Looking after

Corn Buttercup

Ranunculus arvensis

Ecology and Conservation Portfolio

BACK FROM THE BRINK

HERITAGE FUND

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At a glance

Common name: Corn Buttercup

Scientific name: *Ranunculus arvensis*

Habitat types: cultivated arable fields of winter-sown crops, as well as on road verges alongside arable fields and on disturbed soils in grasslands that were once arable

Soil type: mostly heavy clay soils

GB status: Critically Endangered

Contents

Note that many of the sites mentioned in this report are privately owned and not publicly accessible without landowner permission.

Species description

Corn Buttercup is a delicate, branched plant up to 50 cm tall with often rather reddish stems. The leaves are stalked and deeply divided with 3-5 lobes. They are more elongated and linear than those of the commoner buttercup species (Figure 1). The flowers are typical of buttercups, but are smaller, up to 12 mm across, and pale lemon-yellow. The large seeds are distinctive; up to 8 mm long, oval and covered in spines that are up to 2 mm long (Figure 2). Each flower produces up to eight seeds[1].

The prickly seeds distinguish this species from most other buttercups except Rough-fruited Buttercup *Ranunculus muricatus*, which is restricted to the Isles of Scilly and a few mainland populations. Corn Buttercup seeds are prickly all over including the 'spine' of the seed, unlike Rough-fruited Buttercup which has a spine-free edge. Small-flowered Buttercup *Ranunculus parviflorus* seeds have small, relatively inconspicuous, hooked spines on their edges, and are usually much smaller, between 2.5-3 mm long (Figure 3).

Lifecycle and ecology

Corn Buttercup is an annual herb, flowering from May to early July (Figure 4). Seeds mature from June to August and germinate during autumn and winter[1] (Figure 5), although it can germinate in the spring[2]. Seeds turn from green to dark brown in colour and the skin becomes a woody husk (Figure 6).

Accelerated aging experiments under controlled conditions found Corn Buttercup seed was the longest-lived of the 16 buttercup species tested[4]. While these tests do not replicate the conditions experienced by seed 'in the field', they do support the general view that buried Corn Buttercup seed may remain viable in the soil for many years. Thus, it is thought to have medium-term seed longevity, depending on soil conditions[5].

Corn Buttercup plants may be bisexual or gynomonoecious (bearing bisexual and female flowers on the same plant) (Figure 7). Cross-pollination is by small flies and potentially other insects; pollinator interactions for this species have not been described, although other buttercup species are generalists, attracting a broad range of insects[3]. Although plants may display protandry (male parts of the flowers developing first) and other mechanisms to favour cross-pollination, these are not not always present and some self-fertilisation is likely to take place[5].

Figure 1: Plants are often rather delicate and graceful with deeply divided leaves with 3–5 lobes © Francis Buner

Figure 2: Corn Buttercup has characteristic buttercup flowers which are lemon-yellow and have five petals. However, the seeds are distinctive with their large, long spines © Alex Hyde

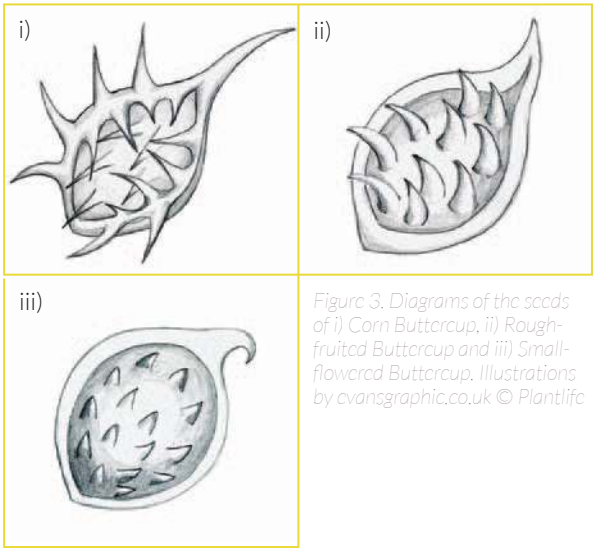

Figure 3. Diagrams of the seeds of i) Corn Buttercup, ii) Rough-fruited Buttercup and iii) Small-flowered Buttercup. Illustrations by evansgraphic.co.uk © Plantlife

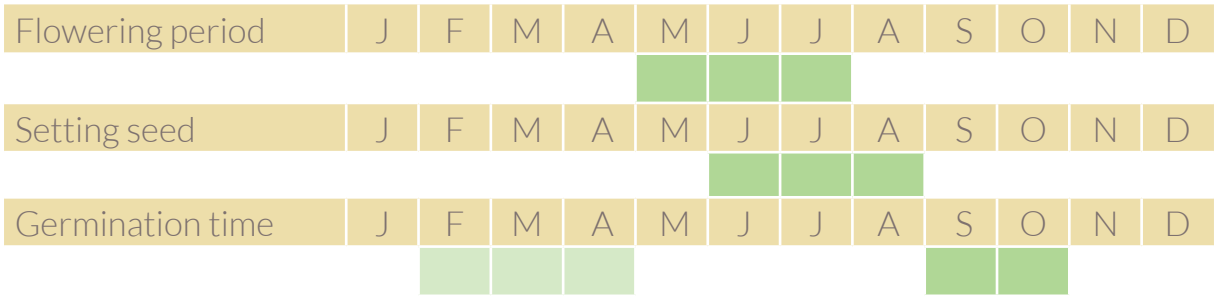

Figure 4: Flowering, seed-setting and germination periods for Corn Buttercup

Corn Buttercup seeds display two forms of dormancy – morphological and physiological – commonly described together as morphophysiological dormancy[6]. As with many species in the buttercup family, the seeds of Corn Buttercup have under-developed, rudimentary embryos at dispersal, resulting in morphological dormancy. Embryos must fully develop inside the seed before germination can occur. The environmental conditions needed for this development differ between species, but may include a period of warm, dry weather to promote after-ripening following seed dispersal. When the embryo has developed fully, physiological dormancy prevents immediate germination of the seed. Corn Buttercup seeds have a hard, thick covering structure which the radicle (root tip) is unable to penetrate. This mechanical restriction is overcome naturally by splitting or decay of the covering structures through repeated cycles of warm-dry and cool-wet conditions over seasons[5]. Buried seed is less likely to experience these weathering effects, which is perhaps one of the reasons why ploughing is so essential for Corn Buttercup, and why smaller populations are found under minimum tillage cultivation.

Figure 5: Newly germinated Corn Buttercup seed © Tristan Norton

Figure 6: Semi-ripened Corn Buttercup seed turning from green to brown © Cath Shellswell

Figure 7: Corn Buttercup flowers which are thought to be pollinated by small flies and other insects © Alex Hyde

Habitat

Corn Buttercup is primarily a species of cultivated arable fields of winter-sown crops where it was once considered a 'pestilential weed' across much of eastern England. Indeed, one reference indicates that Corn Buttercup is considered a 'greedy plant, inhibiting the growth of nearby plants, especially legumes[7].

It has been known to occur on road verges alongside arable fields and on disturbed soils in grasslands that were once arable. The species is most often found on heavy clay soils[1,2] where it can co-occur with a number of other uncommon arable plants including Shepherd's-needle *Scandix pecten-veneris*, Spreading Hedge-parsley *Torilis arvensis*, Broad-leaved Spurge *Euphorbia platyphyllos* and Broad-fruited Cornsalad *Valerianella rimosa*.

