Looking after

Pheasant's-eye

Adonis annua

Ecology and Conservation Portfolio

BACK FROM THE BRINK

HERITAGE FUND

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At a glance

Common name: Pheasant's-eye

Scientific name: *Adonis annua*

Habitat types: in the margins and corners of autumn- or spring-sown cereal fields and on regularly disturbed grassland

Soil type: usually free-draining calcareous soils, but can also grow on calcareous clay soils

GB status: Endangered

Contents

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

Species description

A member of the buttercup family with deep red flowers resembling those of anemones (Figure 1). The central part of the flower has black anthers. Pheasant's-eye can grow up to 50 cm in height with many branching stems and leaves that are deeply divided, giving a feathery appearance. Flowers are 15-25 mm wide and eventually develop elongated, oval seed heads bearing up to around 30 olive-green seeds with hard, green skins, similar in shape to a grape pip[1,2,3] (Figure 2).

Pheasant's-eye is unmistakable when flowering; however, young plants look similar to species of mayweed and fumitories (Figure 3). Mayweed seedlings do not have the long cotyledon leaves that Pheasant's-eye seedlings have. Fumitory cotyledons are similar, but their first true leaves have slightly wider leaflets with rounded tips, whilst Pheasant's-eye leaflets are narrow with pointed ends. As a mature plant, the unscented leaves and hollow stems of Pheasant's-eye easily separate it from mayweeds and fumitories.

Lifecycle and ecology

Pheasant's-eye is an annual herb, mainly germinating in the autumn, but seed can also germinate in the spring. It normally flowers from mid-May to July[1]. Autumn-germinating plants tend to be larger with more flowers and seed heads compared to spring-germinating plants[4] (Figure 4). A study comparing the difference between seed harvested in 1992 and 2010 found that the more recent cohort flowered earlier. This is consistent with higher spring temperatures associated with climate change[5].

Pheasant's-eye may be cross-pollinated by insects or self-pollinated within the bisexual flowers[6]. Pollinator interactions are not known in detail, although the plant is attractive to bees[7]. A study found that flower size had increased over a 20-year period and larger flowers received more pollinator visits[5]. Thus, larger flowers are pollinated more readily and, where pollinators are scarce, appear to attract a greater number of pollinator visits. However, the same study found that these larger-flowered plants did not flower for as long. Plants grown without pollinators are also able to set a high proportion of viable seed, suggesting self-pollination can be an important mechanism in Pheasant's-eye reproduction.

The seeds are heavy and generally fall on the soil surface around the parent plant, limiting colonisation of new

Figure 1: Deep scarlet flowers and strongly divided feather-like leaves make Pheasant's-eye instantly recognisable © Cath Shellswell

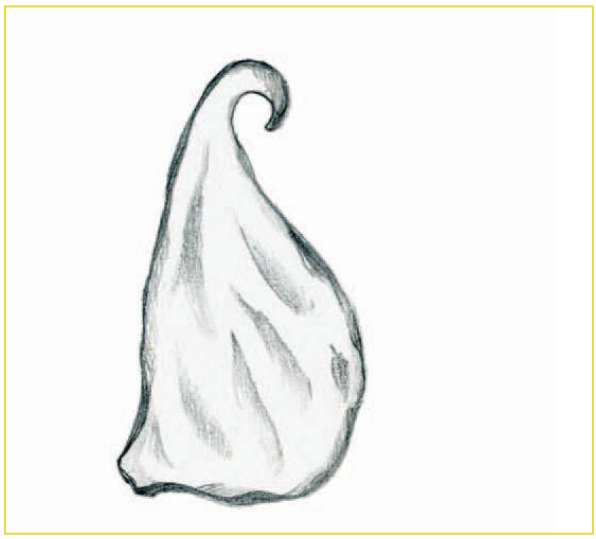

Figure 2: Illustration of a Pheasant's-eye seed. Illustration by evansgraphic.co.uk © Plantlife

Figure 3: Pheasant's-eye seedling with long cotyledon leaves © Plantlife

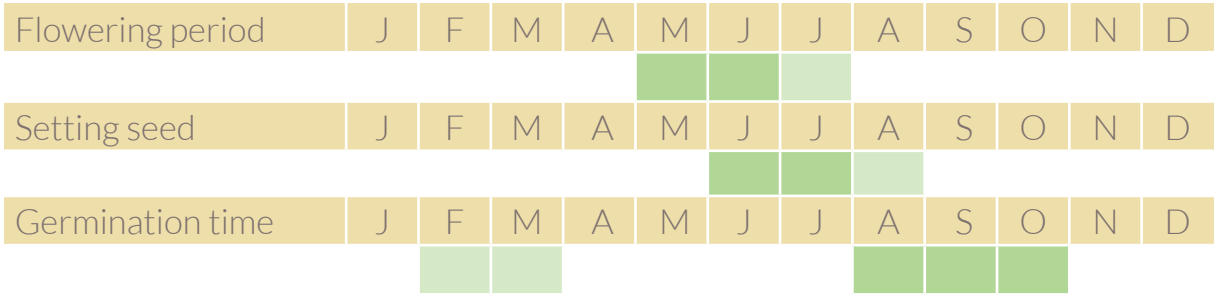

Figure 4: Flowering, germination and seed-setting periods for Pheasant's-eye.

areas. Each individual plant produces relatively few seeds, resulting in similarly low seed numbers remaining within the soil seed bank. Arable species with poor dispersal and low seed production are more vulnerable to extinction compared with those with wider dispersal and high seed production. When grown as a cultivated population at the Royal Botanic Garden (RBG) Kew's Millennium Seed Bank (MSB) in 2014, an average of 259 seeds were produced per plant[4]; field experiments at Ranscombe Farm Reserve showed an average estimate of 170 seeds per plant on shallow chalk soils, and 220 per plant on clay soils.

Whilst there is some uncertainty about the longevity of Pheasant's-eye seed, a research study of 40 seeds buried in soil found that viability rates were 96.5% after two and a half years, the highest viability of the 38 arable species studied[8]. This would suggest the seed has medium- to long-term longevity in the soil[4].

