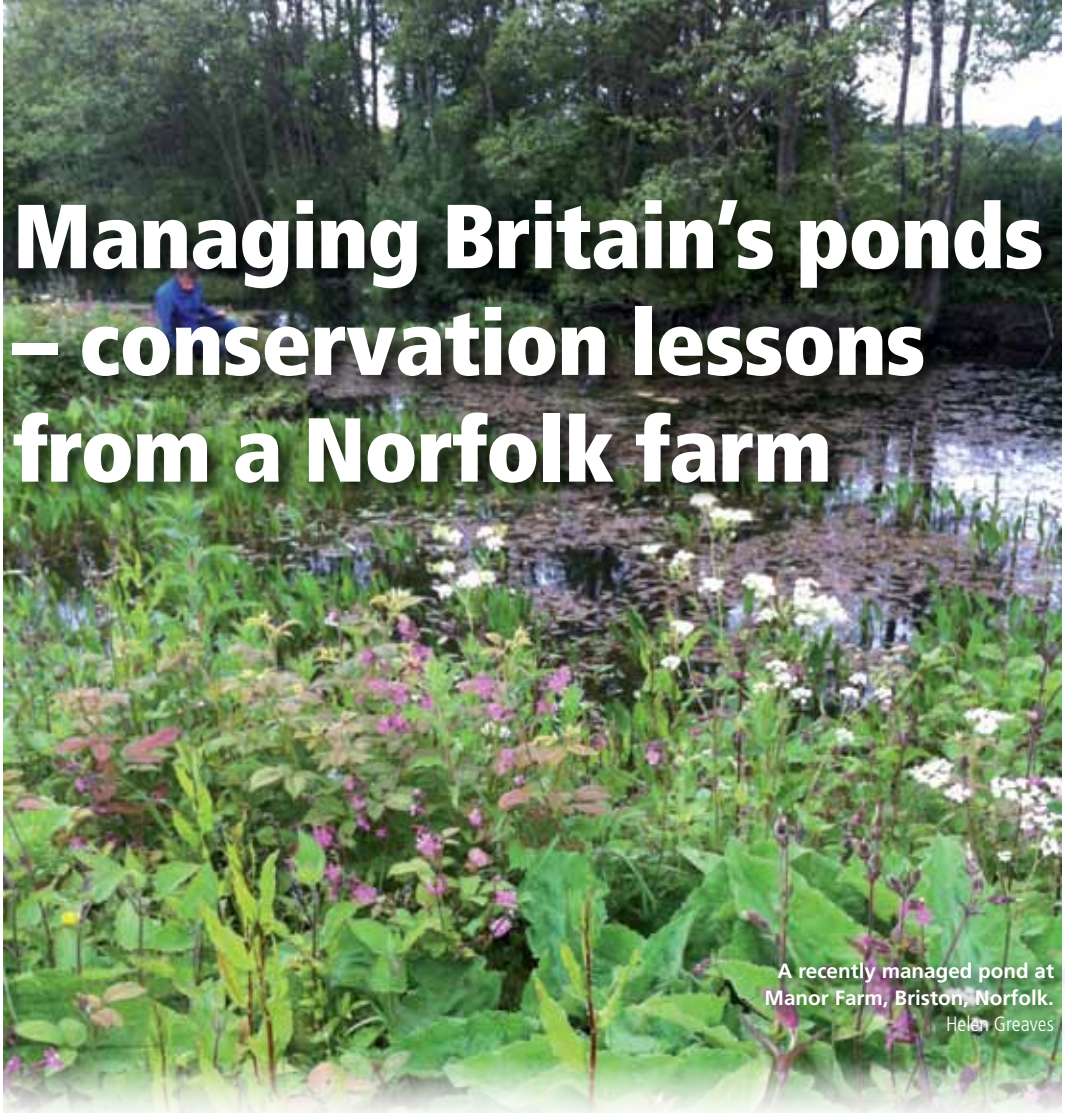
Managing Britain's ponds – conservation lessons from a Norfolk farm



A recently managed pond at Manor Farm, Briston, Norfolk. Helen Greaves

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Ponds are a tremendous, but still largely unrecognised resource for nature conservation in the British Isles. This is especially true in agricultural areas, where, if sufficiently buffered from the farmland, ponds afford wonderful watery patches, often buzzing with species. A recent article in *British Wildlife* admirably celebrated the high conservation value of newly excavated 'clean-water' ponds as delivered by the Million Ponds Project (Williams *et al.* 2010a). We shall not dig over this ground again. Instead, we hack through the undergrowth of another approach to pond conservation, namely the restoration and management of our existing pond resource. This story comes from a Norfolk farm, but has parallels all over Britain, where ponds are common features in the landscape.