Soil profile

Soil tests were taken from 15 populations of Corn Buttercup from Somerset, Worcestershire and Wiltshire. Corn Buttercup is in sharp decline across its range, but there are other locations with extant populations and further soil sampling is recommended to gather a comprehensive account of the soil conditions within which this species inhabits. Soil texture, pH and soil nutrient tests were undertaken.

> Corn Buttercup is a species of cultivated arable fields where it was once considered a 'pestilential weed'

Soil pH

The soil pH ranged from 6.2 neutral to 7.9 calcareous with an average pH of 7.3. Soils with a higher sand component derived from weathered rock had a lower pH compared to soils with more clay. Where several populations were sampled from the same farm, the pH was relatively similar with the exception of a site in Worcestershire which had five populations of Corn Buttercup. On this one holding the soil pH varied between 6.2 and 7.8.

Soil texture

Corn Buttercup was generally present on clay loams, sandy silt loams and a couple of populations were present on sandy loams (Figure 10). The clay and silt loams had lower water permeability than the sandier more free-draining soils, and some of the populations were found in bare open areas adjacent to crops where standing water had pooled. Corn Buttercup is considered a species of heavy clay soils, and the results of the soil texture test show that it grows across a wider range of soil conditions than previously assumed.

Proportion of bare ground

The amount of bare ground around Corn Buttercup populations varied enormously between populations in different fields on the same holding and between holdings. If growing within a crop or densely vegetated margin, the amount of

Changes in Corn Buttercup at Fivehead Arable Fields SSSI in Somerset

Fivehead Arable Fields is owned and managed by Somerset Wildlife Trust and is one of three Sites of Special Scientific Interest (SSSI) notified for the assemblage of rare arable plants.

Figure 8: Seed of Corn Buttercup © Alex Hyde

Crops have not been grown in the fields since 2017-18 when the site was entirely given over to wildlife. The three fields are split into four management units, with the largest field split into two. In any single year, three units are autumn-cultivated and one spring-cultivated to control problem plants.

The rare arable plant populations at Fivehead Arable Fields have been monitored using a Rapid Assessment method since 1997, with some gaps in surveillance. Over time, the number of positive indicator species has been increased, negative indicator species have been included, the number of quadrats has been reduced to 20 per management unit and the quadrat size has been reduced from 2x2 m to 1x1m. Negative indicator species are only recorded when they cover more than 20% of the quadrat, with lower levels tolerated for the food and shelter that they provide for invertebrates, small mammals and farmland birds.

> Monitoring of rare arable plants has been undertaken at Fivehead Arable Fields since 1997

In 2010, Onion Couch *Arrhenatherum elatius* var. *bulbosum* was the first negative indicator species to be added to the monitoring. Black-grass *Alopecurus myosuroides*, Wild Oat *Avena fatua*, Creeping Thistle *Cirsium arvense* and Spear Thistle *Cirsium vulgare* as a single group, Bristly Oxtongue *Helminthotheca echioides* and Perennial Sowthistle *Sonchus arvensis* were added in 2017.

The largest population of Corn Buttercup (Figure 8) is in management unit 3. It grows throughout the unit, with an estimated count of 17,000 plants in 2019 and was found in 95% of quadrats. All the

other management units contain considerably smaller populations (a maximum count of 300 plants) and it has never been recorded in units under spring cultivation.

The population of Corn Buttercup has varied over time in Field 3. The unit was autumn-cultivated in 2017, 2019 and 2020 (Figure 9). Corn Buttercup was recorded in a third of quadrats in 2017 but was not present in 2018 under the spring cultivation. The data shows a sudden fall in all negative indicator species except Perennial Sowthistle in June 2018. This is probably related to the autumn-germinating grasses, thistles and Bristly Oxtongue being affected by the spring cultivation. However, the lower competition may have allowed Perennial Sowthistle to increase in 2018 as it had over 20% cover in 95% of the quadrats. In 2019, Corn Buttercup was present in 95% of the quadrats and most of the negative indicators were present in low quantities. The exceptions were Wild Oat which recovered quickly and covered over 20% of each quadrat in 2019 and Perennial Sowthistle which fell in frequency, possibly due to competition by Wild Oat.

The results in 2020 indicate that the grass weeds are again on the rise with Onion Couch increasing and a downturn in the number of quadrats with Corn Buttercup. The population decrease between 2019 and 2020 could be related to a number of factors. Due to very wet weather in autumn 2019, a rough plough was undertaken and it could not be harrowed leaving clods of soil in rows which then capped and hardened in the spring drought of 2020. This may have prevented young Corn Buttercup seedlings from establishing a good root base, and also caused the desiccation of some plants that were on tenuous ground on the top of the plough ridges. Corn Buttercup also displays a complex seed dormancy which could mean the large amount of seed produced by the 2019 population boom may not have ripened in 2020 but could do so in future years. The high overall weed load may also have suppressed Corn Buttercup seedlings thus reducing the population size.

> The high weed load may have supressed Corn Buttercup seedlings, reducing the population in 2020

Fivehead Arable Fields is a stronghold for Corn Buttercup and the management of the site is being carefully considered by Somerset Wildlife Trust and Natural England with help from Plantlife. Continued annual monitoring will help to inform the management of the reserve so that Corn Buttercup has the opportunity to thrive.

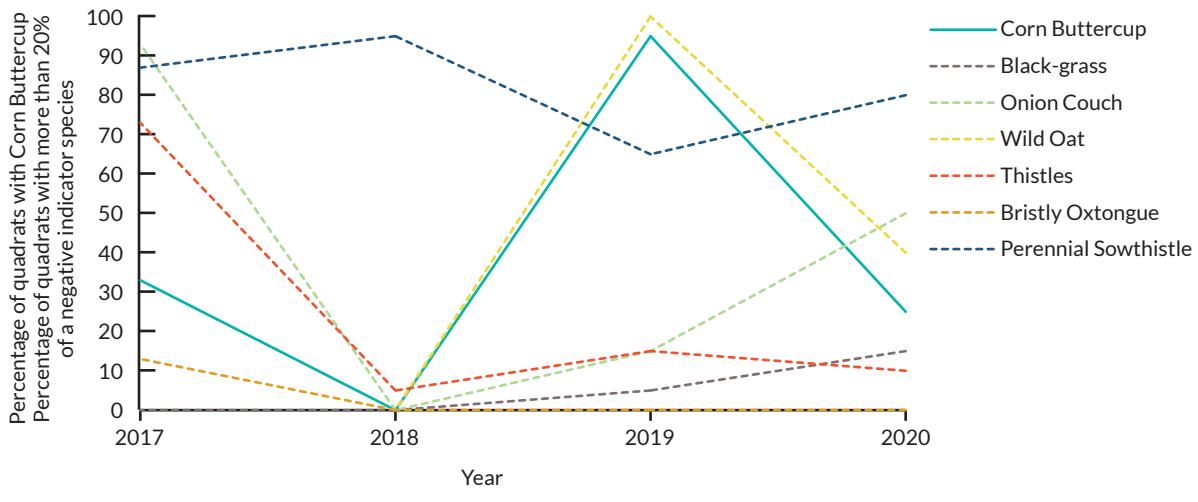

Figure 9: Percentage of quadrats with Corn Buttercup and over 20% cover of negative indicator species between 2017-2020 in Management Unit 3 at Fivehead Arable Fields SSSI

bare ground within a 0.5 m radius of a plant was below 10%, whereas in a sparse margin there could be 90% bare ground with few associated species. The average amount of bare ground within a 0.5 m radius of a Corn Buttercup plant was 39%.

