Management and Restoration of Calcareous, Alkaline Seepage (Spring) Fens in Oxfordshire

(Calcium-Rich, Springwater-Fed Fens)

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Relevant Experience

We are all experienced ecologists, all specifically expert in the ecology of Alkaline, Calcareous, Tufa-forming Valley-head Spring-fens (the rarest type of 'Irreplaceable Lowland Fen' habitat in the NPPF). This expertise includes threats to fen hydrology and hydrochemistry and the management and restoration of fen habitats. JAW and Rd'A have 12 years of experience of dealing with the damaging consequences of housing development in the groundwater catchment of the Lye Valley Fen SSSI in Oxford; a site now surrounded on three sides by development, with impermeable surfacing over much of its rain-water catchment. We work closely with landowners Oxford City Council and Natural England at this site and are respected by the council as the experts in all aspects of site management and hydrology. JAW founded, and has been the Chair of the Friends of Lye Valley group. Volunteers for this group, under her direction, have carried out weekly very successful remedial conservation work on the Lye valley fen site since 2013.

We are all members of the **Steering Group of the Freshwater Habitats Trust (FHT) Oxfordshire Fens Project**. https://freshwaterhabitats.org.uk/projects/oxfordshire-fens-project/ which is currently working to restore **10 such spring-fens** in the county. Rd'A and SJG are the specialist contractors for this project, undertaking the fen restoration and carrying out successful restoration of degraded and damaged examples of such fens in Oxfordshire including hydrological aspects of re-wetting drained sites. SJG is an also an **expert entomologist** specializing in fen invertebrates and management for them; having started management on this type of fen more than 30 years ago.

[This is a rather rough and ready first draft document. It is work in progress that will be updated and improved as more is discovered about these very special fens.]

CONTENTS

SUMMARY

- This type of calcareous, alkaline, spring/seepage fen is an extremely rare and biodiverse groundwater-fed wetland habitat, usually on a depth of wet peat which is an important carbon store accumulated over thousands of years.
- Spring-fens are a rare sub-type of an irreplaceable priority habitat (Lowland Fen) which cannot be moved or recreated, as it is dependent on geology and hydrology. Limestone, chalk or calcareous sand geology is essential. With a layer of impervious 'clay' below these, or there is no spring.
- This fen type has very high biodiversity because the essential springs have been running in the same spot for thousands of years since the end of the last ice age (10,000 years) and have been colonised by a very diverse range of plants and invertebrates, a truly ancient ecosystem, older than ancient woodlands.
- Historically it would always have been a habitat maintained by grazing from wild large herbivores (cow, elk, deer) or, with the first human farmers, domesticated stock of cows and horses, supplemented by vegetation cutting and harvesting for litter for animal bedding.
- Light extensive grazing would have maintained the short turf vegetation which is ideal for many of the smaller rare plants like: orchids, Bog Pimpernel, Butterwort, Grass of Parnassus Flea Sedge etc. and the rare invertebrates in groups such as: Craneflies, Soldierflies and habitat specific beetles.
- In the absence of grazing, the necessary habitat management is cutting and collecting with removal of risings at least twice a year over the whole site of a small fen, or most of the site of a larger fen.
- If not removed off-site, cuttings should be moved off the fen surface to useful habitat piles on drier ground. Never pile them on the spring-head or seepage emergence zone. Burning of cuttings on site is not recommended as it can damage peat and cause enrichment.
- Managed (regularly coppiced) scrub of willow or alder is valuable for invertebrates but should be kept to marginal fen areas and definitely not on spring/seepage emergence zones.
- Spring-heads or seepage emergence zones in particular should always be kept short with areas of tufa (limescale) formation on mosses with small shallow pools and runnels open to sunlight and warmth to favour larvae of rare invertebrates.
- Areas of marginal flower meadow-type flora around the drier edges of the fen are extremely beneficial pollen and nectar sources for flying adults of rare fen invertebrates, forming a vital 'sustenance zone'. Common plants like Hogweed, Wild Parsnip and Wild Angelica produce the most valuable flowers to have near the fen, the larval breeding site for the invertebrates
- If management has been neglected for many years, much of the rare fen flora may have been lost by succession to dominance by tall reed, sedge, rush and scrub/trees. Restoration will need the removal of woody vegetation and intensive cutting and raking several times a year over the majority of the site over a number of years to restore short vegetation.
- Once such a restored spring-fen is back to a short sward, light extensive grazing combined with a reduced and targeted annual cutting regime would be the ideal management combination.
- Introduction/reintroduction of the native fen hemi-parasitic plant **Marsh Lousewort** at an early stage in fen restoration will assist with control of tall reed, sedge and rush and help to regenerate a more biodiverse short fen.
- Soil disturbance from cutting, raking and trampling may bring back some important plant species from the seed bank like Bog Pimpernel, but for those short fen species with short-

lived seed, re- introduction via seed or propagated plug plants may be necessary. Seed from the nearest local fen source should be used. Some plant species returning from seed banks may be problematic and need targeted control to prevent their dominance.

- As most Oxfordshire spring-fens have been previously damaged by artificial drainage drying them out, restoration may involve drain-blocking (log dams) and raising the water table carefully (in stages if necessary) to allow plant and invertebrate species time to adapt and to ensure continued gentle water movement through the system. Regular monitoring of dams and the changes they bring will be needed, and adjustment may be necessary in response to climate variation.
- It is never a good idea to dig up an ancient spring-fen to make a pond because the spring-fen habitat is so valuable and cannot exist anywhere else than a particular hydrogeological situation, ponds can be made in less valuable areas
- Good management and protection of the fen's rainwater catchment area is vital to prevent: water 'starvation' of fen springs and lack of calcium / alkalinity and/or pollution of the spring-water chemistry. The best habitat for the rain-fed catchment is green and permeable vegetation on un-compacted soil with no chemical input; managed as lightly grazed pasture or no chemical input haymeadow or parkland with few trees (i.e. not dense forestry and not conifers).

INTRODUCTION

Habitat Description, Hydrology, Hydrochemistry, Rarity and Legislation

Alkaline, calcareous, spring/seepage fens are the rarest type of Lowland Fen (a designated Irreplaceable Priority Habitat in Britain, as it cannot be re-located or re-created). Such fens are important not only nationally but also in a European context – mentioned on the European Red list of Habitats (listed as **D4.1a Small-sedge base-rich fen and calcareous spring mire**). Alkaline Spring Fens (Calcium-rich Springwater-fed Fens) are also mentioned in the EU Habitats Directive on **Annex 1** as **European Priority Habitat H7230.**

They are very high in biodiversity and for this reason they may sometimes be referred to as '**rich-fens**' and usually occur on slopes or in shallow or steep-sided valleys so they can also be called **valley-fens** or **valley-head fens**. Lye Valley for example is a valley-head spring-fen with steep slopes.

Several types of plant communities occur in these fens described in the National Vegetation Classification (NVC) type M13 (Rodwell 1991). The rarest and most iconic is the **M13 Black Bog-rush *Schoenus nigricans*-Blunt-flowered *Juncus subnodulosus* association** in areas that stay wet all year round. It is of international importance due to its restricted European distribution. Also worth mentioning is are other uncommon associated habitats: M24, the Purple Moor-grass *Molinia caerulea*–Meadow Thistle *Cirsium dissectum* fen meadow and the M22 Blunt-flowered Rush *Juncus subnodulosus*–Marsh Thistle *Cirsium palustre* fen-meadow. These fen-meadow communities often live alongside M13 in drier areas of the site that may be merely damp in summers.

Important plant species of M13 association in Oxfordshire include:

Black-Bog-rush, Marsh Helleborine orchid, Bog Pimpernel, Long-stalked Yellow-sedge, Dioecious Sedge, Tawny Sedge, Early Marsh-orchid, Flea Sedge, Grass of Parnassus, Twayblade Orchid, Parsley Water-dropwort, Fragrant Orchid, Marsh Lousewort, Southern Marsh-orchid, Early Marsh-

orchid, Marsh Arrow-grass, Broad-leaved Cotton-grass, Common Cotton-grass, Common Butterwort, Blunt-flowered Rush, Few-flowered Spike-rush, Marsh Pennywort..

