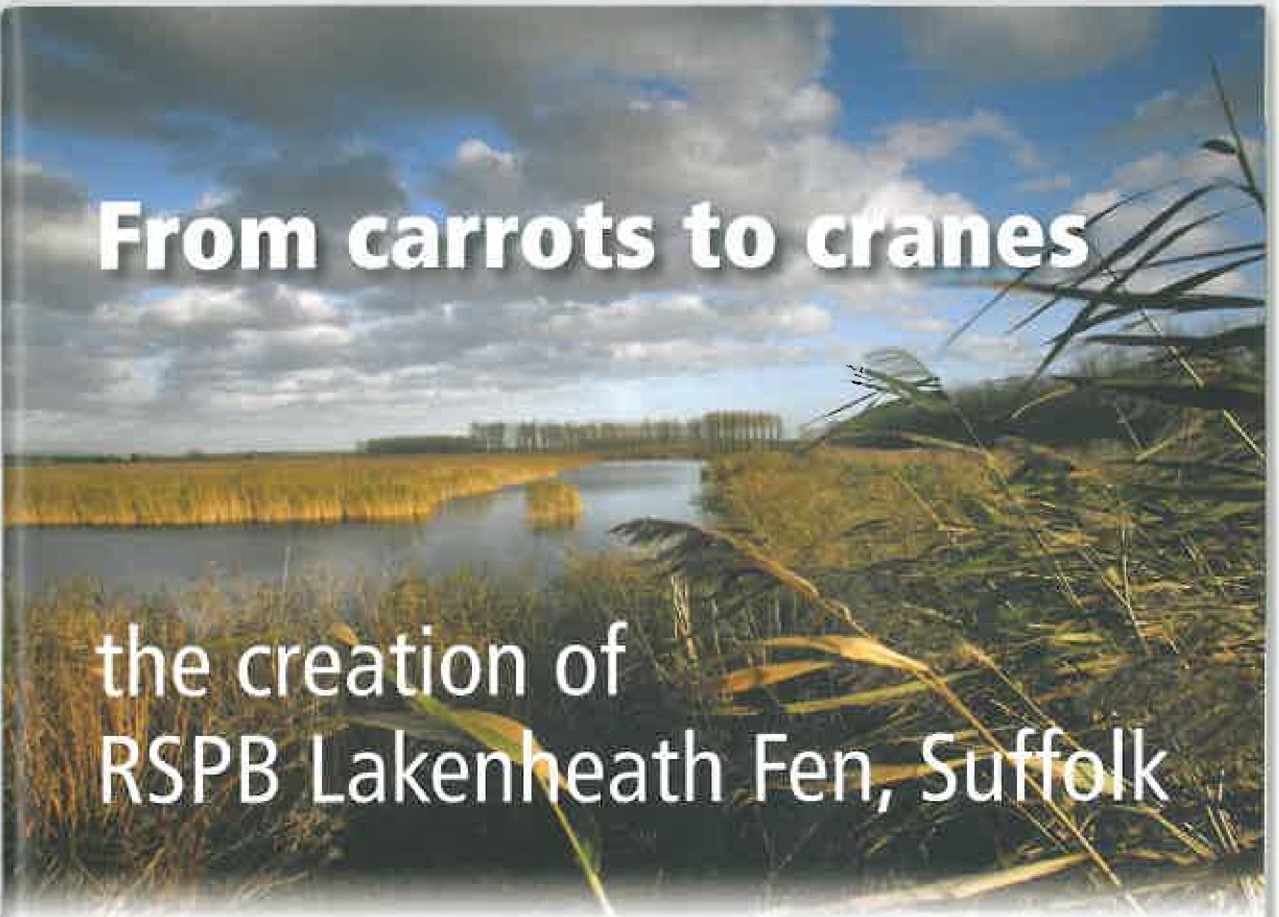


From carrots to cranes

the creation of RSPB Lakenheath Fen, Suffolk

Reedbeds at Lakenheath Fen in 2006.
Andy Hay/rspb-images.com

Norman Sills and Graham Hirons

Twenty years ago, RSPB began an ambitious programme of habitat creation and restoration on a scale larger than anything previously considered by conservation organisations in the UK. One such pioneering project was the creation of 200ha of wetland from arable land at Lakenheath Fen, on the Suffolk/Norfolk border. The success of the project has proved to be the catalyst for much more ambitious wetland-creation projects. This is the story of why and how Lakenheath Fen was created and what it has achieved.

