-action-framework/species-action-list/cow-wheat/ – Scottish Natural Heritage (SNH) Species Action List: small cow-wheat page.
- http://cairngormsrareplants.org.uk/ – Cairngorms Rare Plant Project website, with information on ecology and distribution and an identification guide.
- http://www.forestry.gov.uk/fr/INFD-6ACEMK – Forest Research Species Recovery Project, small cow-wheat page.

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Key Management Messages

- Maintain suitable habitat supporting extant populations, including through control of invasive species, maintenance of favourable grazing regimes and prevention of the canopy becoming closed.
- Local population expansion may prove to be a useful method for improving the resilience of populations to small-scale threats such as landslides, vehicular damage and trampling.
- Collections of the species are maintained at the RBGE and will be important in generating seed for experimental work and possible translocations in the future.

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The SAF Partners

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- University of Aberdeen
- Cairngorms Rare Plants Project
- Royal Botanic Garden Edinburgh

The Species Action Framework Handbook

This account comes from the Species Action Framework Handbook published by Scottish Natural Heritage. For more information on the handbook please go to www.snh.gov.uk/speciesactionframework.

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