On a journey along Norfolk's rural roads, the pond-hunter will find his or her quarry by searching for circular clumps of trees out in the fields. These mini-woodlands often betray the position of 'marl pit' ponds (Box 1). A closer inspection of the ponds reveals them to be almost entirely invaded by trees, with little in the way of open water. And herein lie the debate and some uncertainty in the field of pond conservation: should ponds be managed to reduce terrestrialisation, or should we leave them undisturbed and dig some new ones instead? Currently, the UK's dominant pond-conservation strategy is focused around pond crea-

Box 1 Marl pits

Marl is a friable sedimentary deposit containing both clay and calcium carbonate. The term 'marl' dates back to at least the 13th century, when it was used much more broadly to describe any mineral substance dug from beneath the surface soil to correct the soil's acidity, or improve its texture (Prince 1962). It is this description that lends an explanation for the numerous water-filled hollows found in several English counties, notably Norfolk and Cheshire. Marl-pit ponds are generally small, steep-sided and regular in shape (round or oblong shapes seem to dominate). The majority are situated in the middle of arable fields away from tracks, roads and farm buildings, supporting the suggestion that their origin relates to agriculture and an early means of liming the soil (called 'marling'). It is likely that several men would have been employed in digging out marl pits, loading the material on to carts prior to spreading it on the land. The heavy weight of the clay mixture would have made this process extremely arduous. One theory to explain the fact that marl pits are often found at the highest point in fields is that this made it easier to move the loaded carts downhill (Prince 1964). Marling would have increased and declined over the centuries as farming practices changed and grain prices fluctuated, making the practice more or less economically viable. However, much evidence suggests that it was at its height in the 18th century, but halted before the First World War.

A recent survey recorded 21,222 waterbodies regarded as ponds in Norfolk (Carroll 2009), a very high proportion of which are likely to be marl-pit ponds. To date, minimal information exists regarding the current ecological status and conservation value of these ponds, but mostly they are overgrown and need management to bring them back to life.

Marl-pit landscape in West Norfolk. Note the evidence for ponds lost to recent agricultural-land reclamation (see depressions in the fields). These 'ghost ponds' could easily be resurrected from the dead. English Heritage

A typical overgrown marl-pit pond in Norfolk. Ben Goldsmith

tion and in this respect the Million Ponds Project is leading the charge, aiming to create thousands of new clean-water ponds in England and Wales over the next decade (Williams *et al.* 2010a). At the same time, much of the conservation literature concerned with ponds conveys a degree of nervousness towards management aimed at removing trees and restoring a more aquatic phase. This view stems partly from concerns that disturbance associated with tree and mud removal from ponds might lead to a loss of rare and distinctive species (especially beetles) associated with heavily wooded, so-called 'late succession ponds' (Biggs *et al.* 1994). Certainly, it is true that some species do enjoy the leafy, highly organic habitats afforded by overgrown ponds. But there is more to this story, as revealed by our recent pond studies at Manor Farm, Norfolk (Sayer *et al.* 2012).

Manor Farm and its ponds

Manor Farm is a mixed farm in north Norfolk that straddles the upper reaches of the rivers Glaven and Bure, at an altitude of 50-60m above sea level. The farm grows eight different crops, carries around 800 out-wintered sheep and has grazing cattle during the summer months. Most of the fields and pastures on the farm contain at least one pond (many of these are marl pits), giving some 40 ponds in the farm's 243ha. With few exceptions the Manor Farm ponds are fed by spring water,