The context

The impetus behind the project was that RSPB was looking to create wetland habitat in the Fens which was able to accommodate Bitterns *Botaurus stellaris*. These birds were at risk of being displaced from their coastal reedbed breeding sites in East Anglia because of threats from rises in sea level (Wotton *et al.* 2009). The project would contribute to the Bittern Species Action Plan and create a major wetland in the Fens which would start to redress historic losses from major drainage schemes, dating back as far as the 17th century. Over the centuries, the original 1,300 square miles of almost natural fenland in the region had been reduced to a few square miles.

By the mid-1990s the UK population of Bitterns had declined to fewer than 20 'booming' males, which were mainly confined to coastal wetlands in eastern England. The main causes of this decline were linked to vegetation succession within the reedbeds (Tyler *et al.* 1998). The targets set for 2010 in the 1995 UK Bittern Species Action Plan were for 50 booming males and 1,200ha of new reedbed (in blocks of over 20ha and remote from the coast) (UK BAP 1995).

Lakenheath Fen: a potential new wetland

In 1995, RSPB took the unusual step of circulating to estate agents in East Anglia a description of the type of land it wished to acquire for wetland creation (large, flat, peaty and wettable). As a result,

The original carrot fields at Lakenheath in 1999. Andy Hay/rspb-images.com

Diggers forming channels in 2000. Norman Sills

RSPB was alerted to the potential sale of three contiguous blocks of arable land near Lakenheath, in west Suffolk, before they went on the open market. This was important, because it allowed time to carry out initial hydrological investigations to assess their suitability for wetland creation, to open discussions with the Environment Agency (EA) and the relevant Internal Drainage Board (IDB) about whether the scheme was practicable, and to start the fundraising process.

The land for sale had been drained during the 17th to 19th centuries and eventually converted first to arable, in the 1950s, and then to poplar woodland for matchstick production, from the 1960s. A resumption to arable followed in the mid-1980s. Two of the lots (95ha and 118ha) consisted of flat, Grade 1 fen-peat soil, but were remote from any water source. The third lot (242ha) was essentially similar, except for 10ha of uncultivated 'washland' alongside the river Little Ouse, 10ha of higher, sandy land and 40ha of commercial poplar plantations. Importantly, the Little Ouse formed the northern boundary (5km). This potential access to water was considered important as the peat soil was likely to be 'leaky', and so this plot was purchased. With two later acquisitions in 1997, the total holding reached 298ha.

Planning consent, with strings attached

Planning consent for 'change-of-use' was necessary. With the consent came several conditions, three of which had significant effects on the project. First, the Farming & Rural Conservation Agency (now part of Defra) could not permit the export of large quantities of soil from the site because, being Grade 1, it had to be conserved as part of the nation's soil resource; a future war might demand that all excavated soil be returned to its original location! Also, the soil had to be kept separate from any excavated sand. This constraint meant that the general land surface could not be lowered. As above-ground water is necessary to form a good-quality reedbed, retained water levels would need to be kept significantly above that of the adjacent farmland, but without adversely affecting it. Secondly, with the intention of retaining very large quantities of water (more than 25,000 cu metres) above ground, the project became subject to the Reservoirs Act 1975. This required the construction of a 4km-long safety embankment with a mineral (sand) core to act as a back-stop in the event of water escaping through internal, peat-cored bunds. Thirdly, with the RAF's jet-fighter base at Lakenheath less than three miles away, the site fell within a Statutory Flight Safeguarding Zone and the potential for bird strikes became a concern. To reduce the chances of bird strike, the open waterbodies were limited to 1ha in size so as not to attract roosting gulls, and the proposed reedbed was subject to an arrangement for RSPB to disperse any unacceptably large starling roosts.