How rare are these fens in this country? The data from the **Alkaline Fen Inventory for England** produced for **Natural England** (Tratt et al., 2013) shows that there are **40 ha** of National Vegetation Classification (NVC) designated fen types M13 and M13-related vegetation in England. The M13-related vegetation includes vegetation intermediate between M13 and other NVC types including M10, M22, M9 and M24. It also includes 'recovering' previously damaged M13. Of this total of **40 ha,** vegetation unambiguously referable to M13 covers **19.1 ha**. The stands of M13 and related vegetation captured in this inventory are believed to represent most, if not all, known examples in England.

These fens are simply best described as short-turf, groundwater-fed, calcareous wetlands, with high (alkaline) pH, tufa (calcium carbonate) deposition, very clean water - commonly in shallow valleys but in some steeper valley-head situations. Very low-nutrient (specifically N and P) and no significant amounts of scrub and/or trees present. Sometimes with tussock and runnel micro-habitat structure or small shallow surface pools. On accumulated peat (dead plant remains) and/or whitish tufa usually some 1000s of years old, i.e. ancient ecosystems. Spring/seepage water will have been running for all that time and this situation is dictated by the landform and geology of the site and surrounding area – with rocks (calcium-rich rocks like limestone, chalk, sometimes limy sand) where rainfall enters the ground and eventually makes its way through the underlying rock strata to emerge in the fen due to under lying impervious strata forcing ground water to the surface springs. For further explanation see for example simple explanation by Webb, 2022; types of fens and vegetation communities explained in Fojt, 1994; and many publications by Wheeler et al. for example: 1980b, 1988, 2002.

These sites are very different to **floodplain fens** adjacent to rivers, these being wetted annually by mesotrophic (higher nutrient) river water and having tall herb vegetation (the 'Lowland Fen' habitat category also includes these more numerous and commoner floodplain fens).

In the UK this type of alkaline spring-fen habitats is concentrated in East Anglia, Oxfordshire and Wales with other small areas elsewhere. **It is the rarest single habitat in England**, with though much larger areas still survive in Anglesey, Wales. There is some overlap with other similar habitat types, with these habitats often being small scale features in bigger landscapes e.g. calcareous alpine, riverside or coastal flushes which can support similar species of plants or invertebrates - for example Grass of Parnassus is an arctic alpine species, found on moorland and can be found in dune slacks as well as one of the defining species of calcareous valley spring-fens, where it is in some cases a survivor from the last ice age. Butterworts and Bog Pimpernel can be found in acid bogs as well as calcareous spring-fens.

Historically, a hundred and more years ago, such calcareous alkaline spring / seepage fens were too wet to be suitable for agriculture and were only useful for light extensive stock grazing or harvesting vegetation for litter for animal bedding or other uses. From records for many sites, under this regime, these fens supported their highest plant and invertebrate species biodiversity. They were often drained or had peat cut from them. Surviving examples (even despite some drainage and peat removal) are still very important for many species of flowering plants, mosses and liverworts, stonewort algae and invertebrates (insects, spiders and molluscs including minute snails).

In our experience, the calcareous valley spring-fens in Oxfordshire on average have between 1m and 4m depth of peat/tufa under the surface. Peat being accumulated dead plant remains and very carbon-rich. A student study in Lye Valley spring-fen found the carbon content of the peat (not including tufa) was on average **229.33 tonnes of Carbon per hectare** (Haldar, 2021).

Formation of **Tufa (travertine, calcite or marl if the calcite crystals are finely dispersed**) either hard or soft, whitish **calcium carbonate** deposits (familiar as limescale) is a key feature of these spring-fens. Emerging spring-water has to be super-saturated with dissolved **calcium** (derived from chalk, limestone or limy sand geology) for this calcium carbonate deposition to occur by degassing of CO_2. **Tufa formation significantly reduces the fertility of such fens** for plants by a special process: the calcite precipitation being associated with the co-precipitation (adsorption) of phosphate (Boyer and Wheeler 1989, Wheeler, 2002) effectively removing phosphate (a key plant nutrient) from fen water. In tufa-forming areas, phosphate levels available to plants are thus exceptionally low, favouring orchids with symbiotic fungi and stress-tolerant plants adapted to this low nutrient level. These plants include insectivorous species such as Butterworts that obtain the phosphate and nitrogen they need from trapped insects. Low nitrate is also important, but if phosphate is held very low, increased nitrate does not have so much of eutrophicating effect on plant growth because phosphate is the key limiting nutrient.

MANAGEMENT

Management should cater for the needs of the whole ecological community of such fens, of which the main suite of important species are vascular plants, bryophytes (mosses and liverworts) and invertebrates, especially flies and beetles.

Habitat Needs

A spring/seepage short turf, calcareous, alkaline spring-fen habitat needs:

Water

- A more or less continuous supply of groundwater emerging slowly normally over a broad front (seepage zone, rather than discrete spring emission point, although some point emission sources possible)
- Water table at or very near the surface all year round, even in a dry summer or wet winter, with the water level not dropping to more than 10-20cm below the surface.
- Emerging water to have the right chemistry, i.e. very high calcium and alkaline pH (7-8.5)
- Very clean water - low in polluting levels of nitrate and phosphate
- Water should move gently and slowly through the peat and/or over the fen surface peat ensuring good oxygenation (dissolved oxygen for respiration of invertebrates and roots) this is especially necessary in warm weather when water holds less oxygen.
- Water not immobile and stagnant i.e. lacking sufficient oxygenation (creating anoxia) which limits survival of specific plants and invertebrates
- No flooding with surface water of the wrong chemistry e.g. surface run-off rain water (i.e. no calcium, acidic pH values below 7) or polluted water (high nitrate, phosphate or other chemicals)

Vegetation Management

- Ideally, light extensive grazing (cows or horses) combined with some vegetation harvesting as required, by cut and collect
- If such grazing is not possible, then cut and collect vegetation regularly throughout the year to replicate extensive grazing, with the need to retain any existing structural complexity (e.g. tussocky vegetation) i.e. with everything not cut to the same height at the same time during the growing season. Cutting tussocks is only possible with great care using hand tools such as shears, scythes or possibly (with good technique) brushcutting (avoiding decapitating the tussock). Some tussocks should be left uncut annually to provide invertebrate habitat. Cutting twice a year should be sufficient if the spring-fen has a good low- nutrient water supply and is in good condition in respect of its desirable vegetation structure.
- This management produces high light levels at the ground needed by small plants and plenty of light for the important wet brown moss and liverwort mats, as well as bare wet tufa/ peat areas and shallow warm open runnels, required by specific invertebrates. Bare peat areas are needed to favour seed germination. If shallow pools are present in low lying areas, cutting should prevent them infilling with vegetation and maintain them with open water which is warm, sunny and un-shaded. This encourages species like Stonewort alga (*Chara* sp) Bladderworts (*Utricularia* sp) and Pondweeds (*Potamogeton* sp) and associated invertebrates.

Neglect and Damage

Natural Succession

Many Oxfordshire alkaline calcareous spring-fen sites are in poor habitat condition due to neglect of management for the last 100 years (i.e. the cessation of grazing and/or cutting) leading to natural succession resulting in dominance by tall reed or other similar ground plants and/or trees (creating wet woodland). The resulting shading causing the loss of important short open-fen species. These "lost" or neglected sites can be termed '**ghost fens'** indicated only by presence of peat and wetness. Other sites may have dried-out peat due to drainage and are then over-grazed. All these neglected and/or damaged sites can be returned to biodiverse short fen with appropriate restoration and subsequent good management.