Seed dormancy describes a range of mechanisms that prevent seeds germinating, even in favourable conditions. Dormancy may delay germination until conditions are likely to support healthy plant growth and so stagger germination over multiple growing seasons, helping the population recover from damaging short-term effects such as drought, disturbance or unfavourable management practices. Pheasant's-eye appears to display two forms of dormancy – morphological and physiological dormancy – commonly described together as morphophysiological dormancy[9].

As with many species in the Ranunculaceae family, seeds of Pheasant's-eye have underdeveloped rudimentary embryos at dispersal, resulting in morphological dormancy[9] (Figure 5). Embryos must fully develop inside the seed before germination can occur. The environmental conditions required to promote this development differ between species. As a cornfield annual species, Pheasant's-eye seeds are dispersed onto exposed soils, remaining uncovered for the late summer months. These warm, dry conditions are likely to promote full embryo development. When the embryo has developed fully, physiological dormancy prevents immediate germination of the seed.

Pheasant's-eye seeds have a hard, thick cover which the radicle (root tip) is unable to penetrate. This mechanical

Figure 5: Pheasant's-eye seeds with and without the covering structure. Cut seed (bottom) displays the underdeveloped, rudimentary embryo (pale, v-shaped area at the right) © RBG Kew

restriction is overcome naturally by splitting or decay of the cover through repeated cycles of warm-dry and cool-wet conditions across the seasons.

Habitat

Records of this species predominantly come from arable fields and locations with regularly disturbed grassland. In arable habitats, Pheasant's-eye is typically found in the margins and corners of autumn- (and sometimes spring-) sown cereal fields.

Soil profile

Pheasant's-eye is usually a species of free-draining calcareous soils and it can also be found on calcareous clay loams. Plants on free-draining calcareous soils tend to be smaller with fewer flower heads, but the number of individuals is often more numerous. Although there are often fewer individual plants on calcareous clay loams, the plants tend to be larger with many flowers that produce more seed.

Pheasant's-eye has so few existing populations that there is little information about the soil texture, pH and nutrients that best meet its needs. Only three soil

Early flowering Pheasant's-eye

It has become apparent that Pheasant's-eye flowers slightly earlier in Wessex than in other parts of the country, with most populations flowering in May and having gone to seed by the second week of June.

In 2020, Pheasant's-eye was recorded flowering on a farm in south Wiltshire during January. The plants were growing in a 4 m cultivated margin located alongside a tall, mature hedgerow. The margin was cultivated in the spring of 2019 with a power harrow to encourage fumitories as a food source for Turtle Doves *Streptopelia turtur*, and the rest of the field was under a winter barley crop.

Pheasant's-eye had not been previously recorded along this field margin, although there was a separate population growing in a conservation headland on the opposite side of the field. Here, it flowers at a more conventional time, usually appearing during late May and June. Germination of the cultivated margin Pheasant's-eye may have begun during the spring of 2019 which would enable the plants to reach maturity so early the following year. This is an extreme example of how a species can adapt to the changes in cultivation and seasonal variability. The winter of 2019-2020 was extremely mild and wet, becoming dry and hot from late March onwards. All of this encouraged earlier flowering of Pheasant's-eye in general and enabled the spring germinating 2019 plants to flower exceptionally early from January 2020 onwards.

> The farm manager plans to cultivate the field margin to encourage the population to flourish

The margin was power-harrowed in late spring 2020 and the surrounding field was then sown with a maize crop. It was then topped to control less favourable weeds such as Wild Oat *Avena fatua*. The farm manager at this site plans to cultivate the margin in autumn 2020 to encourage more Pheasant's-eye seed to germinate and the population to flourish.

Texture triangle: Soil Survey of England Wales (UK)

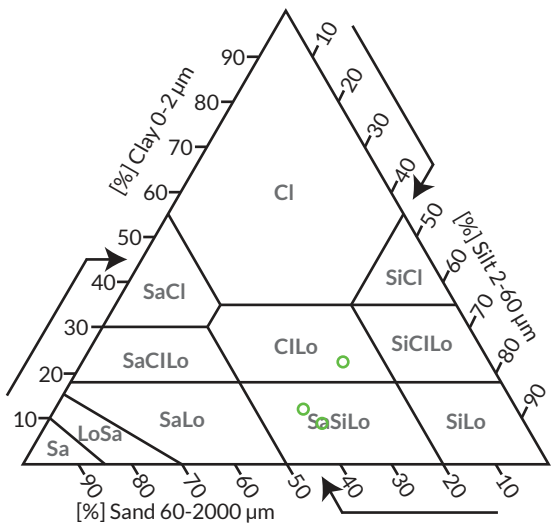

Figure 6: Soil triangle displaying the proportions of clay, silt and sand present at three sampled Pheasant's-eye populations

samples have been gathered: two from Wiltshire, near Salisbury and the border with Hampshire and both from arable land; and a third taken from a Somerset location adjacent to a waterway and on a private track. The Somerset population was the first recorded in the county since the 1960s and, upon examination by experts, was confirmed to be the native form of Pheasant's-eye rather than the often-sown species Pheasant's-eye 'Scarlet Chalice' *Adonis aestivalis*. The unusual occurrence of Pheasant's-eye in Somerset may be transitory, or could have been sown by someone and, as a result of the unknown origin of this seed, any soil characteristics might not be reliable for future reference.

Further soil samples gathered at other current Pheasant's-eye populations would help assess the needs of this species.

Soil pH

All three populations were growing on calcareous soils between pH 8-8.2.

Soil texture

There were two distinct soil textures across the three soil samples. In Wiltshire, the two populations were on sandy silt loam with a higher proportion of sand, around 40%, and a lower proportion of clay, around 10%, compared to the Somerset population. The amount of silt was relatively constant across all three samples, between 45-50% (Figure 6).