Other conditions included: the need to avoid excavating in shallowly buried sand (where important archaeological artefacts had been found);

the need to agree with the IDB how water seepage between the reedbed and arable fields would be limited; and an existing covenant to retain at least 40ha of poplar plantations at all times for the benefit of nesting Golden Orioles *Oriolus oriolus*.

Wetlands need water: would there be enough?

The site selected was not without handicaps when it came to wetland creation: the area has about the lowest annual rainfall in the UK (650mm), the peat topsoil overlying sand (with occasional gravel lenses) is porous, and the long southern boundary of the site abutted arable farmland pump-drained by the main IDB drain, which then traverses the land purchased.

It seemed clear that to maintain wet reedbeds in spring and summer a supplementary water supply would be necessary. However, EA policy forbade direct abstraction of water from the adjacent river from April to October inclusive, so the storage of excess winter water in reedbed compartments farthest from the neighbouring farmland – with its requirement for lower water levels – seemed the only solution. But how much should be stored and how could seepage losses to the farmland and the IDB drain be minimised?

In 1997, RSPB commissioned Silsoe College (Cranfield University) to carry out a detailed hydrological study. This involved five dipwell transects across the site and 19 boreholes along the southern boundary bordering arable land to determine the underlying geology. In broad terms, the dipwells showed that the water table across the site fell by 1.5-2.5m from the river to the arable land, with the certainty that the arable drainage system would pull water from beneath the proposed reedbed. The boreholes showed that 1-3m of peat soil overlay 6-7m of sand/gravel above chalk bedrock. The absence of a clay horizon precluded the possibility of inserting a vertical impermeable membrane around the site to retain water (Spoor 1998).

The data collected suggested that 3,000-6,000 cu metres of water would be lost from the reserve per day, depending on water levels, rainfall and evapo-transpiration. Recommendations of how to counter or compensate for this included winter abstraction from the river (up to 1 million cu metres), storage of about 600,000 cu metres of water in the three main reedbed compartments close to the river (and furthest from the arable), and the interception and recirculation of water seeping towards the arable land. This could be achieved by the use of electric pumps at an estimated annual running cost of £5,000-£6,000 (Spoor 1998). A further recommendation was to divert a 1km stretch of the IDB main channel (from which arable-land water was pumped into the Little Ouse) to increase the distance between it and the nearest proposed reedbed compartment in order to reduce seepage losses.

A factor that could not be assessed in the time available was the volume of river water seeping through the porous ground beneath the 5km length of the river's clay flood-bank. However, a rough assessment by site staff later at two points suggested that the input could easily exceed 200,000 cu metres per year. In the event, the volumes of water actually abstracted from the river between 2002 and 2006 varied from 33,000 to 137,000 cu metres per year (but none since), and the total annual running costs of the recirculation pumps has typically been £3,800 in recent years.