Box 2 Crucian Carp

The Crucian Carp *Carassius carassius* is a chubby, greeny-gold, beautiful little fish thought to be native to south-east England (Wheeler 2000). It is a fish of small, ideally weedy ponds that fares poorly in larger waterbodies, where it is particularly vulnerable to predation by species such as Pike *Esox lucius*. A recent study in north Norfolk has shown a substantial decline (c. 75%) in the number of ponds containing Crucian Carp over the last 30-40 years (Sayer *et al.* 2011). This is thought to be due to a combination of factors: hybridisation with introduced Common Carp *Cyprinus carpio* and Goldfish *Carassius auratus* resulting in genetic contamination and enhanced competition (see Copp *et al.* 2005), land reclamation (and thus pond loss), pond desiccation due to droughts, and, most importantly, pond terrestrialisation associated with prolonged periods of low oxygen. The Crucian Carp can survive anoxia in ponds for several months owing to an armoury of remarkable physiological capabilities, not least an ability to store large quantities of glycogen in its vital organs (Vornanen & Paajanen 2006). That the Crucian Carp has become extinct in many overgrown ponds hints at how stressful conditions must be for all aquatic species when ponds are highly terrestialised. If Crucians cannot ride things out, then nothing can!

A Crucian Carp captured from a small Norfolk marl-pit pond (by means of fyke nets). Bernard Cooper

Surveying a small pond by means of fyke nets in early spring. Carl Sayer

The Crucian Carp has recently been designated as a Biodiversity Action Plan (BAP) species in the county of Norfolk (Copp & Sayer 2010). This plan aims to expand the distribution of Crucian Carp through a combination of pond rehabilitation and reintroduction of the species into suitable ponds.

and all the ponds on arable land are surrounded by grassland buffers. The farm has been in an Environmental Stewardship Scheme (ESS) and has recently (2011) entered into a Higher Level Stewardship (HLS) agreement.

In many ways, the Manor Farm 'pondscape' is typical of Norfolk. The size and number of ponds present is about average, and farming is intensive in the area that surrounds them. In one spectacular way, however, the ponds are highly unusual: their aquatic biodiversity is exceptionally high. Breeding populations of Great Crested Newt *Triturus cristatus* have been recorded in 28 of the ponds; in three ponds the newts share the habitat with Nine-spined Stickleback *Pungitius pungitius*, and in one pond with Norfolk's new Biodiversity Action Plan (BAP) species, the rare Crucian Carp *Carassius carassius* (Box 2; Copp & Sayer 2010; Sayer *et al.* 2011). Some 23 submerged and floating-leaved aquatic plant species occur in the ponds, including Broad-leaved Pondweed *Potamogeton natans*, Pond Water-crowfoot *Ranunculus aquatilis* and Ivy-leaved Duckweed *Lemna trisulca* as widespread species. Further, the scarce plants Soft Hornwort *Ceratophyllum submersum*, Lesser Marshwort *Apium inundatum* and Crystalwort *Riccia fluitans* are also found. Surveys of adult dragonflies have revealed use of the ponds by 20 species (an amazing 16 exhibiting breeding behaviour), including the 'Vulnerable' Scarce Emerald

Left **Mating pair of Scarce Emerald Damselflies.** Above **This species at Manor Farm favours ponds with dense emergent vegetation such as nettle patches (often found after management) and beds of Branched Bur-reed. As successional change makes ponds less attractive to the Scarce Emerald it tends to move to recently managed ponds close by.** Bernard Dawson

Damselfly *Lestes dryas*. In addition, the Threatened Great Silver Water Beetle *Hydrophilus piceus* was recorded in one of the ponds during spring 2012. Some 14 species of wild British duck have been seen on the ponds (including Garganey *Anas querquedula* and Common Shelduck *Tadorna tadorna* as breeding species), which are also home to Reed Warbler *Acrocephalus scirpaceus*, Sedge Warbler *A. schoenobaenus*, Reed Bunting *Emberiza schoeniclus* and Little Grebe *Tachybaptus ruficollis*. That is a lot of important aquatic species. But let us be clear; the pond network is set in land used for intensive agricultural activities. Manor Farm is a working farm, not a nature reserve, yet nonetheless wildlife is thriving.

The custodian of Manor Farm is Richard Waddingham, a man who is passionate about farming and British wildlife. Richard is especially proud of his ponds, and since the 1960s he has managed them through the periodic cutting-back of trees and bushes, with the aim of reducing shading. In addition, at some ponds, in order to increase water depth and further halt successional processes, he has undertaken mud removal, most usually from half or part of the pond. Each year, he assesses the ponds on the farm, and three or four of them are selected for management, mostly in early winter. Not all the ponds are managed, however, and some true 'woodland ponds' are left to natural development. This approach has created a landscape that contains ponds at different stages of succession marked by variations in shading, depth and degree of encroachment by trees (especially willow *Salix*) and fringing wetland vegetation (e.g. especially Branched Bur-reed *Sparganium erectum* and Greater Bulrush *Typha latifolia*).