The texture has an effect on several factors that may affect the growth of plants. The sandy silt loams have rapid drainage with low-medium available water. However, they also have a rapid warming rate. This can help the early flowering Pheasant's-eye as it needs to have a quick start to the spring to enable seed to be set and shed and bake in the sun to mature the embryo. The clay loam has a medium to slow drainage rate, but medium to high water retention, and a medium warming rate. It is also inherently more fertile than the sandy silt loams. The seed longevity of Pheasant's-eye in the soil seed bank is not known on clay soils, where water ingress and rot may set in more quickly. The higher soil fertility may also increase competition, adversely affecting Pheasant's-eye plants.

This might explain the stature of individual plants within the populations. In the Wiltshire population near Salisbury there were individuals with few flowers per plant, whilst the Hampshire border population had slightly larger plants with more flower heads. In contrast, the Somerset plant was very large with many flower heads, but just a single plant. The influence of soil conditions on the size of plants was also apparent at the Ranscombe Farm reintroduction plots, with many small and few-flowered individuals present on the shallow chalky soil, compared with fewer, larger plants on the clay-with-flints soil.

Proportion of bare ground

The proportion of bare ground varied between 5-65% within a radius of 0.5 m of a plant. The average amount of bare ground within 0.5 m of plants was 36%, and the height of surrounding vegetation varied between 15-60 cm. This suggests that Pheasant's-eye may, in certain circumstances, be competitive within relatively dense and tall vegetation once plants are established. However, dense vegetation is unlikely to provide the exposed conditions required for seed to mature: sufficient bare ground must be available during the late summer-early autumn after the seed is shed, and Pheasant's-eye is very unlikely to persist under continuous vegetation cover.

> Pheasant's-eye has so few populations that there is little information about the soil texture, pH and nutrients it needs

Soil nutrients

Pheasant's-eye is associated primarily with arable habitats in the UK. With so few soil samples, no firm conclusions about soil nutrient levels can be drawn. However, this information can form the basis of an assessment of soil nutrient levels that are tolerated by Pheasant's-eye (Figure 7).

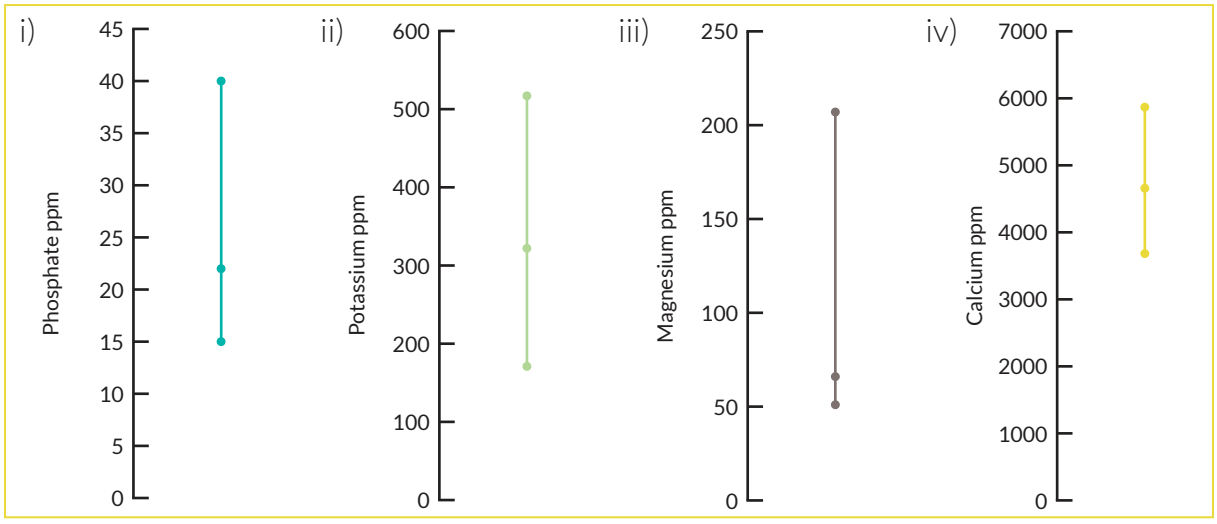

Figure 7: Major plant nutrients present in the soil at three populations of Pheasant's-eye; i) Phosphate, ii) Potassium, iii) Magnesium and iv) Calcium

Phosphate varied between 15-40 ppm (Index 1.9-3.7) between the two sandy silt loams, with the clay loam lying in the middle at 22 ppm (Index 2.6). This may be due to the different situations, as the Salisbury population lies within a cultivated plot for arable plants that has not received any fertiliser for a period of at least 10 years, but the Hampshire border population is at the edge of a conventional arable field which is fertilised.

Potassium varied between 171 ppm (Index 2.4) and 322 ppm (Index 3.5) at the Salisbury and Hampshire border populations, while the Somerset population had a potassium level of 517 ppm (Index 4.5). This is unsurprising as clay-based soils are inherently higher in potassium than more free-draining sands.

Magnesium is also generally higher in clay-based soils, and the level in Somerset was 207 ppm (Index 4.4) compared with 51 ppm (Index 2.0) and 66 ppm (Index 2.3) at the Wiltshire populations.

Calcium levels varied between 3683-5868 ppm.

Vegetation communities

Pheasant's-eye is generally early flowering and can be part of sparse or dense vegetation communities. This partly depends on the type of soil. National Vegetation Classifications (NVC)[10] have been identified for four different populations of Pheasant's-eye where community composition surveys have been undertaken, this is a very small sample size and does not represent the full range of associated species. Further surveys of vegetation stands are recommended and information for populations present on clay loams is particularly lacking.

Where Pheasant's-eye grows on chalk-based soils, the vegetation community most resembles OV16 Common Poppy *Papaver rhoeas* – Night-flowering Catchfly *Silene noctiflora*. The repeated cultivation of the land prevents ecological succession to grassier swards with less bare ground. Associated species, depending on the soil seed bank at individual sites, include the scarce plants Corn Parsley *Sison segetum*, Rough Poppy *Roemeria hispida*, Prickly Poppy *Roemeria argemone* and Field Madder *Sherardia arvensis*. Commoner species include Common Poppy, Common Fumitory *Fumaria officinalis*, Common Field-speedwell *Veronica persica*, Sun Spurge *Euphorbia helioscopia*, Common Couch *Elymus repens*, Fat Hen *Chenopodium album*, Charlock *Sinapis arvensis*, Scarlet Pimpernel *Lysimachia arvensis* and Scentless Mayweed *Tripleurospermum inodorum*. Although Night-flowering Catchfly may be present, this is usually a spring-germinating species and therefore has not been found in close association with Pheasant's-eye which is primarily autumn-germinating.