Engineering works

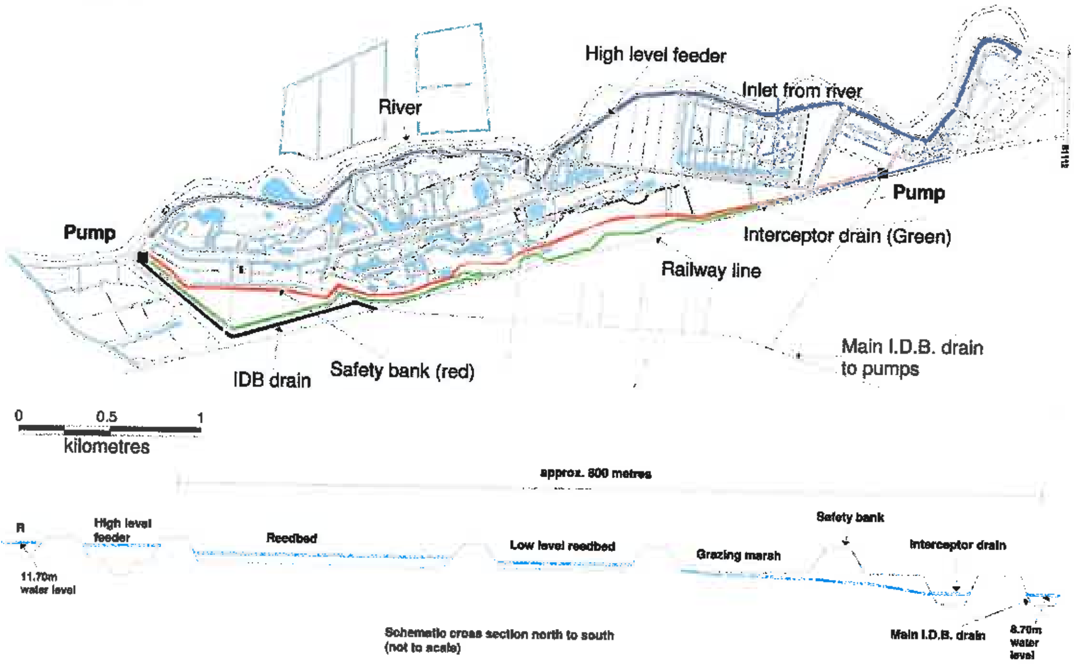
Four major items of infrastructure were engineered between 1999 and 2001. First, the interception and recirculation of water potentially lost by seepage were achieved by excavating a channel 4.2km long and up to 3m deep along the southern boundary, with an automatic, electric pump (160mm diameter) installed on a pontoon at both ends. The two pumps had the *potential* to deliver a total of 14,400 cu metres of water per day back into the reedbeds. The channel excavation yielded spoil (peat and sand) to build the Reservoir Act safety bund. A key feature was its core of compacted sand (density 1.5g per cc) to provide extra stability to the compacted peat soil. The third main infrastructure work, the IDB main-channel diversion, also supplied material for the reservoir bank. Finally, the river-water abstraction pipe (600mm diameter, with penstock sluice and meter) was installed and set at a level such that water could flow in by gravity.

Wetland-habitat creation

From 1996 to 2004, approximately 187ha of arable land were converted to wetland habitat, of which about 80% (152ha) were reedbed and the remainder damp pasture with reed-fringed pools and channels. Most of the work was done by

From carrots to cranes: the creation of RSPB Lakenheath Fen, Suffolk

Plans of Lakenheath Fen, showing the infrastructure and cross-section of the site. RSPB



Aerial views of Lakenheath Fen. Main photograph shows the western half in 2004 when the reed fringes were well established, but before they had amalgamated into reedbeds. The inset shows the same area in 1997, just after Phase 1 of the work was completed. Mike Page external contractors in five main phases, ending in 2000. To avoid costly and over-precise engineering, RSPB site staff undertook the land-forming drawings, assessment of work quantities for tendering, marked out the habitat-related earthworks and supervised the contractors.

The reedbed design parameters were based on the results of research carried out at UK reedbeds where Bitterns were nesting, which showed that the proportion of open water, the length of reed/open-water interface per ha and the dimensions of channels were some of the key features needed to support breeding Bitterns (White *et al.* 2006). The main constraint was peat depth. To avoid disturbing any archaeological interest in the subterranean sand-ridges, pool/channel excavations were generally carried out in peat greater than 1m deep in order to avoid the need for archaeological survey.

When excavated, channels were typically 1.5m deep and 8-10m wide (with shallow gradients), but, once water levels were raised and reeds became established, open-water widths became 4-5m and depths in spring reached over 2m. In 2006, the reedbeds contained 21% open water (22ha in total, mainly in the form of 50 pools), a mean of 435m of reed/open-water interface per ha (total 45km), and all but a few hectares of reed had standing water in spring.

