From science to recovery: four case studies of how research has been translated into conservation action in the UK

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During this century, numbers of Grey Partridges *Perdix perdix*, Corncrakes *Crex crex*, Stone-curlews *Burhinus oedicnemus* and Cirl Buntings *Emberiza cirlus* have declined massively in the UK. These dispersed species are the best studied farmland birds in Britain. In each case, applied ecological studies have established that their declines are associated with agricultural intensification. We review the results of these studies, the management solutions that have been proposed and the actions taken to initiate population recovery. In all four cases, these actions have been demonstrably successful. Current and future success depends, to a great extent, on government agricultural policy. Set-aside and the EU Agri-environment Regulation 2078/92 have been the basis for the success so far. Extensive farming is the common theme connecting the four species, and a policy move towards comprehensive support for extensive farming systems would ensure the future for them and for other forms of declining farmland wildlife.

Out of 195 European bird species that have been classified as having an unfavourable conservation status, approximately 60% use lowland farmland at some point in their annual cycle (Tucker & Heath 1994). Within Britain, Gibbons *et al*. (1993) identified 28 species of birds as being typical of lowland farmland. Of these, 86% declined in abundance in Britain between 1970 and 1990, compared with 51% of non-farmland species (Fuller *et al*. 1995). The Grey Partridge *Perdix perdix*, Corncrake *Crex crex*, Stone-curlew *Burhinus oedicnemus* and Cirl Bunting *Emberiza cirlus* are four farmland species that have been the subject of detailed studies to identify the causes of the declines. We now have a good understanding of the ecology of each species, so that the opportunity exists to translate the scientific knowledge into conservation action.

All four species are listed in the UK Red Data Book (Batten *et al*. 1990), are on the "Red List" of Birds of Conservation Concern in the UK (Gibbons *et al.* 1996), and are the subjects of individual species plans under the UK Biodiversity Action Plan (BAP) (Anon. 1995). These listings were determined on the basis of the magnitude of their decline in abundance and range, as well as their European/global status. The four species have declined massively in Britain, although the full extents of the declines have not been properly quantified because of the lack of reliable national count data from the years before 1960. Nevertheless, since 1960 the numbers of all four species have fallen by at least 60%, the ranges have contracted by up to 83% and, for each one except the Grey Partridge, the population has dropped below 500 pairs (Table 1). Following on from the species' BAP listing, the UK government has nominated lead partners for each of them (Table 1), which effectively confers responsibility for facilitating the implementation of each Species Action Plan to the nominated organisations.

This paper reviews identified causes of the declines, proposed management solutions, actions taken to initiate population recovery, and the evidence to date for their success. It also seeks to determine common features linking these four species, both in terms of ecology and of management, in an attempt to find practical lessons that may apply to other declining farmland birds.

GREY PARTRIDGE

History and causes of the decline

According to UK bag records, the decline of this species began in the 1950s (Potts 1986). By the 1960s, low autumn densities and young:old ratios were giving cause for concern, because the Grey Partridge was an economically valuable gamebird and shooting revenue was linked to autumn densities. In 1968, the precursor of The Game Conservancy Trust (GCT), the Game Research Association, began a research programme investigating the reasons for the decline. This study, led by G. R. Potts, has become one of the longest-running ecological studies of a farmland bird in the world.

Potts (1980, 1986) identified a reduction in chick survival during the first six weeks after hatching as the primary reason for the decline. Grey Partridge chicks are nidifugous

Table 1. Summary of the timings and magnitudes of the declines of the Grey Partridge, Corncrake, Stone-curlew and Cirl Bunting in Great Britain, together with the estimated number of pairs before targeted conservation action began and the nominated lead partners under the UK Biodiversity Action Plan (BAP) process.

Species	Decline started	Change in abundance since 1960	Change in range area between 1970 and 1990	Estimated number of pairs	Nominated lead partner (BAP)
Grey Partridge	1950s[1]	-80%[1]	-26%[2]	145,000 (1992)[3]	GCT[10]
Corncrake	1880s[4]	<-80%[5]	-73%[2]	480 (1993)[5]	SERAD/RSPB[10]
Stone-curlew	1950s[6]	<-60%[7]	-42%[2]	167-169 (1991)[7]	RSPB[10]
Cirl Bunting	1960s[8]	▼[9]	-83%[2]	118-132 (1989)[8]	RSPB/EN[10]

[1] Potts (1986)
[2] Change in number of occupied 10x10-km National Grid squares between the British atlas studies of bird distribution in 1968-72 and 1988-91 (Gibbons *et al*. 1993)
[3] Gibbons *et al*. (1993)
[4] Norris (1947)
[5] Green (1995a)
[6] Sharrock (1976)
[7] Green (1995c)
[8] Evans (1997a)
[9] Decline known to have been large, but no data available to quantify it
[10] EN: English Nature; GCT: The Game Conservancy Trust; RSPB: The Royal Society for the Protection of Birds; SERAD: Scottish Executive Rural Affairs Department

and chicks forage for themselves. Their diet during the first two weeks consists almost entirely of insects, a rich source of protein (Ford *et al*. 1938, Potts 1980, 1986). Chick survival during this early period is closely linked to the availability and consumption of certain preferred invertebrate groups, especially phytophagous insects (Potts 1980, Potts & Aebischer 1991). The average annual survival rate of partridge chicks dropped from over 40% before 1952 to around 30% after 1962 (Potts 1986). This corresponded to a time of rapidly increasing use of herbicides. By 1965, nearly all cereal fields were treated with herbicides, which greatly reduced the abundance of arable weeds that served as host plants to insects, and probably halved the abundance of invertebrates within cereals (Southwood & Cross 1969). More recently, the intensive use of broad-spectrum insecticides on cereals in the summer has been associated with a further reduction in average chick survival rate from 30% to 22% (Aebischer & Potts 1998). An independent review concluded that an indirect effect of pesticides, through shortage of food and reduced chick survival in turn leading to reduced population density, is convincingly shown by the GCT study (Campbell *et al*. 1997).