Pheasant's-eye has also been found in OV12 Annual Meadow-grass *Poa annua* – Field Forget-me-not *Myosotis arvensis* community. This occurred at one of the sites where Pheasant's-eye was present in a margin around a conventional crop. The margin had not been sprayed with herbicide, and over the years a grassier sward had developed, but with regular disturbance preventing many of the perennial grasses from developing. Scarce species associated with Pheasant's-eye included Corn Parsley, Field Madder, Knotted Hedge-parsley *Torilis nodosa*, Venus's-looking-glass *Legousia hybrida*, Long-stalked Crane's-bill *Geranium columbinum* and Narrow-fruited Cornsalad *Valerianella dentata*. Commoner species included the grasses Rough Meadow-grass *Poa trivialis* and Barren Brome *Anisantha sterilis*, as well as

Common Poppy, Dove's-foot Crane's-bill *Geranium molle*, Parsley-piert *Aphanes arvensis*, Wall Speedwell *Veronica arvensis*, Common Field-speedwell, Scarlet Pimpernel and Field Forget-me-not.

The one site with a clay loam soil was in an unusual location along a rough track in a grass ley with some periodic disturbance by passing vehicles. The vegetation community was most similar to OV25 Common Nettle *Urtica dioica* – Creeping Thistle *Cirsium arvense* community; Perennial Rye-grass *Lolium arvense* – Common Poppy *Papaver rhoeas* subcommunity. This community is characteristic of nutrient-rich loamy soils within grass leys where there is much open ground or abandoned arable land, as well as verges and waste ground, which is particularly observed for the sub-community described here. Grasses associated with the Pheasant's-eye plant included Perennial Rye-grass, False Oat-grass *Arrhenatherum elatius* and Cock's-foot *Dactylis glomerata*. Herbs present included Common nettle, Creeping Cinquefoil *Potentilla reptans*, Ground-ivy *Glechoma hederacea*, Cut-leaved Crane's-bill *Geranium dissectum* and Creeping Buttercup *Ranunculus repens*.

Distribution

Pheasant's-eye is an archaeophyte with a single fossil record from the Iron Age[11]. Its distribution in the UK follows that of chalk soils, predominantly in southern England. Given its soil and temperature-dependent seed ripening requirements, Pheasant's-eye has never been widespread (Figure 8). However, it was abundant enough during the 18th century and was frequently picked and sold as a cut flower called 'Red Morocco'[12]. Many of the recent records of this species are in southern and central England on chalk and limestone soils[1].

There is some confusion in the records between the native species of Pheasant's-eye *Adonis annua* and other species of Pheasant's-eye such as 'Scarlet Chalice' *Adonis aestivalis* which is commonly sown in gardens and for floral displays. The two species are often cryptic, being difficult to distinguish, and it is therefore likely that some records for Pheasant's-eye actually represent this non-native species.

Reasons for decline

The large seeds of Pheasant's-eye were historically spread within cereal seed and one of the main reasons for its decline is improved seed cleaning. It is generally a poor competitor, preferring open vegetation, and struggles to survive within a dense cereal crop. It also prefers situations with low soil nutrient levels and

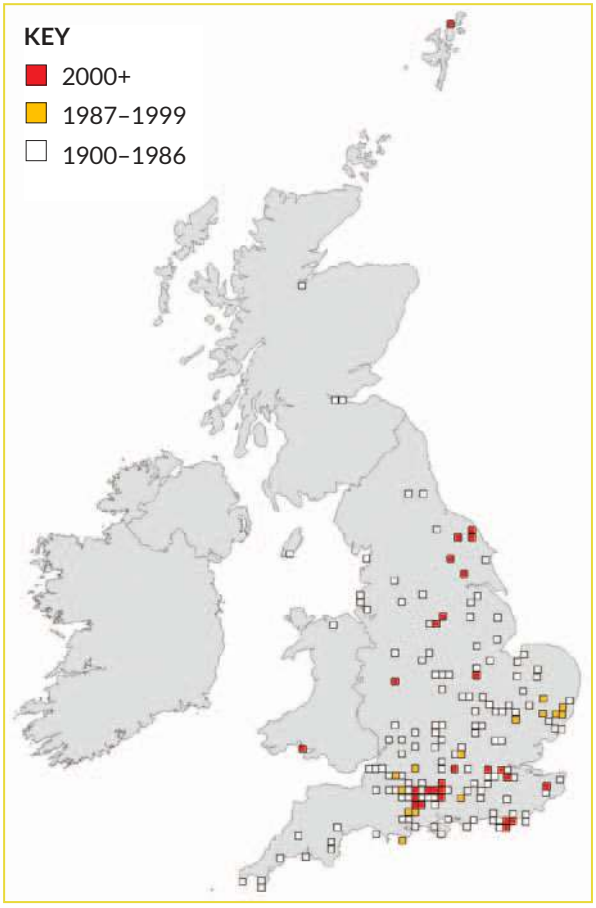

Figure 8: Pheasant's-eye distribution across Britain and Ireland. The data used to create this map has been provided under licence from the Botanical Society of Britain and Ireland (BSBI) and accessed from the Society's online database.

regular cultivation. Threats include intensive farming, particularly the development of competitive cereal crop varieties that grow quickly, closing the cereal sward and preventing light from reaching seedlings. Widespread use of broad-spectrum herbicides has also had a negative effect on this species[1].

Arable species with low seed production are more likely to become extinct than those with high seed production[1,3], with winter annuals such as Pheasant's-eye particularly vulnerable to herbicide sprays applied early in their life cycle[1,4].