These results suggest that the degree of openness surrounding populations of Corn Buttercup is not necessarily a restrictive factor for adult plants, but shading may deter germination and seedling establishment. However, the degree of soil disturbance may be a factor, especially in view of the complex seed dormancy.

Soil nutrients

Corn Buttercup typically grows on arable land in the UK and, as a consequence, is subject to a range of soil nutrient conditions (Figure 11).

Phosphate varies between 5 ppm (Index 0.5) and 26 ppm (Index 3) with an outlier at 37 ppm (Index 3.6). The average phosphate level was 16 ppm (Index 2.0).

Potassium was also variable between 176 ppm (Index 2.4) and 706 ppm (Index 5.4). Average potassium was 416 ppm (Index 4).

Magnesium varied between 80 ppm (Index 2.5) and 267 ppm (Index 5.2) with an extremely high outlier with a level of 1271 ppm (Index 8.5). This may be an analytical error in the test results. The average magnesium level, excluding the outlier, was 170 ppm (Index 3.8).

Not all soil samples were tested for calcium levels. For those samples that were tested, soil calcium levels ranged from 1630 - 6635 ppm.

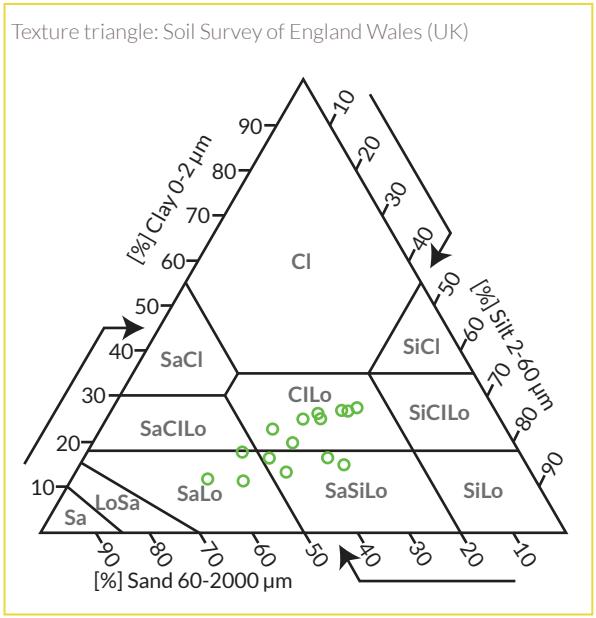

Figure 10: Soil triangle displaying the proportions of clay, silt and sand present at 15 Corn Buttercup populations

There is still much to learn about available soil nutrients and uptake by plants. It appears that Corn Buttercup can survive in a range of conditions and that soil nutrients are not necessarily restrictive.

Vegetation communities

A study of Corn Buttercup populations between 2008-2013 found that the most commonly associated species were Fool's Parsley *Aethusa cynapium*, Black-grass *Alopecurus myosuroides*, Scarlet Pimpernel *Lysimachia arvensis*, Cut-leaved Crane's-bill *Geranium dissectum*,

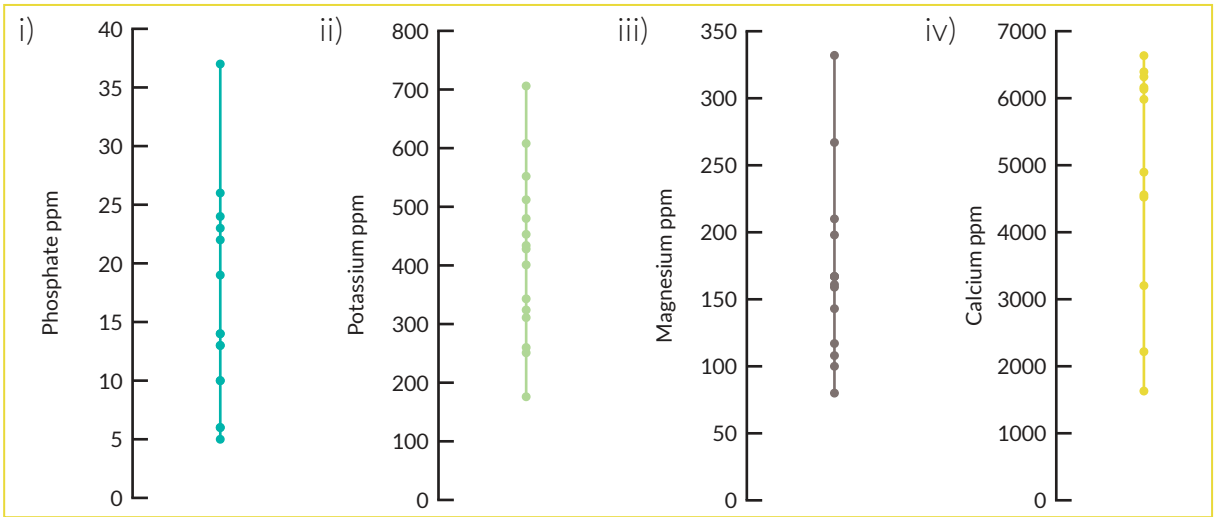

Figure 11: Major plant nutrients present in the soil at 15 populations of Corn Buttercup; i) Phosphate, ii) Potassium, iii) Magnesium (excluding an outlier) and iv) Calcium

Charlock *Sinapis arvensis* and Common Field-speedwell *Veronica persica*. Other threatened plants that occurred with Corn Buttercup included Field Gromwell *Lithospermum arvense*, Shepherd's-needle *Scandix pecten-veneris* and Corn Spurrey *Spergula arvensis*[8]. A more recent National Vegetation Classification[9] study was undertaken at 15 Corn Buttercup sites, in order to improve understanding of the plant communities in which it occurs.

More than half of the Corn Buttercup populations were found to be loosely within an OV15 Scarlet Pimpernel *Lysimachia arvensis* – Common Field-speedwell *Veronica persica* community. These communities are generally associated with lighter calcareous soils derived from chalk and limestone, particularly in the drier south-east and southern England regions. However, all of the Corn Buttercup populations were on poorly draining soils with a high clay and silt content. Five of the populations were on clay overlying limestone bedrock, which increases the topsoil alkalinity. Four of the populations were present on the same holding, and as a result had very similar species. This is a particularly species-rich site, being designated as a Site of Special Scientific Interest for its arable plant assemblage; scarcer species associated with Corn Buttercup included Shepherd's-needle, Spreading Hedge-parsley *Torilis arvensis*, Stinking Chamomile *Anthemis cotula*, Slender Tare *Ervum parviflora*, Dwarf Spurge *Euphorbia exigua* and Broad-leaved Spurge *E. platyphyllos*, Corn Parsley *Sison segetum*, Round-leaved Fluellen *Kickxia spuria*, Narrow-fruited Cornsalad *Valerianella dentata* and Broad-fruited Cornsalad *V. rimosa*, Green Field-speedwell *Veronica agrestis* and Grey Field-speedwell *V. polita*. Common species included Common Vetch *Vicia sativa*, Scarlet Pimpernel, Knotgrass *Polygonum aviculare* agg., Field Bindweed *Convolvulus arvensis*, Creeping Buttercup *Ranunculus repens*, Charlock, Bristly Oxtongue *Helminthotheca echioides*, Onion Couch *Arrhenatherum elatius* var. *bulbosum*, Common Couch *Elymus repens*, Wild Oat *Avena fatua* and Perennial Sowthistle *Sonchus arvensis*. The last seven species are also considered an agronomic problem. They have increased at this site which has been under almost continuous autumn cultivation as the soil is often too wet for spring cultivation. Some of these species were also present in association with Corn Buttercup at the other OV15 sites, but these sites lacked the high density and abundance of the scarce and rare plants.