Availability of nesting cover is an important determinant of pre-breeding density-dependent dispersal, and hence also of breeding density (Potts 1980, Rands 1986). Grey Partridges nest on the ground, and conceal their nest in rank dead grass or other tall vegetation on grassy banks, uncut field margins, hedge bottoms or autumn-sown cereals. The removal of field boundaries to increase agricultural efficiency probably reduced nesting cover by 24% by 1978 (Potts 1980), and is on-going (Brown 1992). Cutting what remains or treating it with herbicide to prevent crop invasion by “weeds” further reduces nesting cover.

Potts (1980, 1986) also identified predation during the breeding season as an important density-dependent regulatory factor for Grey Partridges. Incubating partridges and their eggs are vulnerable to mammalian and avian predators. Up to the 1950s, most estates employed gamekeepers to kill predators. Since then, the number of gamekeepers involved in active predation control has fallen and the number of Foxes *Vulpes vulpes* and Corvidae has increased (Potts 1980, Tapper 1992), as have partridge nesting losses (Potts & Aebischer 1995). A cross-over experiment, with legal predator control in spring and early summer as the treatment, demonstrated that after three years, autumn stock was 3.5 times higher on average when predation was controlled than when it was not, and breeding stock 2.6 times higher (Tapper *et al.* 1996). Loss of suitable nesting habitat does not seem to increase predation rates, as it forces birds to nest in crops where the predation risk is lower, but the risk of destruction due to agricultural operations is higher (Potts 1980).

Conservation measures

Green (1984) showed that parents and their broods spend 97% of their time inside cereal crops, mostly close to the field margin. Farm-scale trials have demonstrated that mean brood size increases from 4.8 to 7.3 when the outer 6 m of cereal crops are selectively sprayed, thereby restoring the understorey of weeds and associated invertebrates to the most frequented part of the field (Sotherton 1991). In such "Conservation Headlands", herbicide use is restricted to selective compounds only (to control pernicious weeds), and insecticides are allowed only up to 15 March. Comparing Conservation Headlands with conventional fully sprayed headlands, the financial penalty is less than 1% (Boatman & Sotherton 1988), weed cover and diversity are 3-4 times as high, and densities of the insect groups consumed by partridge chicks can be three times as high (Sotherton 1991). More generally, insecticides should be applied in strict accordance with known threshold numbers of insect pests and, if possible, the outer 12 m of crop should be left unsprayed to avoid drift into adjacent margins. Broad-spectrum insecticides should be avoided where possible, hence the aphid-specific compound pirimicarb should be used for summer aphid control (Potts 1997).

Nesting cover can be restored by replanting hedges and leaving grassy field margins. Hedgerows should be kept below 2 m in height, free of tall trees that could offer perches to avian predators, and the banks or grassy margins should be cut on a rotational basis, every 2-3 years, so that tall dead grass is present as early-season cover every year. To prevent pernicious weeds invading the crops from the margin, and to provide some protection from fertiliser and spray drift, it is desirable to maintain a 1-m weed-free buffer between crop and margin by rotovation or herbicide use (Boatman & Wilson 1988). Alternatively, selective herbicides used in the margin can eliminate pernicious weeds without affecting the rest of the vegetation (Boatman 1992). Large fields can be subdivided in a non-permanent fashion using raised grass strips or "Beetle Banks" to provide additional cover (Rands 1987, Thomas *et al*. 1991). These strips are raised by ploughing, sown with tussock-forming grasses such as Cocksfoot *Dactylis glomerata* or Yorkshire Fog *Holcus lanatus*, and managed in a similar way to field margins.

Set-aside, which the European Community introduced in 1988 to reduce cereal surpluses, can be managed since 1993 in ways similar to those described above (GCT 1993). Regulations state that set-aside areas must be at least 20 m wide and cover no less than 0.3 ha. After harvest, the set-aside can be left to regenerate naturally, providing overwintering stubbles where Grey Partridges can feed on weed seeds and grain, and where chick-food insects in the soil can hibernate undisturbed by cultivation; the regenerated vegetation can subsequently provide insect-rich brood-rearing habitat (Moreby & Aebischer 1992). Equally good brood-rearing habitat can be created under the "Wild Bird Cover" option, by sowing an unharvestable mixture such as cereals and kale. The "Grass Cover" option allows the creation of nesting and foraging habitat next to arable crops, and can be an alternative to Beetle Banks. Up to 2 m next to a hedge or wood may be left uncut each year, so rotational cutting every 2-3 years will prevent scrub formation while maintaining nesting cover.

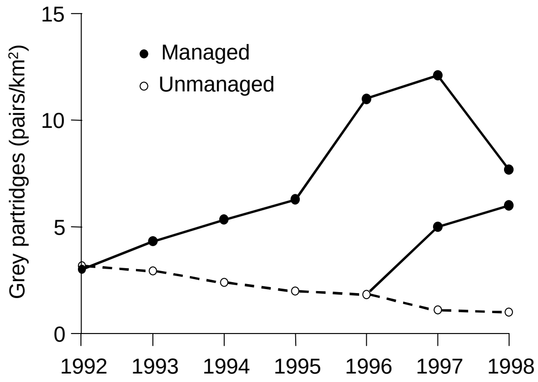

Figure 1. Average annual spring density (pairs/km^2) of Grey Partridges on five estates in Norfolk where partridge management began in 1992 (solid line), and on five unmanaged estates from the same area (pecked line). In 1996, two of the formerly unmanaged estates started management.

The approaches that restore chick-food insects and nesting habitat can be combined for maximum benefit. For example, Conservation Headlands can be placed next to a field margin with suitable nesting cover, or either side of a Beetle Bank. The different set-aside options can be combined to achieve the same juxtaposition of nesting and brood-rearing habitats.

The legal destruction of common predators during spring and summer can help considerably in restoring partridge numbers (Tapper *et al*. 1996). The aim is not the total eradication of the predators, but a local and seasonal reduction in their abundance that allows the partridges to breed successfully.