There is anecdotal evidence to suggest that the weather during the summer before germination play an important role in the germination rate of Pheasant's-eye seed (Figure 9). A warmer, drier summer may increase the germination rate the following spring. Evidence for this can be seen in 2019, which was thought to have been a good year for Pheasant's-eye in the UK, and which was preceded by an unusually hot and dry summer in 2018. Conversely, 2018 was

Figure 9: Weather conditions during the previous summer may play a role in the germination of Pheasant's-eye seed © Cath Shallswell

generally a poor year for this species and followed the cooler summer of 2017.

In addition, there is some anecdotal evidence to suggest that a general increase in landowners using a minimum tillage system across the country has led to a decline in Pheasant's-eye populations in recent years. Pheasant's-eye, like most annual arable species, requires some form of soil disturbance to readily germinate, and current populations are likely to suffer if more land managers decide to opt for a minimum soil disturbance approach. Whilst this method might offer some benefit to soil health, the presence of critically endangered arable plant species such as Pheasant's-eye should be considered beforehand.

GB status and rarity

Endangered.

Protection under the law

This plant is included as a species of principal importance for the purpose of conserving biodiversity under Section 41 of the Natural Environment and Rural Communities Act 2006.

Cultural connections

The genus that Pheasant's-eye belongs to is named after Adonis, who, according to Greek mythology, was a handsome young man loved by the goddess Aphrodite. He was killed by a wild boar, causing Aphrodite great sadness and according to legend, her tears were transformed into the Pheasant's-eye flowers. Another interpretation is that bright red flowers sprang from the drops of Adonis' blood rather than from Aphrodite's tears (Figure 10).

Pheasant's-eye is known by several other names including Red Chamomile, Adonis, Red Morocco, Rose-

Figure 10: Death of Adonis (1684–1686) by Luca Giordano

a-rubie, Red Mathes and Sweet Vernal. These names come from historic, old English names whereas it is most commonly referred to as Pheasant's-Eye, from the resemblance of its little scarlet and black blossoms to the eyes of this common game-bird.

Survey method

Individual plants should be counted in smaller populations of fewer than 100 individuals. Larger populations should be estimated, or an alternative strategy would be to map the extent of the distribution. Other factors could also be recorded, such as the method and depth of cultivation; whether the ground had been disturbed in other ways, such as by vehicle movements along rough tracks; the application and type of any fertiliser or herbicide; soil texture and nutrient levels, if a soil test was undertaken; and associated species. An example of a recording form is contained in the appendix.

Habitat management

Ideal management on arable land involves cutting immediately after seed dispersal in July followed by a short fallow period and cultivation in August or early September. This will enable after-ripening on the soil surface and promote autumn germination. Later cultivation would risk burying or destroying seedlings germinating in the late summer or early autumn. As Pheasant's-eye is suspected to form a persistent soil seed bank and can also germinate in spring, populations may also withstand periodic spring cultivation if required to control weeds or promote other arable plants.

It is highly susceptible to broad-spectrum herbicides and their use will reduce population size. However, if required, treatment of problematic weed species, particularly grasses, could be undertaken through targeted herbicide use. Fertiliser can encourage problem weeds that prefer higher nutrient soils and is not usually applied to uncropped areas. Applications of fertiliser should be limited on cereal headlands, wildlife cover mixes or low-input cereals where Pheasant's-eye is present[15,16].

On conservation headlands, using a reduced seed rate and/or a crop variety that has fewer tillers will also benefit Pheasant's-eye as it is not very competitive. If growing within a crop, the crop should be harvested after Pheasant's-eye has set seed, usually late July and into August.

Estimating Pheasant's-eye population sizes

As Pheasant's-eye does not usually form mats or clumps like some other plant species, counting individuals is often straightforward.

Most Pheasant's-eye populations are small enough for population size to be estimated quite accurately by counting plants. However, there is at least one population in Wiltshire that is large enough to need estimation of the population using quadrats. Population size is calculated by counting the number of plants within a sample of 1 x 1 m quadrats and scaling the average number of plants up to provide an estimate for the entire area occupied by the population. This process is easier and more accurate if the population density is relatively constant across the entire area of occupancy.

There are two approaches that could be undertaken if the density of the population varies across the site:

- A larger number of quadrats could be undertaken to derive an average. This average would need to be scaled-up for the entire area to produce an overall population estimate; or
- The site could be split into areas with relatively similar densities of plants, with quadrats undertaken in all of these areas to derive different averages. These averages would then be scaled-up for each of the areas produce an overall population estimate.

Alternatively, if the population covers a large area, a number of transects could be walked across the area occupied by Pheasant's-eye. This is best done by a group of people standing about 2-3 m apart and walking across the site at an even pace to stay in line with one another. Each surveyor counts the number of plants in their path, and plants that are between people are counted by one or other of the surveyors to prevent double counting. Transects can either be walked across the entire site, or, if just a part of the site can be covered, for example a quarter of the area occupied by Pheasant's-eye, the estimate can be scaled-up for the entire site to provide an overall population estimate. Walking transects is much more difficult if the Pheasant's-eye population is present within a crop and may not be suitable in these circumstances.

Organic control of Barren Brome at a Pheasant's-eye site in south Wiltshire

The removal of pernicious weeds such as Creeping Thistle *Cirsium arvense* and Barren Brome *Bromus sterilis* can be a challenging task when aiming to preserve other scarcer arable plant species.

Figure 11: Pheasant's-eye at a farm in south Wiltshire © Lawrence Sampson

A population of Pheasant's-eye persists in good numbers on a holding in south Wiltshire and the removal of Barren Brome has been successfully undertaken (Figure 11). Pheasant's-eye at this location grows in a specially managed autumn-cultivated plot. It is often thought to be a June-flowering species, but the plants at this location usually flower in mid-May and have generally gone to seed by the second week of June. Whilst Pheasant's-eye grows here reliably each year, in recent years there has been an increase in Barren Brome germination, which could threaten the survival of Pheasant's-eye as it is a less competitive species.