To understand the consequences of management for pond biodiversity, in 2009 we surveyed several species groups at 24 of the Manor Farm ponds: aquatic plants, water beetles, snails, mayflies and damselflies. We also studied four neighbouring ponds in order to increase the number of non-managed sites in the dataset. The ponds were placed into four 'time since management' categories: no management, managed in 1999-2003, managed in 2004-2006, and managed in 2007-2009. This design allowed us to determine the consequences of pond management for aquatic biodiversity and thus its potential role in conservation.

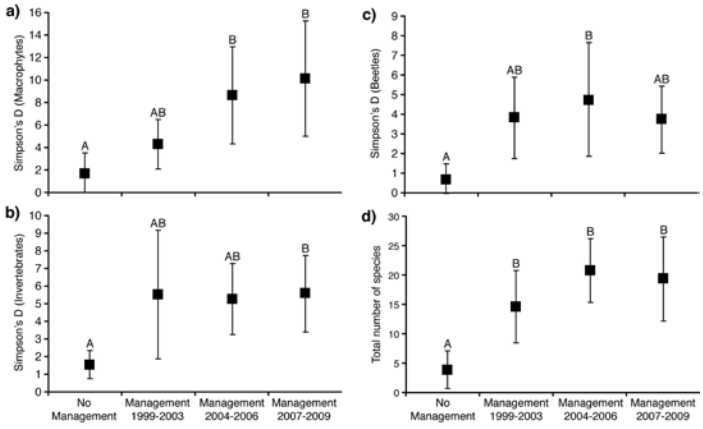


Figure 1 Differences between non-managed ponds and ponds managed during different time intervals in terms of mean diversity values for (a) aquatic macrophytes, (b) all invertebrates, (c) water beetles, and (d) all species. The letters A, B and AB reflect statistically significant differences ($P < 0.05$) in mean diversity values based on ANOVA with a subsequent Scheffé F test. Error bars indicate one standard deviation (see Sayer *et al.* 2012 for more details).

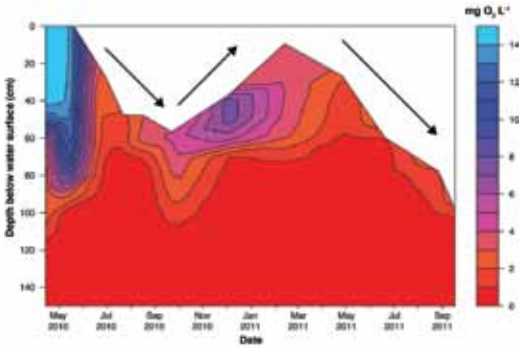
The study revealed some important, but not necessarily unexpected findings. Aquatic-plant diversity was significantly lower in the unmanaged ponds compared with ponds managed in 2004-2006 and 2007-2009 (Fig. 1). Similarly, water-beetle diversity and the overall number of plants and invertebrates found were significantly higher in the managed ponds (see Sayer *et al.* 2012 for more details). In general, a tendency was evident for pond species diversity to peak 3-5 years after management, with a decline thereafter. Interestingly, the different management categories (including the unmanaged ponds) seemed not to contain distinctive communities or species, although a number of species (especially among the water beetles) were confined to individual ponds, thus emphasising the value of having lots of ponds in the landscape. Some of the patterns we have observed at Manor Farm are confirmed in 'real-time' by recent before-and-after studies in other north Norfolk ponds (Box 3 and Table 1).

What is the significance of the above findings? Put simply, if Richard did not manage his ponds there would be far fewer species present. In addition, the study alludes to a severe loss of species as trees and bushes colonise small ponds. In all cases, heavily overgrown ponds had sparse, species-poor communities, the causes of which are probably many. First, aquatic plants are eliminated in highly shaded ponds through a lack of light, which reduces the availability and quality of feeding, hunting and hiding habitats for invertebrates. Secondly, high organic-matter inputs to pond waters from fallen leaves, branches and often entire trees leads to considerable decomposition of organic matter and the development of intense anoxia. Indeed, ongoing monitoring studies of overgrown Norfolk ponds show year-around low oxygen often extending from the pond bed to the water surface (Fig. 2). In certain periods strong oxygen stratification of the water column was evident, suggesting minimal wind-mixing owing to the thick shelter afforded by surrounding trees. Indeed, the middle of an overgrown pond is a cosy place to be in open farmland during winter gales and blizzards, as some of the authors discovered. The anoxic nature of the water must result in extremely testing conditions for many aquatic species and is likely a key cause of low pond diversity.