Evidence that conservation works

An indication of the success of implementing habitat management and predation control on Grey Partridge density at the non-experimental farm scale is given by results from the Norfolk Partridge Group. Since 1991, landowners and farmers in the Group have been encouraging one another to manage land for partridges using the measures described above (Aebischer 1997). On estates that did so, spring stocks were six times higher by 1996 than on ones that did not (although they fell back by a third in 1998 after an unusually wet June resulted in a disastrous 1997 breeding season). In 1996, their success encouraged other members of the Group to undertake partridge management, and here too, spring densities again began to climb relative to the unmanaged sites (Fig. 1). Clearly, management can restore partridges at a local level, and the success of the Norfolk Partridge Group has encouraged the formation of other county groups.

Prospects for a national recovery

Even though in 1994 there were about 1,920 km of Conservation Headlands and at least 98 km of Beetle Banks across the arable areas of the UK (Potts 1997), nationally too few farmers are willing to deviate from intensive farming methods to implement partridge management measures. The sympathetic management of set-aside (see above) could potentially take place on a much wider scale, but no financial incentive is offered to offset the extra work that it entails. More promising is the pilot Arable Stewardship Scheme proposed jointly by GCT, the Royal Society for the Protection of Birds (RSPB) and English Nature (EN). In 1998, it was implemented in two trial areas for three years by the Ministry of Agriculture, Food and Fisheries (MAFF) under EU Agri-Environment Regulation 2078/92. It seeks to promote mixed farming by supporting spring cereals and undersowing, to provide an equivalent of the wildlife-friendly options of set-aside in the form of overwinter stubbles and cover crop mixtures, and to bring together related measures like Conservation Headlands, Beetle Banks and grass margins. Its success will be measured in terms of increases in densities of key species, including the Grey Partridge. If the scheme is judged successful, the intention is to extend it to other geographical areas.

Meanwhile, as lead partner for the Grey Partridge BAP, the GCT launched an expansion of its Partridge Count Scheme in 1999, in collaboration with Green Globe Consultancy Ltd. The idea is to involve as many farmers and landowners as possible, and is based on asking them to count partridges on their land in spring and autumn. By providing feedback to individual estates on the status of their partridge stocks relative to that within their county and region, as well as free management advice tailored to each estate, the Trust aims to generate enthusiasm for at least some management under the motto "Every One Counts". Even small increases in the number of pairs present on individual sites could produce a considerable national knock-on effect, and would ensure that the national target of 150,000 pairs by 2010 is achieved.

CORNCRAKE

History and causes of the decline

In the late 19th century, Corncrakes bred in nearly all British counties, though they were most abundant in the north and west; by 1940 the geographical range had contracted towards the north and west of Britain, Corncrakes being found in large numbers only in the Hebrides and Northern Isles (Norris 1947, Holloway 1996). More recently, numbers recorded in national surveys declined from a known underestimate of 700-746 singing males in 1978-79, to 551-596 in 1988 and 480 in 1993 (Green 1995a).

Corncrakes are trans-Saharan migrants that breed in or around agricultural grassland managed for the production of hay or silage. They are extremely secretive birds that require vegetation that is at least 20 cm tall to provide concealment for foraging and nesting. In Scotland, first nests are usually in stands of Nettles *Urtica dioica*, Cow Parsley *Anthriscus sylvestris* or Yellow Flag *Iris pseudacorus*. Incubation is solely by the female. The chicks are nidifugous and are fed and kept warm by the female as they range within about 200 m of the nest, gradually beginning to catch prey for themselves. The female abandons them at about 12 days old, immediately joins a singing male and lays a second clutch by late June or early July. Second nests are usually in the tall grass of hay and silage meadows. Second broods hatch in late July and, without mowing, their survival is higher than that of first broods (Green *et al*. 1997).

The timing of regional declines in Corncrake numbers in the late 19th and early 20th centuries coincided in each area with the introduction of horse-drawn mowing machines that replaced hand-cutting (Norris 1947, Green 1995b). Mechanised mowing usually proceeds rapidly from the outside of the field inwards, destroying virtually all nests in mowed meadows and often killing flightless chicks, which are reluctant to break cover (Tyler *et al*. 1998). Because mechanised mowing is faster than mowing by hand, the whole hay or silage harvest is completed earlier, before Corncrakes have finished breeding. As a result, the survival of chicks of the first brood is reduced and young production from second clutches is minimal (Green *et al*. 1997). The trend towards earlier mowing continued throughout the 20th century as tractors replaced horses and their speed and power improved (Smith & Jones 1991). Land drainage also allowed earlier mowing of meadows in river floodplains.

By 1993, high densities and stable populations of Corncrakes occurred only at British and Irish sites with substantial areas of suitable tall vegetation present throughout the breeding season and where the mowing of hay and silage meadows was late (Green & Stowe 1993, Green 1996). It seems that each singing male requires 1-2 ha of tall ground vegetation associated with about 7 ha of late-mowed haymeadow. In many parts of western Scotland, the region now holding most British Corncrakes, grazing and winter weather leave only a few patches of Yellow Flag, Nettles or Cow Parsley as suitable refuges in the spring (Green 1996). As the grass in hay and silage meadows grows, more areas become suitable for Corncrakes, but, increasingly, sheep pasture is replacing hay meadows. After hay and silage are mown in the late summer, Corncrakes are again confined to areas that remain unmown and ungrazed.

Conservation measures

Effective conservation measures should include increasing the area of suitable tall vegetation from spring through to autumn, delaying the date of mowing and using mowing methods that allow flightless chicks to escape. Simulation models of Corncrake breeding show that delaying the date of mowing can increase breeding success markedly (Green *et al*. 1997). Mowing from the inside of the field outwards (the reverse of the usual practice), or leaving unmown escape corridors that allow chicks to reach the boundary under cover, increases the proportion of chicks that survive mowing (Green *et al*. 1997, Tyler *et al*. 1998). These methods are termed Corncrake Friendly Mowing (CFM).