Peat cutting and Pond Creation

Historically, the ecological value and importance of spring-fens has not been recognised. Peat was a valuable resource for fuel and tufa/marl valuable for spreading on fields to reduce acidity, therefore many sites have hollows or pools that are relics of extraction of these materials, or the whole site may have lost its surface peat over a large area. These pools from peat or tufa mining may or may not valuable wetland communities.

Deliberate pond creation for fish or to attract waterfowl or for amenity may also have occurred. This happens due to the good groundwater supply and the fen being perceived to be of no particular note or use. Ponds, especially those fed by clean water, can be very good freshwater habitats, however the creation of such habitats in these special calcareous alkaline fens is damaging and creation on a large scale destroys the valuable fen habitats and their peat deposits and associated large carbon store. Often the ponds created in them are ecologically disappointing, especially compared to the potential value of the original valley spring-fen habitat they are derived from. Natural ponds in fens do exist,

but they tend to be small, shallow habitats which provide niches for specialised fen invertebrates, many of which are uncommon or rare, reflecting the scarcity and unusual nature of the habitat. Valuable small marl-rich pools exist in Lye Valley fen where willow tree root bases were winched out during restoration. Unless there is no other option, for ecological reasons it is suggested that the creation of larger, deeper ponds in fens of this kind (especially where this directly or indirectly has a significant impact on the site as whole) is not a good management option. Other management options including some sort of restoration to open fen, should be considered first.

Fen Restoration

Habitat Management

Restoration is necessary if management has been abandoned such that the dominant vegetation of the fen has changed to tall or dense reed, sedge or rush and/or shrubs and trees have invaded. The hydrology of most fens has also been altered, most by drying-out through drainage (often by the means of simple ditches) and it is usually necessary to restore the correct (or where the changes have been too extreme the best possible) hydrological conditions. Heavily degraded fens (a long time deeply-drained for example) may never recover their full biodiversity, particularly of invertebrates; but one has no idea of what can be achieved unless the restoration process is started. There will be some successes, and some failures. The suggested management below applies especially to sites with small areas of fen habitat where the main priority for most of the site is restoration to short fen. In larger sites a more heterogenous habitat mosaic (of short and taller fen plant species) may be possible or desirable and less intensive restoration and on-going management will be possible over parts of the site. Before work starts, historical research on what plants used to be present before management neglect is useful (old county floras tell you this). A baseline botanical survey before work is essential and baseline invertebrate survey desirable. Also take photographs before and during restoration work to record progress.

- Clear trees and scrub, where possible remove stumps – winch or dig these out for preference, as this creates useful **small** shallow pools). Stack or pile deadwood on the edge of fen for invertebrates, fungi and as hibernation sites for reptiles, amphibians and small mammals. Some small diameter deadwood lying semi-submerged in shallow water pools can be important breeding sites for rare Craneflies and Hoverflies. On bigger sites with difficult access, it may be necessary to have these habitat piles within the restoration area, in which case they should be located on areas of the site less likely to become good fen, never on the spring/seepage emergence zones and always be made as relatively small and/or compact as possible. The habitat piles may initially be large but as the restoration process continues less waste material will be created and in time they will get smaller and may even be absorbed into the fen completely as peat. To minimise their impact on the fen habitat, and maximise their ecological value, the same locations should be used every time.
- Where sites have no surviving shorter open species-rich sward at all, cut and remove vegetation from the whole of the restoration area in the first year. Cuttings must always be removed to prevent smothering of re-growth and to lower nitrogen and phosphorus nutrient levels. Don't underestimate how much effort is involved in raking cuttings and removing them. Tip sheets are a quick and easy way to shift cuttings. If possible this should be done three times in the growing season of the first year e.g. early May, July and September/October. A simple indicator of when to cut again is to cut down all regrowth when it gets as tall as the knee. Later in the restoration phase and/or where some existing good flora

survives, it is better to do a selective cut as required throughout the growing season i.e. from spring to autumn (April / May to Sept / Oct) to control only the more vigorous / competitive species. Work around / leave areas with desirable species. In late autumn / winter cut and collect the whole of the restoration area. If a complete end of year cut is not possible and some areas are left standing, these should be the initial target for cutting early in the following spring.

- The aim of this management is to leave a sward of **less than 10cm height** by mid-winter. Cutting can be by scythe, brush-cutter or reciprocal mower (see photographs in Appendix I). Targeting rank / dense reed, sedge and rush areas will reduce the vigour of these species and create a more open shorter sward allowing the smaller species to grow. If only one cut is possible and dense Common Reed is present (and undesirable); a midsummer (June/early July) cut should be prioritised to reduce reed vigour. The midsummer removal of reed leaf area forces reed to use-up food reserves in its rhizomes to power re-growth and it will be weaker the following year. Cutting reed later in the year when it is dead and brown does not reduce vigour of re-growth in the next year, but is useful in creating bare areas for allowing spring germination from the seed bank and for active seed spreading. Note that Common Reed has an important invertebrate fauna and a decision needs to be made as to whether or not to leave uncut areas of it for associated species.
- Cuttings should be raked to piles on site in areas off the fen surface (if possible) and certainly never placed on the important spring/seepage emergence zone. The cuttings may be useful material for the purposes of re-wetting during drain-blocking (see below).
- Burning should never be used as a management tool. It will damage peat, create areas of enrichment and will kill any invertebrates in the cuttings (e.g larval stages in reed).
- Control future scrub invasion by Willow, Alder and Birch - by pulling or digging out seedlings. These species have windblown seed that arrives and takes advantage of newly bared peat/tufa. Cutting rarely gets rid of them and can result in a low sward of woody scrub instead of herbaceous vegetation.
- Trampling that happens during this management will create bare ground and bring up the seed-bank of any species with long-lived seed. The high light levels at the surface generated will stimulate seed germination. In dried-out areas where peat is oxidising and nutrient-rich, other non-fen plant species may be an existing problem, or become a problem as a result of restoration, e.g. commonly Cleavers, Creeping Thistle and Common Nettles. The control of these species will need regular management (all year as required) including cutting, with pulling (removing their roots/rhizomes) being even more effective. Control the over-abundance of other undesirable (including some wetland) plant species that may return in abundance from a long-lived seed bank, the worst problem species for this being Pendulous Sedge, Bittersweet, Brambles, Hard Rush and other Rushes (Juncus species). Plants such as these should be cut back hard regularly, but ultimately to be rid of them, many are likely to need some digging out.
- The non-native Himalayan Balsam (if present) will need similar attention, either cut low down (below first growth node) or ideally pull seedlings or small plants in early summer as many times as needed before it flowers. Repeat the process every year until its seed bank is exhausted.
- Once the fen vegetation is under some control, introduce the hemi-parasitic plant Marsh Lousewort, *Pedicularis palustris*, a normal component of the flora in such alkaline spring-fens, which will most likely have been lost during the period of neglect. It is very unlikely to recur on its own as it apparently does not have a long-lived seed-bank. This species is a root-

parasite and attacks, and is most effective at reducing, the vigour of reed, rushes and tall sedges. However it will only be able to do this reduction of its host species if there is appropriate annual vegetation cutting management to favour it during its period of establishment (further detail in: Decleer et.al, 2013; Webb 2020). As this is a biennial plant, a higher cut in May to remove the upper parts of the vegetation over the top of the young rosettes of the first year plants is beneficial. After flowering in its second year, harvest its seed as it starts to die back (August to October) by cutting off the seed heads or quicker and easier by pulling up the whole plant. Some of the seed will be dropped in situ, but at this time of year a lot will still be present. Store the seeds / plants on site until untreated parts of the fen have been cut. Spread the seed into these newly cut areas to increase the area where target problem species are being controlled. Seed heads / plants can be collected later in the autumn, but by then most of the seed will already have been dropped. Marsh Lousewort (where it grows in dense patches) can be very effective and almost eradicate the target problem species in a short time, without the need for intensive cutting. It appears to be especially effective in reducing Common Reed, Pond Sedges and Juncus rushes. A second hemi-parasitic plant Yellow Rattle could be used in drier areas of fen, or in transition zones between the wet fen and dry grassland to control potentially dominant drier ground grasses (not impacted by Marsh Lousewort).