In the grassland areas, there were 13km of ungrazed reed fringe (206m per ha), mainly bordering the perimeter channels or 'wet fences'. Initially, the pasture was invaded by Nettle *Urtica dioica* and Creeping Thistle *Cirsium arvense*, but these were more or less eradicated by shallow flooding in the lower areas and by application of selective herbicide on the higher land. No reseeding was carried out as various grass species germinated from the seed-bank. Eventually, the grassland was managed by grazing with Highland and Galloway cattle and sheep.

The spoil from all excavations was placed mainly into internal bunds (total 8km long, with a footprint of 8ha) through which 21 pipes with sluices permitted water transfer between compartments. Some spoil was used to create raised areas in order to produce shallower water or islands on otherwise flat land.

Reed establishment

Within a month or two of excavations being complete, reed establishment began along the edges of channels and pools. As the planting areas were devoid of vegetation and close to the water table, planting was easy and establishment unhindered. Two methods were used: first, seedlings were propagated in a polytunnel (on site), using seed from panicles cut from nearby reedbeds; and, second, stem cuttings (40-60cm long) were taken from local sources and planted within 24 hours. Both the seedlings (3-4 months old) and the stems were planted in lines at about three per metre. For the stem cuttings, 100cm-long steel rods were fashioned into dibbers so that, once planted, only the top 10-15cm of the stem remained above water. It was found that roots sprouted from the uppermost buried node and, in many cases, they developed into metre-long rhizomes in the first summer. Success with the seedlings was 100% as they had root-plugs, whereas success with stem cuttings varied; in some plantings it was 100% but in others only 50%. However, seedlings usually took a year or two longer to develop into full-height reed than did successful stem cuttings. In total, over 300,000 reeds were planted by hand at minimal cost. In addition, a small area of reed was established by putting panicles on bare ground, but success occurred only where a constant water level could be maintained precisely at ground level.

Planting Reed cuttings in Phase 1 in 1996. Norman Sills

Between 1998 and 2003, fixed transects across reed fringes established by stem cuttings showed that rhizomes spread 6-12m away from the planting site in six years; this was largely before water levels were raised to above ground level. By 2010, the reedbeds had spread to almost the maximum possible extent.

Fish populations and introduction

Electro-fishing surveys suggested that the biomass density of suitably sized fish for Bitterns was inadequate. For example, a survey in 1999 indicated 0.5g of small fish per square metre of open water, whereas almost four times that amount was found at four sites in East Anglia where Bitterns were breeding (Gilbert *et al.* 2000). Therefore, a total of 1,300 small Rudd *Scardinius erythropthalmus* were introduced to eight sites within the reedbed in 2004 and a further 2,000 to four sites in 2008. In addition, because of the lack of submerged macrophytes in the reedbed waterbodies, 64 fish refuges (willow bundles anchored with concrete blocks) were placed in open water in three of the main reedbed compartments in 2007. It is not known whether they have been effective in helping the fish population to establish itself.

From Brookweed to Bitterns: some ecological outcomes

Given the effort involved in habitat creation, it was important to assess some of the principal effects and benefits. Surveys concentrated on plants, mammals and birds, with some limited work on invertebrates.

Plants

The first species to flower in the new excavations in 1996 was Brookweed *Samolus valerandi*. It was the first of many species to appear spontaneously from the newly exposed, lower levels of damp peat. From 1996 to 2000, a survey was undertaken in each year in Phase 1 (30ha) by recording the presence of hydrophytic species within each square (containing water) of a quarter-hectare grid. A total of 33 species was found in 1996, and a steady increase resulted in 58 species in 2000. In total, 68 species were recorded during the five years. (Species of willow *Salix*, stonewort *Chara*, narrow-leaved pondweed *Potamogeton* and water-milfoil *Myriophyllum* were each grouped as one species owing to difficulties with hybridisation and/or time constraints with regard to identification.)