In the 1990s, the RSPB acquired several nature reserves mainly for Corncrakes, and managed suitable habitat on other reserves more favourably (Williams *et al*. 1997). RSPB reserves now hold about 8% of the national population. Within these reserves, the area of spring and autumn cover for Corncrakes has been increased by fencing off the margins and corners of hay and silage meadows, and establishing stands of suitable vegetation. The impact of hay and silage mowing on breeding success has been reduced by delaying mowing until August and using CFM.

Since 1992, the RSPB has paid Scottish farmers to delay mowing until August and to use CFM within 250 m of the singing place of a male Corncrake (Williams *et al*. 1997). The area for which payments were made in the first year was 582 ha and this rapidly increased to more than 1,000 ha. This voluntary scheme, the Corncrake Initiative, has been funded by RSPB with the help of the EU LIFE programme and Scottish Natural Heritage (SNH).

The UK government has introduced Environmentally Sensitive Area (ESA) schemes under EU Agri-environment Regulation 92/2048 in the Outer and Inner Hebrides. ESA prescriptions for managing hay and silage fields for ground-nesting birds attempted to incorporate Corncrake management requirements. The Machair ESA, designated in 1988, initially did little to influence mowing dates. The prescriptions were revised in 1993 and the Argyll Islands ESA was also created. Both ESAs now encourage farmers to delay mowing until after 31 July and the Argyll Islands ESA also requests the provision and safeguarding of tall vegetation suitable for Corncrakes in spring and autumn.

Evidence that conservation works

The most recent national census of Corncrakes (Green & Gibbons 2000) showed an increase of 23% from 480 singing males in 1993 to 589 males in 1998. Annual monitoring in selected areas of the core of the Corncrake's range in Scotland showed that this overall increase resulted from four successive annual increases of 4-16 % followed by a decline of 15% between 1997 and 1998. A further partial survey showed an increase of 5% between 1998 and 1999, which indicates that the national population probably increased by 28% between the low point in 1993 and 1999. All surveys of distribution and censuses between the late 19th century and 1993 recorded a progressive decline in the national population and range. The average rate of population decline between 1988 and 1993 was 3.5% per year, but between 1993 and 1998 the population increased by an average of 4.2% per year. Hence, the increase in the British Corncrake population from 1993 to 1998 is unusual when set against the compelling evidence, from studies of distribution, of a sustained decline that began in the second half of the 19th century.

The coincidence of the recent Corncrake population increase with the development of the conservation programme suggests cause and effect, but a longer period of implementation and monitoring is required to see whether the population recovery will be sustained.

Prospects for a national recovery

Conservation efforts for this species are co-ordinated by the BAP Steering Group for Corncrakes, led by the Scottish Executive Rural Affairs Department (SERAD) and RSPB. At present, Corncrakes depend upon the continuation of the low-intensity livestock farming that allows them to fulfil their full breeding potential. Future development of the conservation programme is likely to involve wider implementation of suitable measures through existing and new agri-environment schemes, and by a special programme by SNH within Special Protection Areas designated under the EU Directive EEC/79/409 on the conservation of wild birds. Under consideration also are reintroduction attempts, to create new populations of Corncrakes on the British mainland.

STONE-CURLEW

History and causes of the decline

The Stone-curlew occurs in Britain as a small fragmented population at the north-western edge of its world range. Its British range has contracted markedly since the late 19th century (Sharrock 1976, Holloway 1996). The number of Stone-curlews also declined, from 1000-2000 pairs in the late 1930s to 300-500 pairs by 1968-1972 (Sharrock 1976). By 1991 the population was estimated at 167-169 pairs (Green 1995c). The main strongholds are Breckland and the part of Wessex centred on Salisbury Plain.

Stone-curlews are present in England from March to September. They forage mostly at night on bare or sparsely vegetated ground for soil invertebrates and surface-active arthropods. The highest nesting densities occur on semi-natural grassland with a short (<20 mm) sward, in areas with sandy or stony soils (Green & Griffiths 1994, Green & Taylor 1995), but more than half of breeding attempts occur in spring-sown arable crops where densities are much lower. Pairs make an average of 2-3 breeding attempts per year. Annual numbers of breeding pairs on chalk downland fluctuate in line with the number of Rabbits *Oryctolagus cuniculus* present in spring, presumably because their grazing affects sward height (Bealey *et al*. 1999). Rabbit burrowing also brings stones to the surface, which increases the attractiveness of an area to Stone-curlews (ADAS 1997).

Most of the observed decline in the Stone-curlew population since 1940 can be attributed to loss of semi-natural grassland habitats, where the highest population densities occur, and to changes in grazing by Rabbits and domestic livestock. Much Breckland heath and chalk grassland was converted to farmland and forestry (Ratcliffe 1977). In the remaining fragments of semi-natural grassland, a reduction in the number of Rabbits, caused by myxomatosis in the 1950s, and reduced levels of grazing by livestock led to growth of taller vegetation, unsuitable for Stone-curlews (Green & Griffiths 1994).

When semi-natural grassland is lost or its vegetation becomes too tall, Stone-curlews move to spring-sown arable farmland. Stone-curlews are most likely to breed on a spring-sown field if the crop is of a type that does not become too tall and dense until relatively late in the summer, and if the field is close to short semi-natural grassland or sheep pasture (Green *et al.* 2000). The nature of the crop is particularly important for Stone-curlews initiating breeding attempts after mid-May, as they avoid dense crops taller than 10 cm. Thus the recent switch from spring to autumn sowing of arable crops has reduced the area of arable land suitable for nesting. In addition, the decline of mixed farming has reduced the extent to which crops suitable for nesting are close to short pastures that are productive foraging areas. Stone-curlews that breed on arable land make frequent foraging excursions to grazed short grassland, both semi-natural and improved (Green *et al*. 2000), presumably to exploit the higher densities of earthworms, and of other invertebrate prey that are associated with the dung of Rabbits and domestic livestock (Green & Tyler 1989, Green *et al*. 2000).