- Within a few years of this regime of all year round regular cutting / clearing and use of Marsh Lousewort, the dominance of Common Reed, large sedges and rushes will reduce – creating suitable conditions for the return of a greater diversity of shorter flowering plants. How long this takes will vary according to site circumstances and the amount of management possible. Normally, the more established the problem species, the longer restoration will take.
- Where some, or all, of the typical or notable plant species have been lost, especially those without a long-lived seed bank; it may be necessary to reintroduce them. This can be done using either seed and/or green hay, cut and collected from other nearby / local fen sites – or by plug plants grown off site. Green fen hay cut in summer may have more seed but "waste" brown hay from normal autumn fen cutting can still have significant seed of some key species (e.g. Blunt-flowered Rush) so may still be useful. Also, if sufficient material is available, carry out '**assisted colonisation'** of new areas within the site by moving plant clumps around. Move actual plants (or parts of plants) or seed of the species from core areas to restoration zones, as these new areas become shorter and therefore more suitable. Species that produce little seed, or where the seed drops early, will need specific hand-collection when seed is ripe (from June onwards) for the re-introduction at appropriate times. Some species producing little seed will need off-site propagation of the precious few seeds and introduction as plug plants or cuttings or vegetative portions like rooted rhizome fragments. Examples of species that we have found to benefit from assisted colonisation include: orchids (various), Marsh Valerian, Devils Bit Scabious, Marsh Pennywort, Cotton-grasses and Grass of Parnassus. A good time to do species re-introduction by seed is after the final cut and rake of the fen in the autumn. If not available on site, plants to be (re)introduced should be sourced from the nearest local similar calcareous spring/seepage fen that has plants/seeds to spare and collected with the appropriate permissions. See more detailed discussion in separate section below.
- Consider the needs of typical and/or rare fen-breeding invertebrates (like the Soldierflies and Craneflies with aquatic/amphibious larvae) that have mobile winged adult stages needing to search out food from nectar and pollen-rich flowers in the wider landscape to complete their life cycles. Make sure that marginal fen areas have at least some zones of restored flowery grassland with abundant known important nectar producers like Hogweed, Wild Parsnip and

Angelica that are in **flower at the time the adult flies are on the wing** – this may be a narrow period of only a couple of weeks in June-July. These plants with their open, flat flowers are favoured by many species of flying invertebrate and are thus generally beneficial. These flowery 'sustenance zones' around a wet fen beyond the spring-line need to be managed to maximise their flowering (light graze or hay cut and collect annually). For important sustenance flower species see discussion in Webb (2019).

Photographs of cutting (scything) and raking management of fen vegetation by volunteers in Lye Valley are in Appendix I

Hydrological Management

- Valley spring-fens have a very particular hydrology which defines its type and controls the species present. Where this hydrology has been altered (and it usually has, for example by peat cutting or digging ditches to drain the site) it will be necessary to do some management to restore the original, or the best possible, hydrological conditions. It needs to be emphasised that that the hydrology of most calcareous valley fens is complicated, and the potential (often unintended) impact of any re-wetting works needs to be carefully considered. A study of the fen's hydrology (ideally through installed dip-well data) through at least one full year is essential before carrying out any intervention. Hydrological study for a couple of years (encompassing both a very wet year and a very dry year) before intervention would be better, but this is rarely possible.

- Clean water is essential for the "best" spring-fen habitats, however a fen by definition has to be wet, so if clean water is not available either a full restoration to short fen may not be possible, or a taller herb fen without the smaller more sensitive species may be the only practical goal (at least until the water quality can be improved). In our experience, in reality where water is not absolutely clean it is rarely possible to recreate the original fen community, but it is possible to recreate habitats akin to the original short open fen. For example, it is possible to restore and maintain some of the more sensitive species even with poorer quality water, but only by more intensive, more frequent selective cutting and collecting (throughout the year) to remove nutrients and control the more competitive and vigorous plant species. A less intensive cutting regime would achieve the same result for a cleaner water fen habitat.

- One method that has been commonly used to re-wet fens has been to recreate open shallow water features by stripping off the top peat layer so that the existing groundwater level is nearer to, at or just above the surface. This mimics historic peat-cutting for fuel. However, this needs to be considered very carefully (especially if proposed on a large scale) as it can create as many problems as it solves - apart from the practical difficulties of doing the work itself. The first of these problems is the loss of thousands of years of fen history in the form of peat and/or tufa layers (pollen and chemical data preserved in the sediment sequence) and with it, also its potential seed-bank and stored carbon. Secondly, with no changes to the overall groundwater levels across a site, during periods of dry weather and lower ground water levels locally, deep excavations add to the problems of drying-out by creating low areas into which the surrounding un-dug fen drains. This can further dry-out the fen areas surrounding the new low pools. Large scale excavation is also finite, it can only be carried out

a limited number of times, especially on a small site. Eventually, for there to be any long term future for fen habitats, a suitable restorative hydrological regime needs to be in place i.e. reversing the historic processes of long term ditch drainage and resultant drying out by raising the overall site ground-water levels to the former (or near former)state.

- Whenever possible it is better to retain more water within the wider fen system, ideally by reducing losses from the fen by wholly or part blocking artificial drainage structures such as ditches; to restore, or part restore, the wider, more natural, groundwater levels. These drainage structures can be external, controlling the flows into, through and off the site - or internal controlling flows entirely within the site. On many sites, the internal structures are smaller and it is easier to reverse engineer them. Keeping the normally clean spring-water created within the site is a good way to start the re-wetting process. Often (except on exceptionally flat or level sites) this approach recreates small scale shallow water features that are ideal for many fen invertebrates as lower lying areas become at least seasonally wet - without the need for any digging or removal of ancient substrates.

- In addition to and/or following the above work (when water levels are higher and small scale variations in ground level become obvious) - minor, small scale and very local re-wetting can be achieved by blocking or filling low points to hold surface water up and/or direct water flow to enhance the wetness of particular small localised areas. This small scale work can sometimes be effective on even well-drained sites, as an interim measure before larger scale work is possible e.g. on main external ditches that can only be done with the agreement of adjacent land owners. Waste products from site management can be used for this small scale work e.g. logs from tree felling and if needed / available small amounts of peat (avoiding any removal from surviving areas of good fen habitat). In many sites there is a good supply of "waste" peat created by the (past) digging of ditches, pools etc. - much of which is above the general level of the fen in the form of piles or banks along linear features such as ditches, and has consequently lost its entire interesting or valuable flora.

- The existing plant community will have adapted to existing water levels produced by drainage, for example wetter-loving plants will have colonised wetter peat cut pools and died out in the (higher) drier drained fen areas. Raising water levels will generally be beneficial overall BUT care needs to be taken not to drown (kill, potentially lose) any notable or important plant species that have colonised and now survive only in lower areas that will be made unsuitable when much wetter (perhaps with shallow permanent water when formerly "dry"). These species can either be transplanted to more suitable areas either directly (especially if the re-wetting means they will literally be flooded) and/or sufficient material collected and propagated to return the plants once the hydrology has settled down again and/or suitable alternative locations have been identified. Expert site species surveys and mapping are needed in advance of any re-wetting work - and knowledge of the water level tolerances of individual important plant or bryophyte species is needed. Invertebrates are more mobile than plants, but even so, raising water levels may need to be done incrementally to allow time for species to re-locate to new suitable fen areas.