In order to remove the Barren Brome without damaging the Pheasant's-eye population, the farm manager used a slightly deeper cultivation across the whole plot to bury as much of the brome seed as possible. The soil is calcareous with flints, and the normal cultivation is to a depth of 5-6 inches (12-15 cm). Deep cultivation involved turning over the soil by 6-7 inches (15-18 cm). Whilst this management did not totally eradicate the Barren Brome from the plot, it served to remove most of the plants that would otherwise have been present the following year. It is also thought that a slightly earlier working of the ground may help remove this problem species.

Organic pernicious weed control methods can be used in place of chemical treatments

These methods of organic pernicious weed control could be used in place of chemical treatments such as graminicides and may be particularly effective when undertaken on a regular, but infrequent, basis such as once every few years.

Herbicide control of pernicious weeds at a Pheasant's-eye site in Kent

Reeds Farm is a conventionally managed farm in Kingston, Canterbury. The soil coverage on the holding is calcareous loam. Pheasant's-eye was first recorded in small numbers in a field margin on Reeds Farm in 2007.

The following year, the farm was entered into a Higher Level Stewardship (HLS) agreement. Ever since, the Pheasant's-eye margin has been managed as an autumn-cultivated, uncropped plot.

The highest populations of Pheasant's-eye (30+ plants) were recorded in 2008 and 2010 (Figure 12). The species persisted, in smaller numbers in 2011 but was not found in 2012 or 2013. The last record of four Pheasant's-eye plants was in 2014 and, despite further checks in 2016, 2018 and 2020, it has not been found since.

Following internal advice from Natural England, several strategies were trailled to control problem species over this period and reinvigorate the Pheasant's-eye population.

Barren Brome *Bromus sterilis* began to dominate the plot and in early 2009 an application of the graminicide (Fusillade® DX) was approved through a derogation. However, Barren Brome continued to be a problem, and in 2010 the herbicides Starane® XL (which was considered to cause an acceptable level of damage to Pheasant's-eye) and Fusillade® DX were applied following cultivation in an attempt to control it as well as Cleavers *Galium aparine*. This may have resulted in the small number of individuals found in 2011.

The herbicide Falcon® was applied in December 2013 to manage Barren Brome and Rat's-tail Fescue *Vulpia myuros*. Both species remained at concerning levels, dominating the plot even after another graminicide treatment in autumn 2014, which is when Pheasant's-eye was last recorded in the margin. Consequently, the last resort was to undertake late spring cultivations in 2015 and 2016 to break the dominance of the grasses which are mostly autumn-germinating. However, Pheasant's-eye is also autumn-germinating and this management could have been detrimental to the population at the margin.

Following the spring cultivations, in addition to the grasses already mentioned, Bristly Oxtongue *Helminthotheca echioides* became dominant. Glyphosate was applied prior to ploughing in November 2016. In 2017 and 2019, the plot was autumn-cultivated but no Pheasant's-eye was found. It was spring-cultivated in 2020, but again no Pheasant's-eye was found, but any seeds may not have germinated due to the late cultivation and extremely dry spring.

Although grasses are now less of a problem, pernicious weeds are still an issue across the Pheasant's-eye plot. This exemplifies the difficultly of controlling unwanted species while simultaneously attempting to expand a population of Pheasant's-eye.

One further action is being considered to encourage Pheasant's-eye: a deep plough at the site of the last known location of the species to try and bring buried seed to the soil surface. Pheasant's-eye seed has been found to germinate at other sites where a deep cultivation has excavated seed unaffected by herbicide sprays due to the protection afforded by the depth of soil and hard seed coat.

Figure 12: Pheasant's-eye © Cath Shallswell

In non-arable habitats, populations of Pheasant's-eye should be maintained through regular ground disturbance such as ploughing, harrowing or rotavating. Other species and habitats of conservation concern may need to be considered, such as the presence of calcareous grassland. As the seed was historically spread in cereal grain, this mechanism of unintentionally collecting and preserving seed, and re-sowing it with the cereal grain may have led to the large populations that were gathered for sale as a wild flower. Pheasant's-eye has declined with the introduction of seed cleaning and continues to decline at many of its extant sites.

A method for preserving populations of Pheasant's-eye may be the collection of seed each year followed by sowing into the same locations, therefore replicating the historical sowing that would have happened alongside cereal seed.

Pheasant's-eye is suspected to have medium-long term persistence in the soil seed bank and may return with the reinstatement of management practices that provide adequate germination and establishment niches. For example, deep ploughing may bring buried seed to the surface, though this seed may still exhibit morphological dormancy and require after-ripening, and so ploughing should therefore be timed for mid-summer to enable after-ripening and germination in autumn. If the species has not been recorded recently or has failed to return despite favourable management, reintroduction is likely to be required.

> Harvest crops after Pheasant's-eye has set seed in late July

Reintroduction

If seeds are kept in suitable conditions (see Storing Wild Flower Seed guidance in *Further reading*), sowing should be undertaken in late spring and early summer before the end of July (Table 1). This mimics the timing of natural seed dispersal and enables seeds to experience the warm, dry conditions required for after-ripening and dormancy break. Trials have found that seed sown before the end of July is more likely to germinate, even

Activity	Timing (month)
Summer cultivation and sowing	
Prepare the seed bed to create a fine tilth e.g. light cultivation or disking.	May-June.
Mark out the corners of the plot(s).	May-June.
Sow seed by hand combining it with lime-free silver sand (see Broadcast Sowing Method guidance in *Further reading*). Pheasant's-eye seed is broadcast in the summer to allow the undeveloped embryo to develop in the summer heat. This process fulfils the lifecycle of the plant and breaks dormancy.	June-July.
Roll the sown area to push the seeds onto the soil surface and aid germination.	July-August.
Late summer cultivation and sowing using seed that has been artificially matured	
Prepare the seed bed to create a fine tilth e.g. light cultivation or disking.	Early August.
Mark out the corners of the plot(s).	Mid-end August.
Sow seed by hand combining it with lime-free silver sand (see Broadcast Sowing Method guidance in *Further reading*). Seed that has been artificially matured by warming in ovens over a sustained period of time can be sown in late summer and in trials has germinated at a low rate.	By end August.
Roll the sown area to push the seeds onto the soil surface and aid germination.	By end August.
Survey and ongoing management	
Adult/flowering plant survey.	Mid-May to Mid-June.
Continued cultivation of the reintroduction plot(s) in the spring.	September-October and ongoing if the reintroduction is successful.
Annual adult/flowering plant survey.	Mid-May to Mid-June and ongoing to monitor the population.