Three populations had affinity with the OV10 Annual Meadow-grass *Poa annua* – Groundsel *Senecio vulgaris* community. This community has frequent Perennial Rye-grass *Lolium perenne* and is considered a pioneer weed community in trampled ground and where cultivated ground has become moist. Other grass species present include Black-grass, Soft Brome *Bromus hordeaceus*, Annual Meadow-grass and Rough Meadow-grass *Poa trivialis* and Creeping Bent *Agrostis stolonifera*. There were some common herbs present such as Knotgrass, Cut-leaved Crane's-bill, Scarlet Pimpernel, Stinking Chamomile, Sharp-leaved Fluellen *Kickxia elatine*, Wall Speedwell *Veronica arvensis* and Creeping Buttercup. This merges into communities associated with trampled vegetation along pathways and gateways, which may also be where standing water has compacted soil over winter.

Two populations were found in the tall herb community OV24 Common Nettle *Urtica dioica* – Cleavers *Galium aparine* community and another two populations were better placed under the OV25 Common Nettle – Creeping Thistle *Cirsium arvense* community. These are fertile loamy soils often around areas where waste has been dumped and are sometimes considered a transitionary habitat to grassier vegetation dominated by False Oat-grass *Arrhenatherum elatius*. This would probably happen were it not for the regular disturbance in the arable field.

> The population of Corn Buttercup declined by more than 80% across the core of its range during the 20th Century

One site was dominated by Black-grass. This conformed to OV8 Green Field-speedwell *Veronica persica* – Black-grass *Alopecurus myosuroides*. However, the low number of Corn Buttercup plants resulted in few samples, skewing the vegetation description.

Distribution

In the UK, this species was formerly widespread across lowland England and Wales, extending to Scotland (Figure 12). The population declined by more than 80% across the core of its range during the 20th Century, but there remains a stronghold in the south-west Midlands. There are also scattered recent records from Cornwall in the south-west to Newcastle in the north-east and Glamorgan in the west to Suffolk in the east[1,2].

A survey undertaken between 2008 and 2013 found Corn Buttercup at just nine out of 49 pre-selected locations. Seven of these sites had post-2000 records, and just two of these sites had last been recorded between 1970 and 1999. The majority of populations

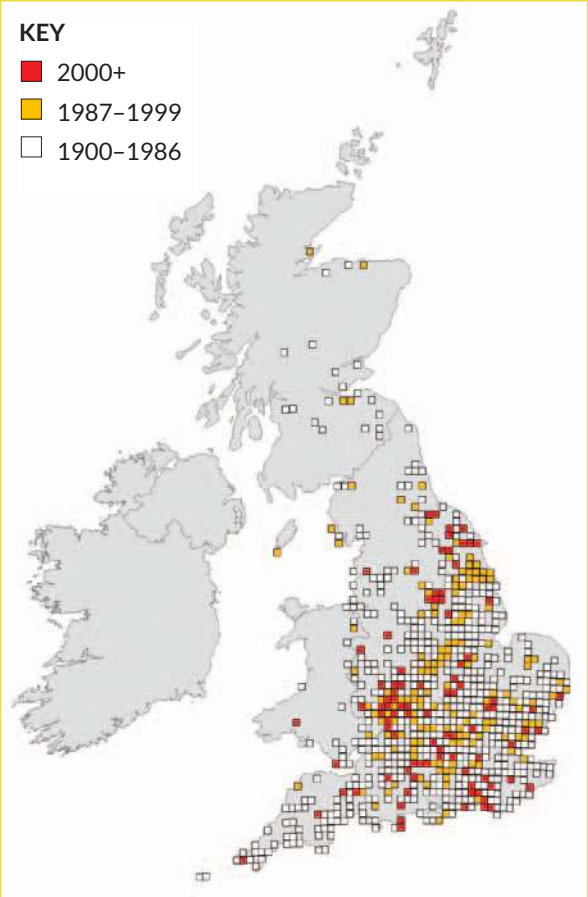

Figure 12: Corn Buttercup distribution across Britain and Ireland. The data used to create this map has been provided under licence from the Botanical Society of Britain and Ireland (BSBI) and accessed from the Society's online database.

Figure 13: Corn Buttercup at Lower Smite Farm in 2019 © Cath Shellswell

surveyed were small with an average of 39 plants (group range 11-100) with some exceptional populations of more than 3,000 individuals. At Fivehead Arable Fields SSSI in Somerset and Lower Smite Farm in Worcestershire, the populations of Corn Buttercup vary enormously from year to year, from very few to over 10,000 individuals in a good year[8] (Figure 13).

Corn Buttercup occurs throughout lowland Europe and is considered Critically Endangered in Andorra, Endangered in the Czech Republic and Germany and Vulnerable in Sweden. It has declined markedly in France and is considered to be Regionally Extinct in Picardy and Critically Endangered in Nord-Pas de Calais and Upper Normandy and Endangered in seven other French regions.

Corn Buttercup is scattered as far as north-west Africa and south-west Asia.

Reasons for decline

The main cause of decline is the intensification of arable farming. Key factors include improved seed cleaning of arable crops, the widespread use of broad-spectrum herbicides and the density of modern crops, as Corn Buttercup competes poorly with a fertilised crop[8]. Fertilised crops tiller vigorously, quickly reducing the availability of light reaching the earth below.

Changes to sowing, particularly the use of minimum tillage cultivation, have particularly affected the remaining populations within the first two decades of the 21st Century. Some populations have been lost to development and this remains a threat to other populations, along with land use changing from arable to permanent pasture.

GB status and rarity

Critically Endangered.

Protection under the law

Corn Buttercup is included as a species of principal importance for the purpose of conserving biodiversity under Section 41 (England) of the Natural Environment and Rural Communities Act 2006 and listed as a priority species under Section 7 of the Environment (Wales) Act 2016.

Cultural connections

Corn Buttercup is also known as Devil-on-all-sides, Scratch Bur or Devil's Claws. All parts of Corn Buttercup are poisonous when fresh and the acidic sap can cause skin blistering. However, the toxins are destroyed by heat. Historically, Corn Buttercup has been used for the treatment of intermittent fevers, gout and asthma[7]. Every member of the *Ranunculus* genus is toxic and can cause ulcers and there are folklore stories of beggars using the sap of buttercups to ulcerate their own feet in order to gain sympathy.

The name *Ranunculus* (the genus of which Corn Buttercup is a member) is Late Latin for 'little frog'. This probably refers to the fact that many buttercup species are found near water, like frogs. The English name buttercup comes from the rumour that the plants make butter yellow, but this is untrue, and buttercups are poisonous to livestock when eaten in large quantities.