- The quality of the water feeding the fen needs to be known at the start. Sufficient water quality testing is needed before making any changes. Low / near zero levels of nitrate and phosphate are desirable for an alkaline, calcareous valley-head spring fen. Full hydrological

restoration may not be possible if nitrate (measured as nitrate not as N) in water entering the site is 5 ppm or over. It should be less than 2ppm and ideally 0.5 ppm or less **measured in winter** when nitrate is not removed by plant growth. High nitrate in spring water can result from arable fertiliser application in the groundwater catchment or sewage leakage or drinking water main leakage to groundwater from developments. The desirable water quality needed is that of an unpolluted chalk stream. However, even if water is not as clean as desirable (and may never be clean again), the restoration of a former entirely drained and dry fen habitat to a truly wet habitat again has so many nature conservation and other benefits (e.g. protection of carbon in peat from oxidation, restoration of common tall herb wetland community) that relatively poor water quality should not stop fen or other wetland restoration, but targets for the type of habitat that can be created need to be realistic.

- There may be more than one water source that can be used. For example, often there are springs from the valley sides (internal source) and water flowing through the valley bottom (from external sources). These sources often vary in quality. For example springs can be clean (derived from aquifers under natural unbuilt catchments) or contaminated (derived from urban or agricultural catchments) – on some sites both clean and contaminated springs are present. External sources of water also vary in quality. It may be possible to use the clean(er) source(s) to restore short fen areas, with less clean water diverted away from these areas and used to restore taller fen habitats on other parts of a site.

- 'Dirty' (high nitrate/phosphate) water cannot be used for the restoration of good quality spring-fen habitat. It needs to be directed to flow through the site and/or diverted away from areas to be managed as "good" fen. It is possible to clean water up to some extent by "filtering" it through a series of channels or pools filled with cut vegetation (waste material from fen cutting), which in combination with anaerobic bacterial decomposition of cuttings and uptake by living plants such as Common Reed in the growing season, strip some of the excess nutrient from the water. The further away from the site to be restored this 'cleaning up' can take place the better e.g. it may be possible to create one or more water 'clean-up' areas in relatively ecologically poor habitats sites higher up in the catchment of the restoration site. Though it may not be ideal, in order to protect the best and most important remaining habitats; other sites or parts of sites may have to be sacrificed for the greater good. Less clean water can be used in raising general groundwater levels, but ideally not close to the surface or as surface water itself. This may be unavoidable in many sites e.g. where drains fed by large scale urban surface drains pass through fen habitats, as in Lye Valley – and these parts of a site may simply have to be written off as they are so severely damage that under current circumstances they will never be good habitat of any kind, let alone open short fen.

- The simplest way to re-wet a spring-fen is to part or wholly block any artificial drainage channels dug in or through the site, restricting loss of spring water. In our experience, even apparently natural channels have been enhanced by man, to maximise their drainage potential. Historically, in too many sites drainage ditches have been regarded as normal spring-fen habitat features when, almost without exception, they dry out and therefore damage the fen habitats they pass through, at least in the areas adjacent to the ditch if not over a wider area. Even a small shallow ditch only 15cm deep can lower the hydrological gradient and dry peat for many metres either side negatively affecting larvae of wetland invertebrates such as craneflies (Stubbs 1999). The natural materials created by site management (logs, brash, cut

ground plants) provide ideal material for use in the structures to block and fill these drainage channels. Hard engineering using building materials brought to the site are not needed. Therefore, in terms of materials at least, these tasks are cheap and have the advantage of losing much of the "waste" material that would otherwise have to either be removed from site and/or stacked on site as habitat piles. It can take many years of work to finally eradicate (fill in) larger ditches i.e. they can provide locations to get rid of unwanted material for a significant period if not the whole of the restoration period of a site. As restoration proceeds, the volume of waste material usually decreases, which in some cases leads to a shortage of material for the re-wetting structures. In the Lye Valley, where restoration is still on-going after many years, it is not possible to create enough material of the right kind from the on-site management to undertake the creation of the structures to protect the site from the potential damage caused by urban drainage channel through the site. Additional material has to be brought from off site.

- Always test water quality first to ensure it does not have unsuitably high nitrate levels (never flood a fen with polluted water). Water levels in dammed drainage channels may need to be raised to only 2/3 of bank height in first instance in order to see the site's hydrological response in the first year. The height of log dams may need to be adjusted (up or down) over time in response to several years weather observations until the most beneficial water levels are achieved – generally the site being just wet enough all summer and not over-wet in winter. Reversing drainage is not a one off action. Monitoring of dipwells and log dams and dam adjustment as necessary should continue to accommodate for changes in our weather due to wider climate change.

- In sites with more flashy flows, with poorer ditch water quality and where it is not desirable for water to temporarily flow over / flood the adjacent fen; it is necessary to leave sufficient open ditch volume for high water flows to be retained in the ditch and/or have bank structures in place to prevent incursions of water where the ditch alone cannot contain the volume at peak flow.

- Creation of stagnant (anoxic) conditions on the fen surface needs to be avoided. Ponded areas need to still provide for gentle water through-flow which gives necessary oxygenation. Many species of plant and invertebrate depend on water flow (even if this is very slow) through the surface layer or over the fen surface to provide oxygen for respiration of roots or aquatic larvae in peat or pools. Water flow through sites from springs may be so slow as to be almost undetectable, but it is still important. Some plant and invertebrate species have no tolerance for anoxia; others are more tolerant and can cope with short periods of anoxia. Lack of oxygen in water can change water chemistry for the worse, affecting plant root growth.

Photographic examples of small and large scale fen re-wetting are shown in Appendix II.

Restoring Typical 'Missing' Alkaline Fen Species (Plants)

How do you know what plant species might have been lost from an overgrown fen habitat? Consult historic floras. In Oxfordshire the Floras written by George Claridge Druce (1897, 1927) are full of plant information and for invertebrates; the Victoria County History (Salman, 1938) is useful. More recent records for all species types are held in the database of the county biological records centre, TVERC. For invertebrates, historic specimens held in museums are also good information sources of past locations.

What follows is knowledge gained from personal experimentation and observation in Lye Valley SSSI and LWS fen in Oxford and using seed bank data from published sources (e.g. Thompson et. al. 1997, Maas and Schopp-guth 1995). Initially the result of cutting and raking of overgrown common reed-dominated fen in Lye Valley was studied for some years to record any species recurrence from the seed bank. After some years of this, some species were recorded as returning, including the following important and desirable species of alkaline fen: Bog Pimpernel, Marsh Arrow-grass, Long-stalked Yellow-sedge, Common Sedge, Water Figwort, Ragged Robin, Square-stalked St John's Wort, Brookweed, Brooklime, Blunt-flowered Rush and Bulbous Rush (these therefore are presumed to have a viable long-lived seed-bank remaining in the peat). Desirable species showing no return (presumably no viable seed bank left - very short-lived seed) included for example: Common Cotton Grass, Broad-leaved Cotton-grass, Devil's Bit Scabious, Parsley Water-dropwort, Marsh Lousewort, Grass of Parnassus, Quaking Grass and Marsh Pennywort. But of course, it should be remembered that the return of a species might not happen simply because a particular plant may not have historically been present in the particular plot you are restoring. Plants can naturally be very localised within a site.

Experimental germination of collected seed of some of these fen plants has shown, for example, that ripe seed of two species of Cotton Grass collected in early June and sown immediately, showed 100% germination within only two weeks - indicating this species is unlikely to have long seed life. Seed of Devil's Bit Scabious is known to be short-lived because it showed no germination if kept in a packet for more than a year at 4 °C in a refrigerator, although for both these examples, seed survival in wet cold peat may be longer. Plants such as these will likely have no viable seed bank left if there has had no appropriate management of the fen for very many years (or for some, even if neglected for as little as five years); so will need seed collection from a nearby fen site and re-introduction. This can happen successfully by scattering freshly collected seed in the autumn in newly cut, raked and thus bared, fen areas. This works very well for species that make a lot of seed like Grass of Parnassus, Marsh Lousewort and Devil's Bit Scabious. For species that produce little seed or with limited seed dispersal, freshly collected seed should be sown and grown-on offsite to small plants for a year and then introduced as plug plants. This works best for low seed-producer species like Meadow Thistle, Dioecious Sedge and Cotton Grass species.