Table 1: Reintroduction plan based on summer sowing using fresh seed or autumn sowing using heat-treated seed.

at a low rate, than autumn-sown seed. Seeds which do not germinate before winter may have successfully overcome morphological dormancy but require further warm/dry and cool/wet cycling events to overcome physiological dormancy before germinating in spring. Experience at Kew's MSB suggests autumn-germinated plants develop to be larger and more productive, although spring-germinated plants can establish and perform well[4].

It may be possible to apply dormancy-breaking pre-treatments to stored seed to enhance germination and establishment in the field. Alternating seeds between warm/dry and cool/wet cycles under controlled conditions may allow slightly later sowing and increase the percentage of seed germinating in autumn. This process should be undertaken in controlled conditions where heat can be applied for sustained periods of time to encourage the seed to ripen. The seed should then be sown before the end of August to catch any late summer warmth. Propagating seedlings in cultivation and introducing them as plug plants would be an alternative means of securing a first generation of flowering plants and direct dispersal of seed into the soil seed bank[4].

The general recommended sowing rate for plants with seeds such as Pheasant's-eye is 100 seeds per m^2 [17] (Figure 13). Complex dormancy mechanisms mean only a small proportion of Pheasant's-eye seed present in the soil is likely to germinate each year. To establish a large, healthy population it would be advisable to assume a low germination rate of <5% and increase the sowing rate accordingly, for example, sowing at least 1,000 seeds to achieve a population of 50 individuals. The seed should be sown into a bare cultivated area; even low levels of shading, for example by young crop seedlings, can prevent germination.

Figure 13: Pheasant's-eye seed ready for sowing © Plantlife

1 g of Pheasant's-eye seed contains approximately 117 individual seeds[4].

Areas for further research

Reintroduction trials

Small-scale reintroduction trials have been undertaken, but these sites are few and far between and provide limited evidence of the potential success of the different timings of sowing and use of un-heated or heated seed. Further trial sites, and controlled trials sowing at different times and using untreated and treated seed would enable a more detailed reintroduction method to be developed. Trials should take place over a number of years to prevent any single year of unsuitable weather patterns from clouding results (for example, years when the summer weather remains cooler than usual, which may affect natural germination).

Soil types and nutrients

Very few soil tests have been taken at populations with Pheasant's-eye. This means that there is extremely limited evidence about the usual conditions within which this species grows. Further soil analyses from other sites would be helpful in understanding the range of soils preferred by Pheasant's-eye.

Pheasant's-eye reintroduction in south Wiltshire

In 2019, Pheasant's-eye was reintroduced into an annually cultivated margin at a site in the south of Wiltshire.

The site was already under sympathetic management and the staff had access to machinery capable of carrying out the necessary management processes. Similarly, the site is located in an area where data searches have shown Pheasant's-eye was historically present.

In July of 2019, 8,000 seeds were sown across two plots that are currently managed for the benefit of breeding birds such as Stone-curlew *Burhinus oedicnemus* and Lapwing *Vanellus vanellus*. Fallow plots like these (which usually measure 2 ha in size) are commonplace on many farms in the Wessex area, and they are the main conservation tool for ground-nesting birds on arable farmland. In order to ensure that the Pheasant's-eye received the correct management at the best time of year, margins measuring 100x6 m were created by cultivation along the short side of both plots. Within these margins, a secondary margin measuring 40x2 m was marked out, and the seeds were broadcast by hand at a sowing rate of 100 seeds per square metre. This was done by dividing each 40x2 m margin into metre squares to ensure that sowing was done as accurately as possible. Seed was hand-mixed with a lime-free silver sand medium to prevent too many seeds being sown into any particular square.

Theoretically, apart from rolling the margins immediately after sowing, there was nothing more to do except wait to see if any seeds germinated and grew into flowering plants in the spring of 2020. Fortunately, this was a success and Pheasant's-eye was found growing at one of the reintroduction plots by the site manager in June 2020 during surveys of nesting Stone-curlew on the plots (Figure 14). Further access was restricted to prevent disturbance to the nesting birds. A later dedicated species population survey for Pheasant's-eye was not possible here due to the Covid-19 outbreak.

Figure 14: Pheasant's-eye at a site in south Wiltshire © Patrick Cashman

Cultivation in September 2020 was undertaken at a slightly earlier time than usual, as it was feared that subsequent growth in each margin between July 2019 and September 2020 might swamp any young Pheasant's-eye plants that successfully germinated. This was especially important due to the presence of Creeping Thistle *Cirsium arvense* and several other pernicious weeds that grow in the immediate vicinity.

> Pheasant's-eye requires autumn cultivation, so management is not compatible with that for farmland birds

Whilst the use of fallow plots for this reintroduction made sense from a practical standpoint (not least because the plots provided an arable option within a habitat otherwise dominated by chalk grassland), there were some conflicts of interest when it came to management of the sites. Fallow plots for ground-nesting birds are generally prepared by cultivation in late February in order to provide birds like Stone-curlews with bare ground nesting habitat in the spring. However, Pheasant's-eye requires annual autumn cultivation, and therefore management for both Stone-curlews and Pheasant's-eye is not possible. This could make reintroduction of Pheasant's-eye challenging for farms with fallow plots specifically undertaken for farmland birds, as there are additional management steps involved which may not correspond with the initial purpose and prescribed management of the fallow plots.

In addition, the presence of breeding Stone-curlews on both plots made a summer survey of these sites difficult, as Stone-curlew is a Schedule 1 species under the Wildlife and Countryside Act 1981, and it is an offence to disturb birds during the breeding season without a licence. Whilst this licence was held by the staff at the Pheasant's-eye reintroduction site, the sensitivity of the birds to disturbance meant that surveys for Pheasant's-eye could still be detrimental to any breeding attempts, particularly if they were sitting on eggs at the time; and further close observation of the Pheasant's-eye margins was not possible in 2020 when the plants were in flower.