The value of pond management

The Manor Farm study shows that pond management has resulted in exceptional aquatic biodiversity. By managing a few ponds in each year, a heterogeneous pond network has been created, with individual ponds exhibiting different levels of shading, oxygen and aquatic-plant coverage, and

Figure 2 Seasonal changes of dissolved oxygen in the water column of Sayer's Black Pit before restoration (see Boxes 1 and 3). Note the very strong stratification of oxygen in spring 2010. Declining and rising water levels are shown (arrows) and 0m depth represents the maximum water depth recorded during the study in May 2010.



Box 3 Sayer's Black Pit restoration study

Since spring 2010, UCL has been studying three small farmland ponds in a before-and-after restoration project. One of these ponds, Sayer's Black Pit, was managed in September 2011 by major tree and mud removal. Prior to restoration the pond was heavily overgrown by willows and Blackthorn *Prunus spinosa* scrub, and our studies revealed a near-complete absence of water plants, dragonflies and amphibians. Just two years after restoration, Sayer's Black Pit has high plant cover (including several species), an amazingly species-rich dragonfly fauna and four species of amphibian, including Great Crested Newt *Triturus cristatus*.

Sayer's Black Pit before, during and after restoration. a) Before restoration, in January 2010; b) After tree, scrub and mud removal, November 2011; c) September 2012, one year after restoration; and d) July 2013, two years after restoration, showing dense growth of Broad-leaved Pondweed. Carl Sayer and Helen Greaves

Table 1 Species lists for Sayer's Black Pit before and after restoration.

	Before restoration (2010-2011)	After restoration (2012-2013)
Aquatic plants		
Broad-leaved Pondweed		✓
Small Pondweed		✓
Curled Pondweed		✓
Common Water-crowfoot		✓
Celery-leaved Buttercup		✓
Common Duckweed		✓
Ivy-leaved Duckweed		✓
Water-plantain		✓
Common Stonewort		✓
Dragonflies		
Common Darter	✓	✓*
Large Red Damselfly		✓
Azure Damselfly		✓*
Common Blue Damselfly		✓*
Blue-tailed Damselfly		✓*
Small Red-eyed Damselfly		✓
Emperor Dragonfly	✓	✓*
Broad-bodied Chaser		✓*
Ruddy Darter		✓*
Banded Demoiselle		✓
Four-spotted Chaser		✓
Southern Hawker		✓*
Emerald Damselfly		✓*
Scarce Emerald Damselfly		✓
Amphibians		
Common Toad		✓*
Common Frog		✓*
Smooth Newt		✓*
Great Crested Newt		✓*

* = breeding behaviour observed.

this clearly favours high landscape-scale biodiversity. It means that mobile species (e.g. dragonflies and several beetles) which favour open, plant-rich ponds always have appropriate habitat. In addition, species which require disturbance in order to persist in the landscape get what they need. Stoneworts (Characeae), for example, are associated particularly with freshly managed ponds at Manor Farm, where they include Common Stonewort *Chara vulgaris*, Fragile Stonewort *C. globularis* and Bristly Stonewort *C. hispida*. In this kind of pond landscape dragonflies always have availability of bare mud (favoured by Black-tailed Skimmer *Orthetrum cancellatum* at Manor Farm), tall emergent vegetation and floating-leaved plants, even though these habitats may shift between different ponds in different years. Overall, our study suggests that a network of mostly open, well-oxygenated and weedy ponds permits the existence of a substantial pool of aquatic species and thus substantially higher species diversity than might be normally expected if ponds were overgrown by trees. Importantly, we found no evidence to suggest that management would lead to a loss of any species from the landscape. To the contrary, the opposite was clearly true.