Volunteers can enjoy helping with plant propagation. Some species have tiny seed almost impossible to harvest by hand collection (e.g. Bog Pimpernel, Marsh Pennywort and Few-flowered Spike-rush). In the case of these species, pulling up rooted portions and propagating them or directly translocating them to newly bared areas within the fen works very well, due to their rhizomatous/stoloniferous habitat (enabling sideways running like a strawberry). Seed harvesting or plant-portion harvesting and translocation between fen sites will need appropriate permissions from landowners and conservation bodies and seed or plants should only be harvested from strong thriving source populations. Some desirable species like Bladder Sedge and Bottle Sedge have proved impossible to return from either scattered seed or seed sown in propagation attempts offsite. They may have germination requirements that are not yet understood and are only effectively re-introduced via vegetative portions.

Return of species from the seed bank is found to be not always a positive in fen restoration (there may be a big return of what we refer to 'undesirable' or 'problem' species). A number of common and dominant plant species have very long-lived seeds and can return quickly in force, producing a dense and dominant new population of perennial plants that can be a problem in that they then inhibit return of more desirable species by competitive exclusion. This is especially observed to be the case on sites with a degree of water enrichment and/or where dried out oxidised peat has been re-wetted thus providing more nutrient-rich conditions which favours these "problem" species. Examples of such

problem undesirable 'returners' are: Pendulous Sedge, Hard Rush, Soft Rush, Bittersweet and Sweet Grasses *Glyceria* sp. Plans for control of these by frequent cutting or actually digging them out may be necessary. Further details on observed seed survival and which introduction method works well for particular fen plant species, are in **Appendix III**.

Restoration of particular rare '**brown mosses'** characteristic of calcareous alkaline spring fens such as: Yellow Starry Feather-moss, Intermediate Hook Moss, Marsh Thyme-moss, Maiden-hair Pocket-moss, Thick-nerved Apple-moss and Curled Hook-moss requires first that the fen be reliably returned to un-shaded short turf with the appropriate hydrology of low-nutrient calcareous spring runnels and shallow surface pools which these mosses can occupy. Re-introduction works well from gathering and planting out small vegetative tufts, which may need to be pegged down with dead twigs until they become attached to the substrate. This is necessary as these now scarce mosses seem to have stopped reproducing sexually by spores (reasons unknown but may be because they are dioecious and relic populations may have only one sex), so will never be able to recolonize any restored fen naturally by wind-blown spores. Apparently no spore-bank of these species seems to exist.

Of course there is no equivalent of the seed bank for invertebrates. Mats of tufa-encrusted brown mosses can be crucial breeding sites for the larvae of rare Soldierflies and the rare Water Penny Beetle, but restoring the rare mosses will not automatically bring back their associated invertebrates. The challenge of re-introducing lost invertebrate species like these, are much greater than for plants and are dealt with in a separate document. Initially, restored short-turf spring-fens may just have to wait for natural re-colonisation by winged adults of mobile species such as flies, but in a fragmented landscape, with isolated fens, this may take a long time or never happen at all. The closer restored fens are to other high quality biodiverse fens, the more likely mobile invertebrates will be to find the newly suitable habitat.

Maintenance Habitat Management

When a spring-fen already has short diverse vegetation with good water levels and flow through the site OR once a site has been restored after a period of neglect and/or other inappropriate management i.e. there is no longer a need for more regular and/or more intensive management.

- Light, extensive grazing potentially for most of the year by low stocking number of smaller-sized, hardy types of cows or ponies is ideal but may be impossible on small sites. (Very small sites would need an impossibly low stocking rate.) Sheep are not suitable for such wet sites.
- Care needs to be taken that the sites are not over-grazed and that for example the plant species that rely on seed production for their continued presence on site are allowed to flower and set seed and invertebrates using leaves or flowers for larval development are not prevented from breeding by unseasonal grazing. Therefore it may be necessary to reduce grazing and/or have no grazing at all for the key time from late spring and through the summer (May to August). Autumn grazing is usually no problem, Mid-August to November is a safe time to graze, being mostly after flowering, seeding and completion of invertebrate life-cycles.
- Small sites may be better cut than grazed. This is because they either have a high level of ecological interest (making them very vulnerable) or where the number of stock needed is so low as to make it make difficult to make it viable in a practical sense. This is so for Lye Valley with one SSSI unit being 1.0ha and the other SSSI unit only 0.5ha. Cut and collect as / when required may be the only "safe" management on such small sites. With future

restoration of both fen and other habitats adjacent to the fen, a larger area (of both wet and dry habitats) may make grazing the most viable / important management type

- Even if the site is grazed, this grazing is best combined with vegetation harvesting of ranker areas where grazers avoid unpalatable tough species, particularly Hard Rush and Black Bog-rush, which can otherwise assume dominance and reduce species diversity. A cut and collect of these will stimulate new growth which will then make them more attractive to grazers, keeping them under control. Lightly grazed Black Bog-rush tussocks can become very biodiverse microhabitats. The cutting of tussocks needs to be done with care and whatever tool is used needs to avoid damaging the main tussock structure. Removal of all cuttings from the fen lowers nutrients on site, reducing plant vigour and promoting biodiversity.
- If no stock is available, then cut and remove vegetation from whole area of fen. **Twice a year** (early spring and autumn) is the minimum to adequately replicate (to some degree) light extensive grazing. Avoid cutting (allow to flower and set seed) better areas of fen with desirable rare spring- or late-flowering plants during the growing season. If the fen is really short and **low nutrient** and has a good Marsh Lousewort population, one autumn / winter cut and collect may be sufficient in some years at least. However it is recommended that the habitat is monitored, and additional cutting is carried out if needed to ensure the desired habitat condition is maintained.
- Once the fen has plenty of Marsh Lousewort, there is no need to specifically collect seed and spread it annually. It will spread naturally.
- Cutting will create material that, when a habitat is in good condition, may not be useful (as it often is during the restoration phase). If no agricultural use can be found for it, and it is not needed as seed-rich "hay" for restoring other fen sites, then as per the restoration phase, it can be retained on site as small / compact on-going (permanent) habitat piles positioned away from important areas such as spring/seepage emergence zones. The piles will provide useful hibernation/refuge areas for invertebrates, reptiles, amphibians and small mammals. None of it should be burnt, this would destroy any resident invertebrate eggs/larvae/pupae. The volume of material created by cutting a short fen in good condition will be much smaller and therefore easy to deal with compared with the material created by managing the tall and/or dense vegetation of a neglected fen.
- The often quoted **three-year rotation for 'Lowland Fen' management** – i.e. cutting and removing vegetation on c. **one third of the fen area per year** is not at all suitable in the case of valley-head spring-fed calcium-rich seepage fens, where short-turf habitats are the most important habitat, especially those with the very rare M13 NVC plant community. **These M13 fens should be cut and raked at least annually if not several times a year** to mimic light extensive grazing.

Catchment Management Issues

Water emerging from an underground porous rock aquifer is the life-blood of spring/seepage fed fens and the **habitat lives or dies by what happens in the rainwater catchment** that recharges this aquifer.

This catchment is the drier land area around the site (usually beyond conservation boundary limits) where rain penetrates the soil and generates the groundwater that emerges from springs and seepage zones in the fen.

Management of the fen itself should go hand in hand with good management of its catchment to ensure continuity of water supply and favourable water chemistry. The catchment area is determined by geology and topography.