On semi-natural grassland, predation is the main cause of breeding failure. Typically about 60% of nests in this habitat fail at the egg stage, mainly because of predators. About 65% of hatchlings fail to fledge, but the relative importance of predation and starvation is difficult to disentangle (Bealey *et al.* 1999). It is possible that once Stone-curlews are concentrated in small fragments of suitable habitat, breeding attempts are more vulnerable to predators. Bealey *et al*. (1999) found that breeding success tended to be highest in years with high Rabbit numbers, maybe because Rabbits provide alternative prey for predators. On arable farmland the main cause of breeding failure was the destruction of eggs and chicks by agricultural operations such as rolling, mechanical weed control by tractor-mounted hoes, and irrigation (Green 1988).

There is evidence that disturbance from road traffic prevents some otherwise suitable breeding habitat from being used by Stone-curlews (Green *et al.* 2000). The increase in the number of major roads in southern England and in the volume of traffic may therefore have contributed to the population decline. A high proportion of the Stone-curlews that breed on semi-natural grassland occur on areas used for military training. The degree of disturbance caused by training and its effect on distribution and breeding success have not been quantified. However, the increasing use made of training facilities in England since the end of the Cold War may be another adverse factor for Stone-curlews.

Conservation measures

Increased levels of grazing of semi-natural grassland by Rabbits and livestock increase the area of suitable habitat for Stone-curlews by reducing sward length. Breckland was declared an ESA under MAFF's agri-environment programme in 1988, and consequently owners of semi-natural grassland became eligible for payments to introduce high levels of grazing by sheep and cattle. As a result of the scheme, grazing levels have increased. ESAs cover very little of the Stone-curlew's range elsewhere in England. Special measures have been undertaken to increase grazing by Rabbits and to provide nesting plots with disturbed soil on nature reserves and military training areas. The number of breeding pairs of Stone-curlews on semi-natural grassland has increased (Green & Griffiths 1994).

In some areas of arable farmland the area of crops that remain open and sparsely vegetated until mid-summer is small. Some farmers have established tilled plots, or modified the management of plots of gamebird cover to provide nesting areas for Stone-curlews. Provision of nesting areas has also been possible under the set-aside regulations. Under special derogations provided by MAFF, parts of set-aside fields have been cultivated in spring to create bare or sparsely vegetated ground. Areas managed in this way have been much used by Stone-curlews.

Since the mid-1980s, dedicated wardens employed by the RSPB (with funding from EN's Species Recovery

Programme during the 1990s) have located a high proportion of Stone-curlew nests on arable land and drawn the attention of farmers to them. This has enabled the farmers to avoid damaging eggs and chicks by postponing agricultural operations or avoiding the area around the nest. In some cases, chicks are held while an agricultural operation takes place and released afterwards. Farmers have shown considerable enthusiasm for these measures, which improve the breeding success of Stone-curlews nesting on arable farmland by about 35%.

Evidence that conservation works

Systematic searches for breeding pairs of Stone-curlews have been made throughout the range annually since the early 1990s. A total of 233 pairs were proved to breed in 1999 compared with 150 pairs in 1991 (Green 1995c). Other pairs were located but not proved to breed. Mark-resighting analysis of observations of individually colour-ringed adults has shown that the proportion of birds of breeding age that are not proved to breed may be about 10% more than the total proved breeding (Green 1995c). These results indicate a considerable recent increase in the Stone-curlew population contrasting with the rapid decline between 1940 and the 1980s.

Prospects for a national recovery

The status of the Stone-curlew as a breeding species in the UK remains precarious. Its retention depends upon high levels of grazing of key habitats by domestic and wild mammals, and on the types of tillage crops grown and their management. Grazing of semi-natural habitats by Rabbits is reduced by Rabbit control and disease outbreaks, such as myxomatosis and the recently established Rabbit (Viral) Haemorrhagic Disease. Grazing of these habitats by sheep and cattle can be encouraged by agri-environment measures, but depends upon the availability of livestock in surrounding areas and the willingness of farmers to place them on unproductive rough grazings.

Future changes in farm economics could have a large effect on the types of arable crops being grown and, hence, the area of arable land suitable for Stone-curlews. In addition, the general trend in crop husbandry is towards early and uniform establishment of the maximum leaf area, achieved by improved varieties, irrigation, nutrient supply and pest and disease control. Stone-curlews, which exploit slow-growing, gappy, late-sown crops are likely to be harmed by this trend. Finally, the decline in mixed farming, with tillage and invertebrate-rich pasture in close proximity, is probably continuing to be harmful to Stone-curlews. Given these uncertainties, the UK BAP for the Stone-curlew seeks to maintain and increase numbers in different regions and on both semi-natural grassland and farmland, to avoid concentrating the population in one area or habitat.

CIRL BUNTING

History and causes of the decline

In the 1930s Cirl Buntings were fairly common and widespread across southern Britain (Evans 1997a). Between then and the late 1960s the population apparently underwent a slow decline, disappearing from Wales and some of south-east England, before collapsing in the 1970s. In 1982 the population was estimated at just 167 pairs (Sitters 1985) and had become confined to the far south-west. By 1989 the population had fallen to between 118 and 132 pairs (Evans 1992).

In 1988, the RSPB began a detailed study of the ecology of Cirl Buntings at two study sites in South Devon. At both sites, birds foraged in winter almost exclusively on stubble fields left after cereal harvest (Evans & Smith 1994). This pattern was constant over three winters, and birds followed overwinter stubble fields between years as they rotated around the farm. A wide-scale study of randomly selected stubble fields reinforced the importance of this habitat feature but also demonstrated that stubble fields with higher numbers of broad-leaved weeds tended to hold higher numbers of foraging Cirl Buntings (Evans 1997b). Faecal analysis showed that the birds were taking a range of both invertebrate and vegetable matter. The plant material included cereal grain (mostly barley), grass seed and broad-leaved weed seeds (Evans 1997a).