Several previous pond studies have recognised the importance of maintaining a mix of early-, mid- and late-succession ponds in the landscape (e.g. Boothby 1997; Hassal *et al.* 2012). We fully agree with this idea. The question is that of how to do it. The Million Ponds Project suggests that ponds should be allowed to progress naturally from an aquatic to a wet-woodland phase and that, to compensate for the loss of open ponds, we should dig some new ones nearby. We would not dispute the ideals and potential of Million Ponds, but in practice, within existing pond-rich agricultural regions of Britain (e.g. Norfolk, Suffolk, Cheshire and many other areas), is this being too idealistic? Will we really be able to persuade farmers to dig enough ponds to replace all those that are lost to succession, especially when it comes to giving up productive farmland? Even if each farmer digs one new pond, this will not prevent overgrown ponds from dominating and is unlikely to make a major difference to aquatic biodiversity at the landscape scale. We strongly suspect that digging ponds on a scale necessary to redress this problem in pond-rich areas of Britain may not be possible and certainly, given the rapidity of tree encroachment in ponds, the sustainability of this approach can also be questioned.

Conversations with older Norfolk farmers and farm workers over the last few years reveal that, perhaps until the 1960s and 1970s, ponds were managed for a whole range of reasons: (i) cattle and shire-horse watering before grassland was removed from arable-crop rotations; (ii) 'corner of the cornfield' fishing for Crucian Carp (Box 2), an art very nearly lost from the British countryside (but one of the authors is keeping it alive); (iii) a means of obtaining firewood; (iv) removal of habitat for Brown Rat *Rattus norvegicus* as a form of pest control; (v) a need to provide work for farm labourers during quieter periods in the agricultural calendar, i.e. early winter. Indeed, one farmer to whom we recently talked recalled a fire of willow brash on the ice of a Norfolk field pond during the ultra-harsh winter of 1963. It would seem that this was very much at the end of a long era of pond management. Now, the above reasons to manage ponds, and probably many more, have mostly faded into rural history, and we need a new one – nature conservation. Why should we not put back a process that has maintained farmland ponds in good condition for centuries and maybe ponds in general for millennia? Clearly, pond biodiversity responds positively to management activities, and it might be that periodic tree and mud removal helps to mimic the natural disturbance regimes associated with ancient river-valley pondscapes. Ponds in lowland river valleys must have been constantly created and disturbed by flood events, tree fall and the feeding activities of large herbivores. And let us not forget that many pond species appear to be excellent dispersers and/or survivors, suggesting an evolutionary history punctuated by disturbance.

Lessons for pond conservation

Two important messages for British pond conservation arise from the Manor Farm story. In recent years most pond conservation, especially pond creation, has been undertaken in nature reserves and semi-natural habitats. In part, this trend stems from rightly held concerns that poor water quality may negate the benefits of excavating and restoring ponds on arable land (Williams *et al.* 2010b). Reassuringly, however, we show that farmland ponds can be wonderful clean-water reservoirs of aquatic wildlife, so long as they are buffered from

the fields and protected from pollution. It can be strongly argued that it is the arable landscape that needs pond conservation most and where the benefits are likely to be greatest. If we want species-friendly pond networks in the British countryside, we must not ignore the huge tracts of farmland in between our nature reserves and higher-quality habitat patches. Farmland ponds can be great, and intensive agriculture and nature conservation can co-exist – Manor Farm shows this.

Secondly, on the basis of our studies at Manor Farm and observations made elsewhere in Norfolk, we strongly argue that pond restoration and management should be brought to the centre of British pond-conservation plans. We are not arguing that all ponds should, or need to, be managed, and in reality arable areas will always contain many overgrown ponds, so fears that management will lead to major losses of semi-terrestrial and woodland-pond species should be allayed. But surely pond management needs to be more fully embraced by agri-environment schemes and nature-conservation legislation? Ponds remain a lesser promoted option in HLS and still seem to be low on the agenda when we assess the state of the British countryside. Nevertheless, the benefits of caring for farmland ponds are potentially enormous and undoubtedly extend way beyond true aquatic species, influencing birds, bats and mammals, and who knows what else, in ways that we still need to learn about. At the start of this article ponds were described as buzzing with wildlife, and you might feel that this was overly dramatic. As I (Carl Sayer) write this I have just returned from a sunny day at the Manor Farm ponds and I have never seen so many dragonflies, bees and butterflies on flowering plants and brambles – buzzing is an understatement: the ponds and their surrounds were completely alive! Could pond management be a key way of engaging more farmers with nature conservation and of redressing species losses in the British countryside? The Manor Farm story suggests that this is not such an outlandish thought.

Acknowledgements

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