A popular children's game also involved holding a buttercup up to the bottom of your chin and its yellow reflection is supposed to mean that you like butter! There have been documented cases that if you were to get a yellow hue under your chin, you would be rich, as if you were able to afford butter in the 1930s you were wealthy. A further tale was if there was a yellow reflection on the chin, you were 'as good as gold' or well-behaved.

> One children's game holds a buttercup up to the chin; the yellow reflection supposedly means you like butter

Discovering a new population of Corn Buttercup in Wiltshire

In 2019, a farm adviser based with the RSPB was made aware of a possible population of Corn Buttercup growing on an organic farm in Wiltshire. The farmer reported seeing swathes of yellow amongst the oat crop in June and July.

By the time a survey for the fields in question was organised, the buttercups had gone to seed and there was very little colour on show (Figure 14). However, on close inspection, a very large population of Corn Buttercup was discovered. The total population number was hard to estimate given its size and location within a crop, but it was thought to be almost 1000 plants if not more, despite being confined to just two field parcels. Corn Buttercup is a very scarce species in Wiltshire, which is dominated by free-draining chalk soils, and this newly discovered population was found growing in an area of heavier soils adjacent to a river.

The fields containing Corn Buttercup were due to go into a grass ley in 2020. However, the farmer was asked to delay harvest, cultivation and the sowing of grass seed for as long as possible in 2019 in order to allow Corn Buttercup to finish seed-set. The farmer was very accommodating and sympathetic towards the needs of this species. It is likely that the farm's organic status has been beneficial for a wide-range of arable plants species that are present on the holding, including Narrow-fruited Cornsalad *Valerianella dentata*, Venus's-looking-glass *Legousia hybrida*, Rough Poppy *Roemeria hispida* and Night-flowering Catchfly *Silene noctiflora*. Additionally, it was noted that whilst the oat crop looked healthy, it was relatively widely-spaced therefore, leaving plenty of room for Corn Buttercup to grow.

A further survey of these fields was carried out in the summer of 2020, but both fields were under grass and being grazed by sheep and no Corn Buttercup plants were found. It is anticipated that there is a substantial quantity of Corn Buttercup seed in the seed bank of these two fields, and as the rotation returns to organic arable management, this species will reappear from buried seed and flourish.

Figure 14: Corn Buttercup © Alex Hyde

Survey methodologies for different population sizes

There are three recommended methods for assessing population size depending on the general abundance of the plant being surveyed.

1 **Counting:** If the number of plants present appears to be small or if they are scattered and easily seen, it is recommended that a simple count is made. This is likely to be the most suitable method if walking around the margin of a field. This method can be difficult if the surrounding vegetation is tall as branching can occur making it difficult to know the extent of a single plant. Giving a plant a wiggle can help identify if more than one plant is present or if a single plant is branched.

2 **Scaling-up using quadrat data:** If plants are scattered evenly throughout the vegetation, it might be worth counting the number of plants within quadrats, taking an average and then scaling-up. The size of the quadrat used will depend on the frequency of the target plant species. This method is probably best suited when Corn Buttercup is present within a crop and not just restricted to the margin and/or if only one or few people are surveying the population. For ease, use a quadrat size no larger than 2x2 m, preferably 1x1 m. For example, ten 1x1 m quadrats were surveyed within a field where Corn Buttercup seemed evenly distributed. An average of 2 plants were found per square metre. The total field size was 1 ha (10,000 m^2) and so the estimated population is 2 x 10,000 = 20,000 individual plants.

3 **Scaling-up using transects:** This is the most suitable method if several people are available to help estimate the population and if the entire field can be walked, for example a fallow field with no crop. The process starts by walking over the site to see if the species occurs throughout the entire area or is restricted to a part of the field. Once the extent of the population has been assessed, the surveyors stand along one edge of the population in a line about 2-3 m apart. Everyone then walks forward together keeping an equal distance between one another – this is easier said than done, and several stops may be needed to line everyone up at intervals and wait for those with more plants to count, as they will be slower. Each surveyor keeps a tally of the number of plants they count within their strip. Once the area has been walked, everyone's counts should be combined to total the population count for the area covered. This process can be repeated in another part of the population area (if only part of the population has been covered in the first transect walk) or scaled-up to estimate a population across the entire extent of the occupied area.

Box 1: Survey methodologies for Corn Buttercup populations

Survey method

For smaller populations of less than 100 individuals the number of individual plants should be counted. The size of larger populations can be estimated and/or the extent of the distribution mapped. Other factors useful to record include the method and depth of cultivation, the crop type, the application method and type of any fertiliser or herbicide that has been applied, soil texture, nutrient levels, and associated species. An example of a recording form is contained within the *Appendix*.

Habitat management

The ideal management for Corn Buttercup on arable land involves annual cultivation in autumn between September and early October, without subsequent disturbance until the plants have flowered and set seed. Seeds are immature when shed in late June/July and require time to ripen[5] (Figure 15).

Corn Buttercup will grow within a crop, such as an autumn-sown cereal, or within an uncropped cultivated area or plot. It is susceptible to broad-spectrum herbicides and their use will reduce population sizes. If Corn Buttercup is growing within a crop, reduced fertiliser application and lower cereal density can increase light levels, benefitting the species; indeed, reduced cereal sowing has been shown to increase rare arable species richness more broadly in cereal crops[10,11]. If necessary, problematic weeds could be treated with targeted herbicides, particularly graminicides for autumn-germinating grasses. Fertiliser can encourage problem weeds and is not usually applied to uncropped

Figure 15: Corn Buttercup seedlings shortly after germination © Caroline Corsie

areas for arable plants and may be restricted on cereal headlands and wildlife cover crops.

Harvesting the crop in late July-August, removing the straw of cereal crops immediately after and allowing a short fallow period before cultivation in September-early October will help Corn Buttercup seed to mature and promote autumn germination. As Corn Buttercup is believed to form a soil seed bank, and can also germinate in spring, populations may also withstand periodic spring cultivation if required for other rare arable species or to control autumn-germinating weeds, particularly grasses.

Corn Buttercup is thought to have medium term persistence in the soil seed bank and may return with the reinstatement of management that provides adequate germination and establishment niches. If the species has not been recorded recently or has failed to return despite favourable management, reintroduction is likely to be needed. Reintroduction should take advantage of natural opportunities for dormancy release and germination, with germination likely to be spread over many years.

Survival of Corn Buttercup in Devon – an outlier site

Corn Buttercup was first recorded within a field at a farm on the eastern edges of Dartmoor in Devon in 2006. This population is on the fringes of its extent and is one of the most westerly known populations of Corn Buttercup.

Surveys were undertaken in 2019 and 2020 to assess the population size and extent, and on both occasions the monitoring revealed that the number of plants reaching maturity was low. In 2019, 20 seedlings were recorded in March yet only one plant reached maturity. In 2020 three plants were seen in both March and June.

The field at this farm is currently part of an arable rotation which includes a two-year Red Clover ley followed by six to seven years of arable cropping. For the most part the cropping consists of autumn-sown crops including wheat, barley, oilseed rape, forage rape (which would always be followed by a spring-sown combinable crop), and oats. This type of rotation has been used for the past ten years or so; previously, the general cropping would have been broadly similar and if anything, more arable and less often sown as grassland. Historically, every crop would have been established by plough; however, in the last five to seven years minimum cultivation has been practised with ploughing limited to once every four to five years.