Full-grown birds rarely moved more than 2 km from their wintering grounds to set up a breeding territory (Evans 1997b), and there was considerable seasonal variation in nesting success. Nests where the first egg was laid before 1 July had only a 28% chance of producing fledglings. After this date the probability of success almost doubled (Evans *et al*. 1997). This difference was driven by differences at the nestling stage; chicks in 'early' nests had only a 37% chance of surviving to fledge, rising to nearly 90% in 'late' nests. Most losses of chicks were due to predation or starvation and it is thought that these two causes were linked. The growth rates of chicks that were subsequently predated were lower than those that fledged, but no different to those that subsequently died from starvation (Evans *et al*. 1997). It is possible that the increased begging of hungry chicks attracted the attentions of predators. Rainfall contributed to poor growth, and in rainy conditions adults switched from provision of predominantly invertebrate food to cereal grain (Sitters 1985, Evans 1997b). Chicks in early nests were fed mainly caterpillars, spiders and beetles whilst those in later more successful nests were fed a much higher proportion of

Orthoptera (Evans *et al.* 1997). Intensification of pasture management by application of inorganic nitrogen and associated high stocking rates are highly detrimental to grasshopper populations (Van Wingerden *et al.* 1991, 1992).

This research demonstrated that Cirl Buntings require extensive (low-input) arable farmland and extensive pasture in close proximity, i.e. extensive mixed farming systems. Modern arable farming has moved away from spring-sown barley to winter wheat (O'Connor & Shrubb 1986, Fuller 2000) and, in the absence of set-aside, very few stubble fields would be left unploughed for even part of the winter. Moreover, those stubble fields that remain have become increasingly the product of cereal fields that have received several herbicide applications (Campbell *et al.* 1997) and that harbour relatively low densities of broad-leaved weeds (Sotherton & Self 2000). The vast majority of arable grassland now receives artificial fertiliser (O'Connor & Shrubb 1986) and, despite few quantitative data, grasshopper densities must have declined dramatically. Perhaps the most damaging change, however, has been the trend towards specialisation of individual holdings in arable or pastoral production and a consequent loss of mixed farms (O'Connor & Shrubb 1986).

Conservation measures

Initially, the RSPB made direct payments to farmers to leave stubble fields and plant spring cereals (in six locations); four of these stubbles were used by a total of 75 Cirl Buntings. EN funded a management agreement (which included provision of overwinter stubble fields annually) on an important site for Cirl Buntings that was already designated a Site of Special Scientific Interest for other wildlife. The National Trust contributed financially to further agreements. In 1992 the introduction of mandatory set-aside improved the delivery of conservation measures for Cirl Buntings. Since most farmers went for the rotational option with a naturally regenerated green cover, large areas of overwinter stubble fields suddenly re-appeared in the landscape. Also, more money became available for habitat improvement under the Countryside Stewardship (CS) scheme. The initial objective of the scheme along the South Devon coast was to revert arable land to pasture for landscape reasons. This would have been disastrous for Cirl Buntings, which need the arable component of mixed farming systems. Once the scheme administrators realised the conflict of interest, they used the scheme instead to set up ten-year management agreements with farmers specifically for Cirl Buntings. Management agreements can include the provision of overwinter stubble fields, grass margins, hedgerow and pasture management. Advice on drawing up a management agreement is available free of charge from a dedicated project officer jointly funded by the RSPB and EN. By April 1999 there were 32 agreements covering 119 pairs (26% of the population).

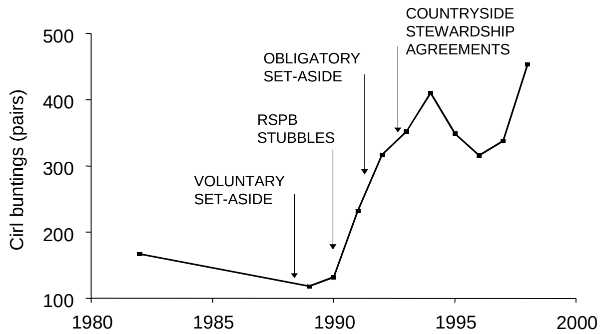

Figure 2. Recovery of the UK Cirl Bunting population in relation to the timing of conservation actions and implementation of set-aside.

Evidence that conservation works

Since the recovery plan was implemented, the Cirl Bunting population has increased to an estimated 453 pairs (Fig. 2, Wotton *et al.* 2000). Between 1992 and 1998, numbers on land in CS agreements have increased by 70%, from 60 to 102 pairs, compared with a 2% increase (124 to 126 pairs) on adjacent non-agreement land (RSPB unpubl.). There has also been an encouraging increase in the number of 2x2-km squares that are occupied (Wotton *et al.* 2000).

Prospects for a national recovery

The CS scheme seems to have been successful in delivering conservation measures for Cirl Buntings. However, it is already over-subscribed and more funding is needed to increase the percentage of the Cirl Bunting population that is on land covered by management agreements. On non-CS sites, there is a need to find other sources of funding to encourage positive management, and afford them greater protection against development. Such management also needs to be encouraged on potential sites in order to facilitate range expansion.

The concentration of the population in one area makes it vulnerable to severe weather, especially prolonged snow cover. The RSPB/EN recovery project includes emergency measures to provide artificial food sources should these conditions prevail. If UK Cirl Buntings fail to expand their range, reintroduction might be considered as a means of establishing a second core population. Any decision to proceed with such a programme would depend on finding a suitable recipient site, developing appropriate translocation/release/captive-breeding methods and being able to satisfy the IUCN guidelines on reintroductions (IUCN 1995).