Water-violet at Lakenheath Fen. Jo Jones

In summer 2001, the survey was extended to include the whole of the new wetland, on a 1ha-grid basis. All 220 ha/part-ha squares containing wetland were visited and the presence of every species recorded. Within the survey area, 82 hydrophytic species/species groups were found. Most squares contained 20 to 30 species, but five squares contained more than 30. The number depended partly on the time since excavation; in 2001, Phases 1 and 5 were six and two years old, respectively.

Other than Reed *Phragmites australis*, the most frequently occurring species (>70% of squares) were, in descending order: Hemp-agrimony *Eupatorium cannabinum*, Great Willowherb *Epilobium hirsutum*, Soft Rush *Juncus effusus*, Purple Loosestrife *Lythrum salicaria*, Bulrush *Typha latifolia*, Reed Canary-grass *Phalaris arundinacea* and willows (mainly Grey Willow *Salix cinerea*). Thirteen species occurred in less than 2% of squares, including Fen Pondweed *Potamogeton coloratus* (found in the new seepage-interception channel), Knotted Pearlwort *Sagina nodosa* and Marsh Pennywort *Hydrocotyle vulgaris*. In an associated study, Henderson (2000) found five species of narrow-leaved *Potamogeton* in Phase 1, and these, with Broad-leaved Pondweed *P. natans*, Shining Pondweed *P. lucens*, Curled Pondweed *P. crispus* and Fen Pondweed, brought the total to nine species overall.

The 82 or more species recorded in the surveys above originated from the seed-bank. Its creation and persistence was probably the result of four main factors: widespread seed dispersal caused by extensive Fenland floods in the past (prior to 1953); the existence and maintenance of the arable drainage system whereby unwanted plant material in ditches was removed and spread on the land (Sills & Leadsom 2005); the use of ditch water for spray-irrigation of crops; and the proximity of the water table to the ground surface – typically 0.75m even in mid-summer (Spoor 1998). Leck (1989) cites desiccation as being extremely detrimental to buried seeds, and Thomson *et al.* (1997) suggest that the viability of the seeds of certain aquatic species can be measured in decades.

Since the surveys, low-growing plants such as Marsh Yellow-cress *Rorippa palustris*, Brookweed and Marsh Pennywort have declined because of shading from the spreading Reed, whilst species of open land (pasture and bank sides) or open water, such as Common Meadow-rue *Thalictrum flavum*, Water-violet *Hottonia palustris* and Branched Bur-reed *Sparganium erectum*, have become more frequent.

For comparison, a similar survey (quarter-hectare grid) was done in 2002 on 31ha of long-established river-washland nearby. The results showed that eight species occurred on the washland but not on the new wetland, whereas 29+ species occurred on the latter but not on the former (Leadsom 2003). Reasons probably include differences in soil type, habitat structure and presumably land-use history.

Mammals

Surveys of Water Vole *Arvicola amphibius*, Otter *Lutra lutra* and American Mink *Mustela vison*, based on signs of presence in hectare squares, were carried out in 2004, 2005 and 2006 (Walker 2004; Martin 2005; Martinez-Abarca 2006). In 2004 Water Voles were present in 17% of the 272 squares surveyed throughout the reserve, their distribution being nearer to the river and old arable drains rather than more recent excavations. In 2005 and 2006, square occupancy was 36% and 30%, respectively, both based on a smaller number of surveyed squares, but both showing a wider distribution than in 2004.

Signs of Otter were found in 2% (six), 3% (four) and 4% (five) of surveyed squares in 2004, 2005 and 2006, respectively, and an additional seven squares in more recent years. Sightings of Otters, including young animals, have become more frequent during the last few years. Square occupancy by Mink was 5% or 6% in all three years and they were distributed throughout the reserve. A control programme began in 2008, resulting in 9-13 animals per year being caught in each trapping period of two to four months. A further 26 species of mammal have been recorded, including the widely distributed Harvest Mouse *Micromys minutus*.

Variable Damselfly. Richard Revels

Invertebrates

Among the usual species lists, *ad hoc* recording showed that Odonata totalled 21 species between 1996 and 2010. Recent additions have included Small Red-eyed Damselfly *Erythromma viridulum*, Variable Damselfly *Coenagrion pulchellum* and Scarce Chaser *Libellula fulva*.