The best habitat in any spring-fen rainwater catchment which will ensure maximum rainfall infiltration into the ground and into the limestone, chalk or sand aquifer is a green vegetation cover on an un-compacted good, humus-rich soil with an '**active soil horizon'** (see Webb 2022 'How does a Valley-head Spring-fen Work?'). So, ideally grassland (an open habitat) with no artificial chemical input, managed as either pasture or hay meadow. **This grassland does not have to be biodiverse**, but there needs to be no compaction to ensure maximum infiltration. Arable cultivation provides infiltration, but changes ground-water chemistry for the worse in terms of chemical pollution of groundwater from artificial fertilizers (the main problem being nitrate) and pesticides such as herbicides fungicides and insecticides (Ref European Environment Agency Dec 2024). Any soluble chemicals applied to a field will potentially be leached (washed out) by rain into the aquifer, then travel underground and emerge in dependent fen springs; this is particularly true for nitrate which can travel long distances underground in a rock aquifer. High nitrate emerging from springs will stimulate growth of common and dominant 'nitrophilic' wetland species at the expense of rare low nutrient-dependent fen plants and invertebrates. In theory reversion of arable cultivation in the catchment to no-input grassland should lower legacy nitrate groundwater pollution from fertiliser use eventually, but this may take many years. Pesticides may also leach to groundwater from arable fields.

Damaging activities in the catchment should be avoided. All the following are likely to adversely affect either the groundwater supply volume, rate and pattern of delivery and/or the high calcium alkaline, clean groundwater chemistry needed by a spring/seepage fen:

Rarely considered are development **offsite impacts outside the development red line**, but these can be hugely important if the development is within the spring-fen catchment area.

Building on the rainwater catchment of a groundwater dependent spring-fen can be a serious and permanent problem - even housing hundreds of metres away from the fen site can have a devastating impact on a fen's hydrology. Summarised here is a list (not exhaustive) of actions in any **alkaline spring-fen catchment** that are likely to be damaging to the dependent rare wetland biodiversity and in some cases also to peat carbon storage and carbon accumulation. Development in spring-fen catchments should be highly restricted or eliminated (Lamberth, 2007). Note these spring/seepage fens are exceptionally low-nutrient (nitrate and phosphate mainly) dependent sites, needing the high water quality of a chalk stream; and that groundwater pollution cannot be undone or remediated once it has happened. We have knowledge of these issues from Lye Valley fen SSSI in Oxford (almost surrounded by urban development in its catchment) and Cothill Fen SAC (with intensive arable in its catchment and also affected by mineral extraction):

- Housing development on a previous greenfield. **Soil-sealing** has an impact, **putting a permanent impermeable lid on the catchment**; even with infiltration SUDS or soakaways – the pattern, volume and chemistry of groundwater flow to the fen maybe altered unpredictably. SUDS decline in effectiveness over time (as they silt up) and thus infiltration declines. Water starvation of fen springs, means spring line moves downslope leaving dry peat higher up.
- Development resulting in directing run-off drainage rainwater from roofs, paved areas roads, concrete, tarmac in catchment areas as concentrated flows (e.g. via pipes or ditches) **into a fen** resulting in peat erosion, and pollution; even the 'greenfield rate' emitted from a point source like a pipe can be erosive.

- Water abstraction from the aquifer for drinking water or irrigation, results in a lowered groundwater table, and springs starved of water.
- Development - leakage from drinking water pipe infrastructure – pollution from nitrate into groundwater and springs at more than 0.5ppm (Oxford tap water has more than 20ppm nitrate on average.)
- Development – effluent leakage from sewerage pipe infrastructure as it ages– pollution from nitrate into groundwater and springs of more than 0.5ppm.
- Ground-source heat pumps (leakage of liquid from pipes e.g. antifreeze) to contaminate groundwater.
- Deep heat seeking boreholes (damage to geology, fracturing layers, damage aquifer water storage)
- Tree planting – trees intercept rainwater and evaporate it before it hits ground and suck water from soil and evaporate it from leaves – reducing the water moving into soil and subsequently underground to the springs. Planting conifers detrimentally acidifies groundwater, a green covering of any other sort of vegetation with no fertilizer or pesticides input is ideal.
- Mineral extraction with consequent landfilling with clay lining and capping - lack of essential rain infiltration to aquifer due to clay lid effectively resulting in the extinction of rainwater /groundwater catchment, the lack of aquifer recharge area , groundwater table generally lowered reducing fen spring-flow plus possible pollution leak to groundwater if domestic rubbish infill occurs. Lack of calcification of any surface water reaching fen. Increase run off from clay capped areas creates fast flashy surface flows and potential erosion of the fen during heavy rain fall events and short lived inundation with unsuitable water.
- Intensive agriculture with artificial fertilizer application plus pesticides (all may travel in groundwater to the fen - nitrate pollution an obvious result, but herbicides/insecticides also a worry.

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APPENDIX I

Photographs of Spring / Seepage Fen Vegetation Management

Scything and raking with removal of cuttings by volunteers in a Valley-head alkaline spring-fen In Lye Valley (this section photographs by Tony Gillie). Thanks to all volunteers for permission to include these photographs.

Annual scything to a short sward in the autumn, mimicking grazing. 18.12.2024.

Scything of new rush and sedge re-growth. 16.10.2024

Raking and removal of autumn fen rush and sedge cuttings, mimicking grazing.18.12.2024

Moving autumn cuttings off the fen using tip sheets. 13.11.2024

Use of fen cuttings in bank restoration, Lye Valley Fen SSSI. 30.10.2024.

End result, nearly all Lye Valley spring fen cut short and raked by the end of the year. Note shallow spring-fed pools are open and sunny. Hanging spring-fen exists on the far slopes from a high level spring line. It is important for rare invertebrates to always keep the spring/seepage emergence zone short as here. 17.01.2020

APPENDIX II

Examples of methods for reversing historic drainage of seepage/spring fens by using natural materials which can often be sourced on site. All photos by J A Webb or Tony Gillie.

Photographs of Small Scale Fen Re-wetting, Reversing Drainage

Board Damming and Re-Direction of Surface Spring-Fed Runnels

Steve Gregory using **small pegged board dams** to keep the clean surface spring-water flow on the fen (on right) rather than allowing it to be lost into the drainage ditch (on left). Keeping this clean spring water on the fen keeps the fen wetter - especially important at drier times of year and/or during droughts when spring flow is reduced. After construction, the boards are hidden under fen cuttings. Lye Valley SSSI North Fen December 2024.

Larger Scale Re-wetting by Damming a Small Drainage Ditch With Slow Water Flow

Rod d'Ayala and Steve Gregory construct and install log bunds / dams in a shallow drainage ditch, raising the water level to the height of adjacent fen. Sealed at the base with waste peat, partially leaky in the top log section. Bottom two photos shows peat and cut vegetation added to the upstream (bottom left photo) and downstream (bottom right photo) side of the dam to seal and completely cover the dam. Top left photo, Lye Valley SSSI South Fen marginal ditch. All other photos a fen on Frilford Heath Golf Course SSSI. (Natural England grant-funded work.)

Larger Scale Re-wetting by Damming a Much Wider / Deeper Drainage Ditch With Slow Water Flow.

Photo 1 - Information Caption on Next Page

Photo 2 - Information Caption on Next Page

Photo 3. (Two photos on above page.)

Many logs used in the dam, well anchored into banks**.** Rod d'Ayala filling the **c**hannel between log dams with brash. Raleigh Park LWS fen, 2021 and 2024. Logs used are from trees removed from fen margin, there are more trees to remove in the centre (Photo 3, above). This management is work in progress. (Freshwater Habitats Trust grant-funded work.)

APPENDIX III

Some Key Alkaline, Calcareous Short Turf Spring-Fen Plant Species and Discussion of Seed Banks in Restoration (all photos by Judy Webb)

Marsh Lousewort *Pedicularis palustris* (left) and Bog Pimpernel *Lysimachia (Anagallis) tenella* (right)


Marsh Helleborine orchid *Epipactis palustris* (left) and Grass of Parnassus *Parnassia palustris* (right)


Broad-leaved Cotton-grass *Eriophorum latifolium* (left) and Common Butterwort *Pinguicula vulgaris* (right)


Few-flowered Spike-rush *Eleocharis quinqueflora* - male stage (left) and Flea Sedge *Carex pulicaris* (right)


Examples of the important and now scarce '**brown mosses**' of alkaline spring-fens, some of these are involved in tufa formation and become encrusted with limescale as they grow. Most need high light (only *Palustriella commutata* tolerates some shade). Some can grow in/under shallow water others don't tolerate inundation but need just a constant trickling water flow through their branches.