DISCUSSION

All four of the species reviewed here are widely dispersed at relatively low densities across the farmed landscape. Their conservation is thus particularly difficult, because the option of setting up nature reserves to protect large proportions of their UK populations or habitats is impractical. However, reserves may be valuable in providing recruits as farmland becomes suitable and for the development and demonstration of appropriate management techniques (as done for the Corncrake). Moreover, because these birds make use of the same areas that are used for farming, their recovery requires changes in management not just of the unproductive field margins, but especially of the farmed land itself. This means that conservation action is currently working against the massive economic forces that have driven the intensification of livestock and arable farming, most recently as a result of the EU Common Agricultural Policy (Potter 1997). The problem is twofold: changing economic incentives can alter the farmland environment so rapidly and on such a large scale that direct conservation measures may do little to mitigate the effects, and resources available for such measures are puny compared with agricultural commodity support payments. Reversing the fortunes of these farmland birds depends, in the long term, on major changes in agricultural policy that alter the economic balance between production and conservation.

That is not to say that all is doom and gloom. The point of this review is, in fact, to highlight the good news. All four of the species examined here have been the subject of intensive scientific studies that have identified the root causes of the declines. Armed with that ecological knowledge, it has been possible to devise and implement suitable conservation management practices. These have now been in place long enough to provide indications of their effectiveness, as shown by the monitoring that is essential to measure management performance and provide updates on the status of the species. Unfortunately, the practices cost money, and it takes a dedicated farmer-conservationist to implement them if no other sources of funding are available. Being a gamebird, the Grey Partridge is the only one of the four species where private revenue from shooting provides a financial incentive for management. Otherwise, as seen in the species accounts, the RSPB or the government's statutory conservation agencies have had to make contributions out of their limited budgets.

Encouragingly, the species accounts have also shown that many of the successes have been achieved by making use of the limited reforms that have already taken place in agricultural policy. EU Agri-environment Regulation 2078/92 provides a legislative framework that can be used to promote arable extensification on a national scale. It led to the development of the ESA scheme in England and Scotland that has helped the Corncrake and Stone-curlew, the CS scheme in England that has helped the Cirl Bunting, and the pilot Arable Stewardship scheme that holds great potential for the Grey Partridge (and many other declining farmland birds). Set-aside, which originally was brought in purely to depress cereal production, has become a versatile means of providing nesting and foraging habitats tailored to individual species' needs in intensively farmed and largely inhospitable landscapes. Apart from set-aside, the funding available through these schemes compensate farmers for the agricultural revenue forgone when specific positive management practices are undertaken.

When the four species accounts are considered together, several common themes emerge. One is that all four species rely on habitats that have a particular physical structure and also harbour invertebrate prey during the breeding season. Conservation action is needed that creates or maintains these habitats. Examples are: cereals with an insect-rich understorey of broad-leaved weeds (Grey Partridge), stands of tall herbage or meadow vegetation (Corncrake), heavily grazed semi-natural grassland (Stone-curlew) and extensively grazed unimproved pasture (Cirl Bunting). Another common theme is the loss of suitable nesting habitat caused by agricultural intensification: loss of stands of tall undisturbed vegetation (Grey Partridge, Corncrake), loss of hedgerows (Grey Partridge, Cirl Bunting), loss of bare or sparsely vegetated ground (Stone-curlew). The conservation actions needed to restore these involve maintaining what remains of the original habitat, and re-creating an equivalent one.

Several of these requirements are provided by extensive, and usually mixed, farming – a third common theme. For the Grey Partridge, the practice of undersowing a spring crop in order to produce a grass ley the following year produces the weedy cereal understorey favoured by chick-food insects and also benefits the overwinter survival of sawflies, whose larvae are one of the main chick-food items (Potts 1997). The emphasis on spring crops and mixed farming benefits the Stone-curlew, as bare ground is available for nesting in close proximity to grazed grass. This emphasis also benefits the Cirl Bunting over winter, as stubbles from the preceding crop are left for longer than those from a winter crop and sometimes remain through to the following spring. For the Corncrake, low-intensity livestock farming systems provide areas of tall grass in hay and silage meadows suitable for nesting and foraging during the middle of the breeding season. Hence, changes in agricultural policy that lead to a reduction in the intensity of farming systems, and in particular an increase in the extent of spring-sown arable crops and traditional mixed farming, would be favourable.

All four species also benefit from agri-environment measures specifically targeted at creating habitats or encouraging practices that farmers would be unlikely to adopt without financial incentives. Examples include the provision of nesting cover and Conservation Headlands for Grey Partridge, stands of tall herbage and marshland vegetation as early and late season cover and Corncrake-Friendly Mowing for Corncrake, and tilled nesting plots for Stone-curlews in areas where suitable nesting habitat is restricted. Therefore, successful conservation will require a combination of changes to agricultural policy, which affect the nature of farming systems, with targeted agri-environment measures, which provide for special requirements.

In addition to habitat considerations, nest predation is a factor that can potentially affect two of the three ground-nesting species considered here. Its impact has been well quantified in the case of the Grey Partridge (Potts 1980, Tapper *et al*. 1996), for which predator control is an integral part of traditional shoot management. The control of egg predators is likely to be beneficial on semi-natural breeding sites of the Stone-curlew, where predation is the main cause of nest failure (Bealey *et al*. 1999). However, Corncrake nests are rarely destroyed by predators, even in areas where egg predators are abundant (Green *et al*. 1997). Predation is not thought to be a factor limiting recovery of Cirl Buntings in South Devon.

The notions discussed above also apply to the conservation of other declining farmland species. The importance of mixed farming in this context cannot be overstated. Research on Lapwings *Vanellus vanellus* has emphasized the value of spring-sown arable crops for nesting, and of adjacent grass to provide food and shelter for the chicks (Hudson *et al*. 1994). In contrast to intensive arable farming, traditional mixed farming in Sussex was associated with high densities of Corn Buntings *Miliaria calandra* and with high densities of caterpillars, one of the components of chick diet (Aebischer & Ward 1997). Spring-sown crops also benefit Skylarks *Alauda arvensis*, which prefer to nest in a relatively open situation and feed their chicks on caterpillars too (Poulsen *et al*. 1998). In the winter, several other buntings and finches take advantage of the grain and wild seeds found in the weedy stubbles that are characteristic of rotational mixed farming, and also take advantage of winter food provided for livestock (Evans 1997b). Many more examples are provided by the studies on farmland birds presented later in this proceedings volume. The four case-study species reviewed here thus share common elements not just among themselves, but also with many other species. This is excellent news, because it means that conservation actions taken to save them are likely to have a ripple effect, producing benefits for many other forms of farmland wildlife. The task now is primarily to promote the required policy changes, and to persuade farmers to make the best possible use of options that exist already.