> This field has been entered into an arable plant option in an agri-environment scheme

There may be several reasons why Corn Buttercup has survived in the field corner. The corner has a heavy clay soil which, due to the contours of the land, tends to pool water periodically in the winter, reducing vegetation growth. Being prone to waterlogging, the field corner is often ploughed or cultivated right to the edge but not drilled which also reduces the surrounding vegetation. Finally, as the corner is wider than 90 degrees, there is a temptation when spraying to sweep around the corner whilst keeping the sprayer switched on, hence the boom tip speed on the outer edge is fast, reducing the dose of herbicide delivered to the field corner.

This field has been entered into an arable plant option in an agri-environment scheme, which is due to start in 2021. The field will be ploughed annually and the field corner will be left untreated with herbicide. These conditions are considered optimal for this species, particularly if cultivated in the autumn and it is hoped that the population will increase.

How do herbicide, season and depth of cultivation affect Corn Buttercup?

A series of trials undertaken at Fivehead Arable Fields Site of Special Scientific Interest (SSSI) investigated the effect of season of cultivation, depth of cultivation and herbicide application on the arable flora, including Corn Buttercup.

Although Corn Buttercup had sporadic and low presence within the trial plots, the experiment was able to establish that the species had an almost exclusive preference for autumn cultivation (Figure 16). There was no significant effect of depth of cultivation or herbicide applications on Corn Buttercup, although this may be related to the low number of plants in the trial plots making any treatment effect undetectable. The sporadic occurrence probably reflected uneven distribution of seed in the soil bank, which is also consistent with heavy seed which has limited opportunities for dispersal in the absence of grazing livestock.

> The experiment was able to establish that the species had an almost exclusive preference for autumn cultivation

There was a possible positive effect of spraying a graminicide (Figure 16). Graminicide, either on its own or in combination with a broadleaf herbicide, led to populations of Corn Buttercup 2-3 times higher compared with plots without these treatments. At Fivehead Arable Fields SSSI, cultivation in autumn was associated with the undesirable grasses Creeping Bent *Agrostis stolonifera*, Black-grass *Alopecurus myosuroides*, Onion Couch *Arrhenatherum elatius* ssp. *bulbosus*, Wild Oat *Avena fatua* and Smooth Brome *Bromus racemosus*. In addition, a number of undesirable weed species were associated with the less intensive cultivation methods of discing and/or harrowing, such as Smooth Brome and Italian Rye-grass *Lolium multiflorum* and the broadleaved weed Bristly Oxtongue *Helminthotheca echioides*. The application of graminicide may have reduced the dominance of these species, enabling more Corn Buttercup seeds to germinate and establish. There was anecdotal evidence that soil inversion methods could also be used to reduce these undesirable species.

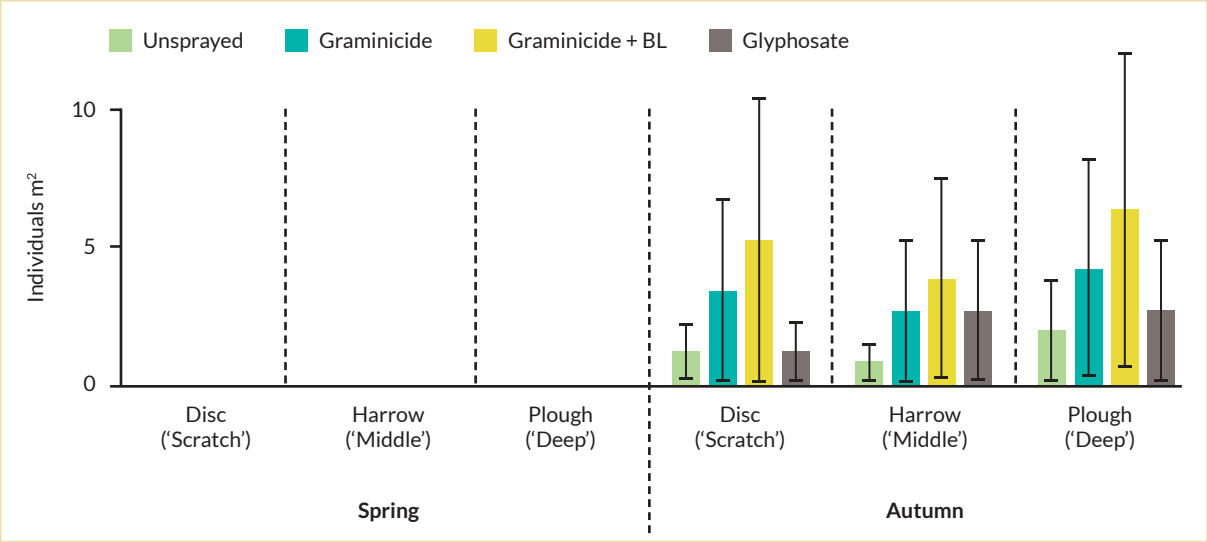

Figure 16: Densities of Corn Buttercup plants within the experimental plots at Fivehead Arable Fields SSSI under: i) different timing of cultivation (spring or autumn), ii) depth of cultivation (discing which disturbs the soil surface and is used for initial seed bed preparation; power harrowing which is a non-inversion method of cultivation creating a tilth to a depth of 10 cm; and ploughing which is inversion tillage, turning over the soil to a depth of 30 cm with a subsequent pass over with a power harrow to create a fine seed bed), and iii) herbicide treatment (untreated; treated with graminicide; treated with graminicide and broad-leaved herbicide; treated with Glyphosate, which kills both grasses and broad-leaved weeds.)

The effect of different cultivation practices on the Corn Buttercup population at Naunton Fields, Worcestershire

Naunton Fields is a Worcestershire Wildlife Trust Reserve in Naunton Beauchamp near Worcester. The Trust recognised the unique assemblage of arable plants surviving in the fields by buying the land in 2006.

The reserve consists of two fields, Church View and Piddle Brook, and the soil texture varies from sandy loam to sandy silt loam. This means that the land is relatively free-draining but there is some pooling of water in areas with more silt. Before 2006, the fields had been farmed conventionally with arable crops.

The importance of the site for arable plants was first recognised in 1990 when Corn Buttercup, Shepherd's-needle *Scandix pecten-veneris* and Field Gromwell *Buglossoides arvensis* were discovered during a survey. In 2001, Corn Buttercup and Shepherd's-needle were recorded as frequent and Field Gromwell as rare across the two fields. In 2007 Corn Buttercup was recorded as rare – occasional, but the majority of plants were seedlings at the time of the survey and cover may have increased later in the year.

The management of the reserve has varied over the years and the fields have been broken into different management blocks. The fields have a range of land management issues. In some years the site cannot be autumn-cultivated due to waterlogging, with the soil remaining wet and unworkable into the spring. The Trust has had problems finding contractors with appropriate cultivation machinery, particularly a plough, as most of the surrounding land is under minimum tillage. There is also quite a high burden of problem species. Various cropping regimes and cultivation methods have been trialled over the years to try and sustain the populations of arable plants, such as low-input cereal crops, winter beans, cultivated fallow and extended over-winter stubbles.

A trial undertaken in 2018-19 investigated whether the method of cultivation affected the arable plants, particularly Corn Buttercup. Both fields were cultivated in autumn 2018 and each field was partitioned with one area ploughed and another area under minimum tillage (Figure 17). Corn Buttercup responded very well to ploughing with 100-300 plants in Church View and over 10,000 plants in Piddle Brook. These areas did have some problem plants, particularly Charlock *Sinapis arvensis*. In comparison, there were no Corn Buttercup plants in the areas that were cultivated by minimum tillage in each field. The sward was very grassy and perennial plants were present in these aareas, most likely due to insufficient ground disturbance and no herbicide. Herbicide is usually used in conjunction with minimum tillage to clear the land of vegetation.