Intermediate hook-moss *Scorpidium cossonii* (left), Yellow Starry Feather-moss *Campylium stellatum* (right)

Claw-leaved Hook-moss *Palustriella commutata* (left), Maiden-hair Pocket-moss *Fissidens adianthoides* (right)

Stonewort Algae (Chara species, most commonly *Chara vulgaris*) are typical of shallow sunny pools and runnels in areas of tufa or marl deposition in alkaline spring-fens. The branches of the algae become encrusted with limescale giving them a hard and crunchy feel (hence ‘stone’worts). Here with sedges and Marsh Pennywort leaves. Important invertebrate larval habitat.

Some Key Alkaline Spring Fen Invertebrates With Larvae in Wet Mud of the Fen,

Examples of Commoner Soldierflies and of the Breeding Habitat:

Four-barred Major *Oxycera rara* (one below) and Three-lined Soldier *Oxycera trilineata* (two below) - both reared from larvae collected by Judy Webb.

Three specimens of the tiny rare Water Penny Beetle *Eubria palustris* (Near Threatened) next to a pencil point. This needs bare open wet runnels in short fen for its larval development, the larvae graze on algae and bacteria.

Shallow open, sunny, warm, low-nutrient whitish marl / tufa pool near spring-line; with sparse rush, reed and Marsh Lousewort in Lye Valley fen. An important breeding area for aquatic larvae of Soldierflies and Water Penny beetle.

Tufa –encrusted brown moss (probably *Scorpidium cossonii*) on the edge of shallow marly pool, preferred habitat for some soldierfly larvae

Information For Re-Introducing Lost Fen Plant Species

There is much more to find out about seed longevity and viability and germination requirements for plants in fens. What follows is just our early observations from 12 years of work and study in the Lye Valley. **Note our views on which appear to have short-lived or long-lived seed could easily change with more research.**

Fen Species With A Long-Lived Seedbank

The list below is of those species observed to return by germination from seeds in the peat, as a result of the introduction of better management (cutting and raking) resulting in more light and surface disturbance. Note it is sometimes hard to distinguish return from the seed bank from return from non-flowering unrecognisable vegetative remnants just about hanging on in unsuitably shaded conditions. There are lots of species for which we do not yet understand how long their seed lives in peat e.g. Black Bog-rush *Schoenus nigricans*. **Also not all returning species are desirable, some give problems.**

Species recorded returning from areas disturbed in previous years work

Bog Pimpernel *Lysimachia (Anagallis) tenella*

Wavy Bittercress *Cardamine flexuosa* (the first to return)

Marsh Arrowgrass *Triglochin palustre*

Fen Bedstraw and Marsh Bedstraw *Galium uliginosum and G. palustre*

Sedges (*Carex* sp, but not all of them) particularly: Long-stalked Yellow-sedge *C. lepidocarpa*, Common Sedge *C. nigra*, Distant Sedge *C. distans*, Remote Sedge *C. remota*, Pendulous Sedge *C. pendula* (the latter two may be undesirable as can assume dominance)

Rushes: *Juncus* species i.e. Blunt-flowered Rush J. *subnodulosus*, Jointed Rush *J. articulatus*, Bulbous Rush *J. bulbosus*, Hard Rush *J. inflexus*, Soft Rush *J. effusus* and Toad Rush J. *bufonius*. (The return of large amounts of *J. inflexus* and *J. effusus* may create problems)

Common Butterwort *Pinguicula vulgaris* (a very rare return)

Bristle Club-rush *Isolepis setacea* (Suspected very long lived seed)

Hemp Agrimony *Eupatorium cannabinum*

Tormentil *Potentilla erecta*

Some Sweet Grasses *Glyceria* sp e. Plicate Sweet Grass *G. notata* (maybe undesirable)

Creeping Bent *Agrostis stolonifera* (maybe undesirable)

Rough Meadow Grass *Poa trivialis* (may be undesirable)

Water Figwort *Scrophularia auriculata*

Tufted Hairgrass *Deschampsia cespitosa* (undesirable)

Heath Grass *Danthonia decumbens*

Lesser Spearwort *Ranunculus flammula*

Brookweed *Samolus valerandi*

Marsh Willowherb *Epilobium palustre*

Bittersweet *Solanum dulcamara* (maybe undesirable)

Lesser Water-parsnip *Berula erecta* (A potential problem if abundant)

Fool's Water-cress *Helosciadium nodiflorum* (maybe undesirable)

Stonewort Algae (*Chara* sp.) no seeds, but have a long –lived spore bank

Fen Species Without A Long Lived Seed-bank

Observed to show no return with only cutting / raking and repeated light peat disturbance and which are found to need re-introduction by collected and broadcast seed (target newly bared peat or tufa areas, not dense vegetation for best seedling germination) or use of propagated plug plants or vegetative portions**.** Spread seed in the autumn as soon as bare fen areas are available, as seed may need some weeks of cold winter temperatures to trigger spring germination. If seed has to be stored, store dry in paper in a refrigerator, but make sure sown by next spring or viability may be lost.

Recommended re-introduction method in brackets:

Orchids (all) - Marsh Helleborine *Epipactis palustris*, Southern Marsh Orchid *Dactylorhiza praetermissa*, Narrow-leaved Marsh Orchid (in Oxon now thought to be a variety of *D. praetermissa*), Early Marsh Orchid *Dactylorhiza incarnata*, Twayblade *Neottia ovata*, Marsh Fragrant Orchid *Gymnadenia densiflora* (all introduction by seed but may have to wait 2-7 years for result of flowering from seed spreading. All need mycorrhizal fungi to form symbiosis with roots. Fungi have to be present, only low nutrient peat/tufa likely to favour the specific fungi needed).

Common Cotton-grass *Eriophorum angustifolium* (plug plants, vegetative portions)

Broad-leaved Cotton-grass *Eriophorum latifolium* (plug plants, vegetative portions)

Purple Moor-grass *Molinia caerulea* (seed)

Devil's-bit Scabious *Succisa pratensis* (seed)

Grass of Parnassus *Parnassia palustris* (seed)

Meadow Thistle *Cirsium dissectum* (plug plants)

Marsh Thistle *Cirsium palustre* (seed)

Meadowsweet *Filipendula ulmaria* (seed, plug plants)

Wild Angelica *Angelica sylvestris* (seed, plug plants)

Parsley Water-dropwort *Oenanthe lachenalii* (seed, plug plants)

Tufted Vetch *Vicia cracca* (seed, plug plants)

Greater Bird's-foot Trefoil *Lotus pedunculatus* (seed, vegetative portions)

Yellow Flag *Iris pseudacorus* (vegetative portions)

Marsh Marigold *Caltha palustris* (seed, plug plants)

Marsh Pennywort *Hydrocotyle vulgaris* (vegetative portions)

Few-flowered Spike-rush *Eleocharis quinqueflora* (plug plants, vegetative portions)

Purple Loosestrife *Lythrum salicaria* (seed, plug plants)

Yellow Loosestrife *Lysimachia vulgaris* (seed, plug plants)

Quaking Grass *Briza media* (seed, plug plants)

Cuckoo Flower *Cardamine pratense* (vegetative portions or plug plants from leaf cuttings)

Water Mint *Mentha aquatica* (vegetative portions)

Marsh Woundwort *Stachys palustris* (vegetative portions)

Dyers Greenweed *Genista tinctoria* (plug plants)

Judy Webb with collected armful of dead Purple Loosestrife seed heads, ready for processing before seed spreading. Lye Valley SSSI North fen, 29.11.2017.