A structured study in 2008 examined the difference in invertebrate populations between a long-established reedbed on a nearby washland SSSI and a reedbed created in 1998. Using randomly positioned water-traps, Booth & Ausden (2009) found that the new areas of reedbed had been rapidly colonised by a diverse fauna of wetland Diptera, with similar numbers of species of nationally notable or rarer Diptera caught in the new and old areas of reedbed.

When the water table was raised, Common Meadow-rue appeared in damp areas of peat and sand. From 2004 to 2010, annual inspection (in July/August) of about 60 patches of post-flowering plants revealed 70 to 170 larvae of the Marsh Carpet moth *Perizoma sagittata* (Nationally Scarce A). Recent management has aimed at preventing such patches from being overwhelmed by rank vegetation.

Birds

When the land for Lakenheath Fen was acquired, three key species of reedbed-breeding bird were recognised and each had a long-term target applied in the initial management plan, as shown in Table 1. Targets for all three species have been

Table 1 Targets and outcomes for the three key bird species in the created reedbeds.

Species	Target	Year of first breeding	Target achieved	2010 status
Bittern *Botaurus stellaris*	5 males	2009 4 males, 4 nests	2010	6 males 5 nests
Marsh Harrier *Circus aeruginosus*	8 nests	2001	2009	12 nests
Bearded Tit *Panurus biarmicus*	120 pairs	2004	2010	100-120 pairs

Table 2 Estimated breeding population (pairs) of selected species in the new wetland between 1996 and 2006.

Species	Pairs in 1996	Peak pop. (pairs)	Year of peak
Mute Swan *Cygnus olor*	0	13	2004
Little Grebe *Tachybaptus ruficollis*	0	6	2002
Great Crested Grebe *Podiceps cristatus*	0	4	2004
Marsh Harrier *Circus aeruginosus*	0	4 nests	2006
Coot *Fulica atra*	0	136	2003
Lapwing *Vanellus vanellus*	0	13	2003
Wren *Troglodytes troglodytes*	2	60	2006
Grasshopper Warbler *Locustella naevia*	0	9	2006
Sedge Warbler *Acrocephalus schoenobaenus*	7	174	2005
Reed Warbler *Acrocephalus scirpaceus*	6	780	2006
Whitethroat *Sylvia communis*	10	101	2002
Reed Bunting *Emberiza schoeniclus*	6	163	2003

met or exceeded.

The populations of most other breeding species were estimated by using the BTO's Common Birds Census method of mapping singing males to identify territories (Bibby *et al.* 1992). For each species, minimum and maximum numbers per year provided the mid-point figures shown in Table 2. The surveys were carried out over the whole of the new wetland from 1996 to 2006 inclusive (Sills *et al.* 2008).

A dozen species bred during the period of large-scale excavations (the late 1990s) but no longer do so: Red-legged Partridge *Alectoris rufa* (peak of six pairs), Grey Partridge *Perdix perdix* (2), Spotted Crake *Porzana porzana* (1), Oystercatcher *Haematopus ostralegus* (2), Little Ringed Plover *Charadrius dubius* (2), Redshank *Tringa totanus* (9), Skylark *Alauda arvensis* (38), Meadow Pipit *Anthus pratensis* (9), Yellow Wagtail *Motacilla flava* (4), Stonechat *Saxicola torquatus* (1) and Corn Bunting *Emberiza calandra* (4). These nested in a range of temporary habitats, from abandoned dry arable land dominated by ungrazed grass to areas of bare, levelled-out peat interspersed with waterbodies of various depths and vegetation in various stages of regeneration.

Other species either increased or colonised, as shown in Table 2.

After their peak year, the Coot and Lapwing breeding populations declined by 32% and 38%, respectively, because open land with shallow water developed into reedbed. Similarly, Sedge Warbler, Whitethroat and Reed Bunting populations diminished by 14%, 25% and 17%, respectively, probably because encroachment of Reed caused their preferred habitat, a diverse structure of ruderal species, to decline.