Trialling techniques to break Pheasant's-eye seed dormancy

Reintroducing Pheasant's-eye is difficult as the complicated dormancy means that specific processes are required to trigger germination before even considering preparing the site and the vegetation that may grow-up alongside Pheasant's-eye seedlings.

A series of trials were undertaken during the summer of 2019 to establish different reintroduction processes. The results, population counts of flowering plants, were gathered in May 2020.

2019 was a very warm year with a spring drought and hot conditions remaining into July and August. From mid-September onwards, the weather turned remarkably wet, with many farms unable to undertake autumn cultivation. The wet weather lasted until the beginning of March 2020 when drought conditions resumed.

Timing of sowing and natural maturation of the seed

Three farms were sown with Pheasant's-eye plants at different periods during the summer of 2019:

- A farm in Kent was sown with 7,200 seeds spread across two plots, one plot on calcareous free-draining chalk and the other on calcareous clay with flint, at the end of July.
- A farm in Wiltshire had two plots on calcareous chalk soil sown with a total of 17,000 seeds at the end of July/beginning of August.
- A plot was sown with 3,000 seeds on calcareous chalk soil at the end of August on Portland.

Prior to sowing, the plots were prepared by cultivating the ground and creating a seed bed. The sowing rate at each location was 100 seeds per square metre.

The plots on the Kent farm had the most flowering plants; 110 plants in total across the two plots (germination and survival rate of 1.5%; Figure 15).

- The calcareous chalk plot had 108 small plants. This was a germination and survival rate of 3.0%, an average of 1.4 flowers per plant, and a potential 17.6 seeds per plant based on the number of seed-heads, flowers and flower-buds counted.
- The clay loam with flints had two plants, although the plants were much bushier with a greater number of flower heads on the clay soil. The germination and survival rate was 0.06%, with an average of 9 flowers and a potential 219.5 seeds per plant.

Figure 15: Pheasant's-eye at the Kent site. Left: one of the larger and more robust plants on clay soil. Right: one of the smaller plants on chalk soil. © Plantlife

The presence of Stone-curlews nesting on the plots in Wiltshire prevented a full examination of the sown plots, but four Pheasant's-eye plants were spotted whilst a surveyor was out monitoring the bird nests. No Pheasant's-eye plants were found on Portland, but surveys were limited due to the access and movement restrictions caused by the Covid-19 pandemic. Thus, there could have been some plants that were missed as Pheasant's-eye is difficult to see when not in flower.

Artificially maturing the seed

Cultivation and creation of a seed bed in July does not always lead to ideal growing conditions. A thick cover of vegetation can grow relatively quickly over-shading geminating Pheasant's-eye seedlings. A better time to create a seed bed is towards the end of August, but the Pheasant's-eye seed does not then receive the summer warmth essential for ripening and, as a consequence, does not break dormancy and germinate.

Four farms in Hampshire took part in a trial reintroduction of heat-treated seed, which enabled the seed to be sown in late summer or early autumn. The MSB exposed seed to dry after-ripening conditions of 30°C and 60% relative humidity (rh) for two weeks, followed by warm stratification on damp sand at 30°C for a further two weeks. The seeds were finally exposed to an overnight 'heat shock' drying treatment of 40°C and 60% rh before being dispatched for sowing. The reintroduction plots had been cultivated to a fine tilth by the third week in August 2019 and seed was spread during the last week of August, to enable any further ripening in the late summer warmth. This was short-lived, and although the autumn was mild, it was cool with high levels of rainfall which lasted until the beginning of March 2020.

All of the farms receiving the heat-treated seeds had Pheasant's-eye flowering plants in 2020 with a germination and survival rate of between 0.04-0.36%. Although very low, these reintroductions were considered a success and it is likely that other seed sown in 2019 could germinate in future years. To create the best germination conditions, the farmers have been shallowly cultivating the plots so that the seed is not submerged under soil.

None of these field trials were undertaken with scientific scrutiny with replicates and controls and all the results are anecdotal. However, experimental work at the MSB suggests germination is significantly increased by exposing seed to high temperatures and alternating dry and wet conditions – conditions that are less likely to be met naturally from late summer and autumn sowing (Figure 16).

Figure 16: Pheasant's-eye germination is increased by exposing seed to high temperatures and dry and wet conditions © Cath Shallswell

> The cultivation and creation of a seed bed in July does not always lead to ideal growing conditions

This work demonstrates that it is possible to generate an initial Pheasant's-eye population. However, it does not provide information about whether successive reinforcement sowings across the same plot are required to produce a self-sustaining population.

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

Archaeophyte – A plant species which was introduced to an area by humans and became naturalised before 1500 AD. Most archaeophytes in Britain first appeared during the Iron Age.

Cotyledon – An embryonic leaf, one or two of which are the first leaves to appear from a germinating seed.

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

Case studies

- *Early flowering Pheasant's-eye* by Rob Blackler (RSPB)
- *Estimating Pheasant's-eye population sizes* by Rob Blackler (RSPB)
- *Organic control of Sterile Brome at a Pheasant's-eye site in south Wiltshire* by Rob Blackler (RSPB)
- *Herbicide control of pernicious weeds at a Pheasant's-eye site in Kent* by Alison Mitchell (Plantlife)
- *Pheasant's-eye reintroduction in south Wiltshire* by Rob Blackler (RSPB)
- *Trialling techniques to break Pheasant's-eye seed dormancy* by Cath Shellswell (Plantlife), Richard Moyse (Plantlife) and Ted Chapman (RBG Kew)

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Further reading

Back from the Brink (2019) Broadcast Sowing Method. https://naturebftb.co.uk/wp-content/uploads/2019/09/Broadcast-sowing-method.pdf

Back from the Brink (2019) 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

Ecology and Conservation Portfolio / Pheasant's-eye, *Adonis annua*

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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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