This anecdotal evidence suggests that Corn Buttercup does not respond well to minimum tillage due to its complex germination requirements. Worcestershire Wildlife Trust is now entering a new management phase for the fields and these trials will help inform the management to boost the arable plant populations.

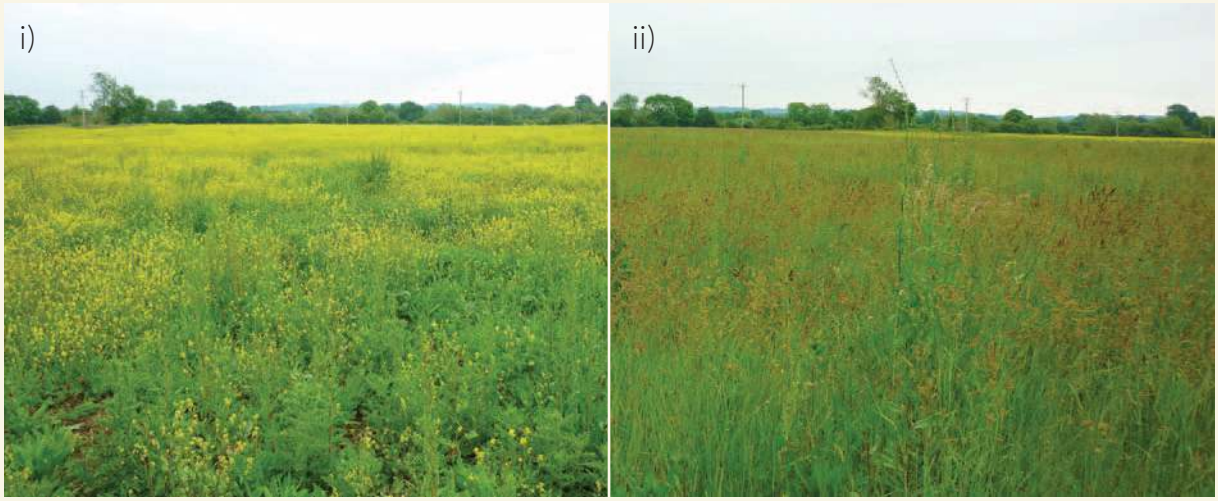

Figure 17: Photos of the vegetation of the fields under; i) ploughing with Charlock and Corn Buttercup present, and ii) minimum tillage with more grasses and perennial broadleaf plants © Cath Shellswell

Reintroduction

Sowing seeds in autumn mimics natural seed dispersal and lets seeds experience the seasonal temperature fluctuations that may be required to weaken the hard covering structure, promote internal hormonal changes and break physiological dormancy. If seeds are kept in suitable conditions (see Storing Wild Flower Seed in *Further reading*) sowing could be undertaken in the spring, but is unlikely to result in many seedlings as the embryo may not have matured and the husk of the seed might not have weakened enough to break dormancy.

The recommended sowing rate for plants with seeds such as Corn Buttercup is 100 seeds per m^2 [12]. The seed is intolerant of shade and should be sown onto a bare cultivated area. Even low levels of shading, for example by young crop seedlings, can prevent germination. The dormancy and germination behaviour of Corn Buttercup appears to be quite variable, making it hard to predict germination and establishment success.

1 g of Corn Buttercup seed contains approximately 89 individual seeds[5].

Areas for further research

Seed longevity

Given the high conservation value of Corn Buttercup and the importance of the soil seed bank in the recovery and persistence of annual plant populations, it would be useful to conduct some longevity or seed aging experiments on this species.

Activity	Timing (month)
Autumn cultivation and sowing	
Prepare the seed bed to create a fine tilth e.g. light cultivation or disking.	September-October.
Mark out the corners of the plot(s).	September-October.
Hand sow seed (use a combination of seed with lime-free silver sand) at a rate of approximately 100 seeds per m^2 (see Broadcast Sowing Method in *Further reading*).	September-October.
Roll the reintroduction plot(s) press the seeds onto the soil surface.	September-October.
Survey and ongoing management	
Adult/flowering plant survey.	July-July.
Continued autumn cultivation of the reintroduction site.	September-October and ongoing if the reintroduction is successful.
Annual adult/flowering plant survey.	July-July and ongoing to monitor the population.

Table 1: Recommended sowing, survey and management plan for Corn Buttercup

Reintroducing Corn Buttercup at Hope Farm

A reintroduction of Corn Buttercup was undertaken at the RSPB's Hope Farm in 2019. The farm is within the Cambridgeshire claylands and is used as a demonstration and experimental farm to show how to balance commercial and nature-friendly farming.

Figure 18: Seedling Corn Buttercup plant © G. Bray

There are records of Corn Buttercup in the 1970s and 1980s 4-6 km away from the farm, but none from the farm itself. Generally, the arable land is cultivated using minimum tillage, which involves spraying off the surface vegetation that has grown underneath the previous year's crop, and then undertaking a shallow cultivation. Much of the farm has problems with herbicide-resistant grass weeds, so cultivated margins have been avoided, but two areas without many problem weeds were identified for the reintroduction:

- School Field (also known as Field 1) – was in a conventional arable rotation until 2013, after which it had been managed as a conservation area, latterly with a pollen and nectar mix. It had not been cultivated since autumn 2017, and then only a few inches deep as part of minimum tillage, and the rest period had reduced the problem weeds.
- Yard Paddock – had been managed as a wildflower area since 2014, with herbicides to control injurious weeds. Around 20 years ago this area was a barn which was knocked down and clay topsoil imported to create an arable field. The most recent cultivation prior to summer 2019 was in spring 2018 to establish an annual wildflower mix including Cornflower *Centaurea cyanus*.

Seed for this reintroduction was produced by Kew's Millennium Seed Bank (MSB) in 2017 by propagation from seed collected in Cambridgeshire at a former arable site that was destroyed by road widening. The source population size was estimated to be 500 individuals and seed was collected from 200 individuals to provide a wide genetic base for future grow-outs.

The first step of the process in August 2019 was to create a stale seed bed. The plots were cultivated by minimum tillage on the 28th August and sprayed with PasTor and glyphosate to control germinating problem weeds on the 18th September and 5th October. The intention was to cultivate again on the 5th October to create a seed bed, but the wet weather over the preceding month prevented any form of soil disturbance. On the 7th October, plant debris was manually hand raked from School Field plot prior to sowing. This activity wasn't required on Yard Paddock, as there wasn't much debris on the surface.

The Corn Buttercup seed was combined with lime-free silver sand and hand sown. A handful of seed and sand was sown across each square metre which was measured using a 1x1 m quadrat. The sowing rate was 100 seeds per m^2. Each plot received 10,000 seeds in total. Immediately after the sowing, the plots were trampled by foot, which was followed by heavy rain. This was deemed sufficient to push the seeds onto the soil surface and aid germination without the need for rolling.