The extensive CBC survey was discontinued after 2006 because of the presence of Common Cranes *Grus grus*, but about 33 wetland species have bred in recent years. However, by using other methods, the populations of selected species were surveyed, in chronological order of their first breeding:

Marsh Harrier: increased to 12 nests and 30 young fledged in 2010.

Bearded Tit: increased to 100-120 pairs in 2010. Whole-reserve surveys were done in late March/early April when birds were establishing nest areas. In each reedbed-creation phase, first nesting occurred five or six years after reedbed establishment (Sills 2005).

Common Crane: two pairs arrived in March 2007, one of which reared a single young in 2009 and again in 2010 (Sills 2008, 2010). They last nested in the Fens in about 1600.

Cetti's Warbler *Cettia cetti*: two held spring territories in 2009, although up to 12 singing males occurred at other times and/or areas adjacent to the new wetland.

Bittern: booming was first heard in 2006, followed by successful breeding in 2009 (four nests) and 2010 (five nests). The first 'booming site' and one of the earliest nest sites were in the hectare square containing the highest proportion of open water and the highest reed/water interface on the reserve.

Wintering wildfowl: including about ten common species, totalled 1,000 to 2,000 birds in the late 1990s and early 2000s, but, since the areas of shallow water have been invaded by reeds, numbers have decreased to usually fewer than 1,000.

Common Cranes at Lakenheath Fen. Andy Hay/rspb-images.com

Costs

The capital cost of completing the work described amounted to about £681,000. This excludes land-purchase costs and salaries of staff; the latter were one full-time site manager, one full-time assistant and usually one full-time summer-contract assistant. Sub-totals were: professional advice, planning fees, excavations, pipes, sluices and even fish, total £581,000; pumps and power supplies, £61,000; abstraction sluice/pipe, £20,000; reed establishment, £5,000; and fencing/herbicide for the pastures, £14,000. The area developed was about 187ha, giving a mean cost of about £3,600 per ha.

Some concluding remarks

Appropriate habitats have been created at Lakenheath Fen, and the original targets for the three specialist reedbed bird species have been met or exceeded by applying the results of research into the ecological requirements of Bitterns. However, colonisation took longer than expected (13 years for Bitterns). This needs to be borne in mind when planning similar habitat-creation projects, especially as compensation for habitat lost to development.

Although habitat creation was targeted specifically at one rare breeding bird species, the additional ecological benefits have been spectacular, in terms of both the number of other wetland bird species that have been supported (e.g. Bearded Tits, Marsh Harriers, Reed Warblers) and the benefits to other wildlife. And there are always some surprises, such as colonisation by breeding Common Cranes, or the persistence of a significant seed-bank of fen vegetation, in spite of 50 years of arable farming and silviculture.

There were five Bittern nests at Lakenheath Fen in 2010. Richard Revels

There were 12 Marsh Harrier nests at Lakenheath Fen in 2010. Richard Revels

The initial hydrological study was essential in providing a guide to the amounts of water needed to create and maintain a wet reedbed and in giving confidence that the project was achievable. In the event, the volume of water that needed to be abstracted from the river Little Ouse was overestimated because of the magnitude of the seepage losses from the river into the site.

When conceived, the project seemed very ambitious, and some authorities (e.g. EA and the IDB) and neighbouring landowners were rightly wary of its magnitude and implications. A lot of things we now take for granted were innovative then, and the project attracted the first ever Heritage Lottery Fund grant for land purchase for conservation. The fact that the project has since been widely replicated and would now be considered routine may be its greatest achievement.

Acknowledgements

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Planning and implementing the project required input from a wide range of RSPB Regional and Headquarters staff, as well as a team of dedicated volunteers to plant reeds on a massive scale. The help and advice given by Professor Gordon Spoor (Silsoe College) on many aspects of site hydrology also helped to ensure the overall success of the project.

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