Seedlings were visible in early March 2020 (Figure 18), giving hope that there would be flowering and fruiting plants later in the year. A survey on 8th June 2020 found 194 plants in Yard Paddock, a germination and survival rate of 1.9%. School Field had been heavily grazed by Rabbits and there were no Corn Buttercup plants present. However, the seed sown in 2019 and shed from plants in Yard Paddock will be viable for a few more years and may germinate in 2021 or 2022.

Other species associated with Corn Buttercup plants in Yard Paddock included Common Poppy *Papaver rhoeas* which bees seek out for pollen and Long-stalked Crane's-bill *Geranium columbinum* a scarce plant that also grows in cultivated areas. Cornflower was also present, probably from the annual seed mixture sown previously. The management is to continue to undertake an autumn minimum tillage with herbicide sprays to reduce any problem species and prevent the build-up of too much vegetation. This will be ongoing, and the population of Corn Buttercup will be monitored.

Species Population Survey Recording Form: Arable Plants

Species:	Survey Date:
Site/SSSI/Farm Name:	Field/Unit Name:
Site Code: / Site Designation:	SSSI Unit/CWS Reference/RNR Number:
Recorders:	Central Site Grid Reference:

Population Extent: Please record presence in 100 m (six-figure grid reference) or 10 m (eight-figure grid reference) cells.									
Grid letters		Easting				Northing			

Growth Stage Counted: (✓)	
Seedlings	
First year rosettes	
Vegetative growth	
Flowering	
Fruiting	
Female	
Male	
Combination:	
Growth Type Counted: (✓)	
Individual	
Clump/patch	
Mat	
Combination:	

Population size: (✓)	
0 (null)	
1-10	
11-100	
101-300	
301-500	
501-1000	
1001-3000	
3001-10000	
>10000	
Actual number if counted	

Estimated area of cover: e.g. approx 10 x 2 m strip

Density description: e.g. dense cover, patchy, widely scattered

Site Description: e.g. wheel ruts, road verge, centre of ride, bank, sand/chalk pit/quarry, arable margin, etc.

Management: detail:	(✓)	High	Mod	Low	None
	Grazing				
	Shading				
	Disturbance				
	Sward height (cm)	**<10**	**11-30**	**31-100**	>100

Habitat type and condition: broad habitat, crop, soil type, NVC, flooding etc.				**Threats or reason for the null record: (✓)**		**Aquatic plants only: (✓)**		
				Afforestation		Water-body margin grazed		
				Agricultural improvement		Water-body recently cleared		
				Burning		Water-body margin affected by drainage		
Is there an agri-environment scheme option? (i.e. wild bird mix, wildflower margin, cultivated area?)				Lack of management		Soil nutrients:		
				Invasive species		Soil test taken?	Yes	No
				Mineral extraction		pH		
Is the species growing within a crop?				Overgrazing		Phosphorus (mg/l or index)		
Yes		No		Pollution / eutrophication		Potassium (mg/l or index)		
What is the type of crop?				Recreation		Magnesium (mg/l or index)		
None		Barley		Species transient		Clay content (%)		
Wheat		Potato		Under-grazing		Silt content (%)		
Roots (i.e. beet, parsnips, carrots). Please state:				Urban/road development		Sand content (%)		
Brassicas (i.e. cabbage, sprouts, radish). Please state:				Other:		Textural class i.e. clay loam		
Other. Please state:						Other:		

Reproduction potential: **Are the plants in seed? Are there any young plants?**	
Is the site suitable for germination of seeds? Provide a percentage cover of bare ground.	
Describe the vegetation around and among the plants:	
Are there any aggressive species suppressing the plants? e.g. bracken, bramble, coarse grasses	
Are the plants being shaded out by trees or shrubs? e.g. conifers, bramble, hawthorn thickets	
Is there any disturbance/activities which are affecting the plants in a good or bad way? e.g. horse riding, motor-bikes, dog walking, tree-felling	
Please list any other nationally rare species present	

Type of cultivation/disturbance?			
None		Min till (0-4 cm/0-1.5 in)	
Plough (4-8 cm/1.5-3 in)		Deep plough (8 cm+/3 in+)	
Other – state depth of disturbance (i.e disturbance by vehicle movements)			
Month and year of last cultivation/ disturbance		Month	
		Year	
Type of herbicide?			
None		Graminicide	
Broad-leaved		Graminicide and broad-leaved	
Month and year of herbicide application		Month	
		Year	
Type of fertiliser?			
None		Organic	
Inorganic		Other?	
Month and year of fertiliser application		Month	
		Year	

Percentage of bare ground within 5 1 x 1 m quadrats centred on plants of the target species				
Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5

Height of vegetation within 5 1x1m quadrats centres on plants of the target species				
Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5

NVC and associated species within a 1 m quadrat

Method for recording associated species:

- Centre the 1x1 m quadrat over an individual of the target species. Try and do five quadrats within the same area/field/habitat with individuals at the centre if the population is large enough. If fewer than 5 individuals just do the number of quadrats with an individual at the centre according to population size.
- The quadrats should not overlap.
- Record the grid reference of the quadrat to 10 figures, percentage bare ground and estimate the height above ground with the densest vegetation in centimetres (vegetation height).
- Record all species within the 1 m quadrat.
- Record the abundance of all species including the target species using the DOMIN scale.
- Record occurrences of the species from different habitat types on separate forms.

DOMIN cover scale	
<4% with few individuals	1
<4% with several individuals	2
<4% with many individuals	3
4-10%	4
11-25%	5
26-33%	6
34-50%	7
51-75%	8
76-90%	9
91-100%	10

Physical Attributes	
Altitude	
Slope	
Other:	

Quadrat	**1**	**2**	**3**	**4**	**5**
Grid reference					
Bare ground (% cover)					
Vegetation height (cm)					
Crop (% cover)					

		Cover using DOMIN				
Common name	**Scientific name**	**1**	**2**	**3**	**4**	**5**

		Cover using DOMIN				
Common name	Scientific name	1	2	3	4	5

Glossary

Minimum tillage – ('min-till')	A soil cultivation system with the goal of minimum soil manipulation necessary for successful crop production.

Case studies

- *Changes in Corn Buttercup at Fivehead Arable Fields SSSI in Somerset* by Alison Mitchell (Plantlife) and Cath Shellswell (Plantlife)
- *Discovering a new population of Corn Buttercup in Wiltshire* by Rob Blackler (RSPB)
- *Survival of Corn Buttercup in Devon – an outlier site* by Paul Tripp and Hannah Gibbons (RSPB)
- *How do herbicide, season and depth of cultivation affect Corn Buttercup?* by Cath Shellswell (Plantlife)

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- *The effect of different cultivation practices on the Corn Buttercup population at Naunton Fields, Worcestershire* by Alison Mitchell (Plantlife) and Cath Shellswell (Plantlife)
- *Reintroducing Corn Buttercup at Hope Farm* by Cath Shellswell (Plantlife), Elizabeth Cooke (Plantlife) and Georgie Bray (RSPB)

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Further reading

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Back from the Brink (2019) Seed conservation and sowing: Storing wild flower seed. https://naturebftb.co.uk/wp-content/uploads/2019/09/Storing-seed.pdf

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Contributors

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BACK FROM THE BRINK

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Creating the conditions threatened species need to thrive: our unique programme at a glance.

Back from the Brink is the first time ever that so many conservation organisations have come together with one focus – to bring back from the brink of extinction some of England's most threatened animals, plants and fungi. Natural England is working in partnership with Rethink Nature, and the entire project is made possible thanks to funding from the National Lottery.

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