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REFERENCES

ADAS 1997. *Biological Monitoring of Lowland Heathland in the Breckland ESA 1988-1996*. Unpublished report to MAFF. London: Agricultural Development & Advisory Service.

Aebischer, N.J. 1997. Gamebirds: management of the Grey Partridge in Britain. In Bolton, M. (ed.) *Conservation and the Use of Wildlife Resources*: 131-151. London: Chapman & Hall.

Aebischer, N.J. & Potts, G.R. 1998. Spatial changes in Grey Partridge (*Perdix perdix*) distribution in relation to 25 years of changing agriculture in Sussex, U.K. *Gibier Faune Sauvage* **15:** 293-308.

Aebischer, N.J. & Ward, R.S. 1997. The distribution of Corn Buntings *Miliaria calandra* in Sussex in relation to crop type and invertebrate abundance. In Donald, P.F. & Aebischer, N.J. (eds) *The Ecology and Conservation of Corn Buntings*: 124-138. UK Nature Conservation No. 13. Peterborough: Joint Nature Conservation Committee.

Anon. 1995. *Biodiversity: The UK Steering Group Report, Vol. 2: Action Plans*. London: Her Majesty's Stationery Office.

Batten, L.A., Bibby, C.J., Clement, P., Elliott, G.D. & Porter, R.F. 1990. *Red Data Birds in Britain: Action for Rare, Threatened and Important Species*. London: T. & A.D. Poyser.

Bealey, C.E., Green, R.E., Robson, R., Taylor, C.R. & Winspear, R. 1999. Factors affecting the numbers and breeding success of Stone-curlews *Burhinus oedicnemus* at Porton Down, Wiltshire. *Bird Study* **46:** 145-156.

Boatman, N.D. 1992. Improvement of field margin habitat by selective control of annual weeds. *Aspects Appl. Biol.* **29:** 431-436.

Boatman, N.D. & Sotherton, N.W. 1988. The agronomic consequences and costs of managing field margins for game and wildlife conservation. *Aspects Appl. Biol.* **17:** 47-56.

Boatman, N.D. & Wilson, P.J. 1988. Field edge management for game and wildlife conservation. *Aspects Appl. Biol.* **16:** 53-61.

Brown, A. 1992. *The UK Environment*. Department of the Environment. London: Her Majesty's Stationery Office.

Campbell, L.H., Avery, M.I., Donald, P.F., Evans, A.D., Green, R.E. & Wilson, J.D. 1997. *A Review of the Indirect Effects of Pesticides on Birds*. JNCC Rep. No. 227. Peterborough: Joint Nature Conservation Committee.

Evans, A.D. 1992. The number and distribution of Cirl Buntings *Emberiza cirlus* breeding in Britain in 1989. *Bird Study* **39:** 17-22.

Evans, A.D. 1997a. Cirl Buntings in Britain. *Brit. Birds* **90:** 267-282.

Evans, A.D. 1997b. The importance of mixed farming for seed-eating birds in the UK. In Pain, D.J. & Pienkowski, M.W. (eds) *Farming and Birds in Europe: The Common Agricultural Policy and its Implications for Bird Conservation*: 331-357. London: Academic Press.

Evans, A.D. & Smith, K.W. 1994. Habitat selection of Cirl Buntings *Emberiza cirlus* wintering in Britain. *Bird Study* **41:** 81-87.

Evans, A.D., Smith, K.W., Buckingham, D.L. & Evans, J. 1997. Seasonal variation in breeding performance and nestling diet of Cirl Buntings *Emberiza cirlus* in England. *Bird Study* **44:** 66-79.

Ford, J., Chitty, H. & Middleton, A.D. 1938. The food of Partridge chicks (*Perdix perdix* L.) in Great Britain. *J. Anim. Ecol.* **7:** 251-65.

Fuller, R.J. 2000. Relationship between recent changes in lowland British agriculture and farmland bird populations: an overview. In Aebischer, N.J., Evans, A.D., Grice, P.V. & Vickery, J.A. (eds) *Ecology and Conservation of Lowland Farmland Birds*: 5-16. Tring: British Ornithologists' Union.

Fuller, R.J., Gregory, R.D., Gibbons, D.W., Marchant, J.H., Wilson, J.D., Baillie, S.R. & Carter, N. 1995. Population declines and range contractions among lowland farmland birds in Britain. *Conserv. Biol.* **9:** 1425-1441.

GCT 1993. *Factsheet 3. Game, Set-aside and Match.* Fordingbridge: The Game Conservancy Trust.

Gibbons, D.W., Avery, M.I., Baillie, S.R., Gregory, R.D., Kirby, J.S., Porter, R.F., Tucker, G.M. & Williams, G. 1996. Bird species of conservation concern in the United Kingdom, Channel Islands and Isle of Man: revising the Red Data list. *RSPB Conserv. Rev.* **10:** 7-18.

Gibbons, D.W., Reid, J.B. & Chapman, R.A. 1993. *The New Atlas of Breeding Birds in Britain and Ireland: 1988-1991*. London: T. & A.D. Poyser.

Green, R.E. 1984. The feeding ecology and survival of Partridge chicks (*Alectoris rufa* and *Perdix perdix*) on arable farmland in East Anglia. *J. Appl. Ecol.* **21:** 817-830.

Green, R.E. 1988. Stone-curlew conservation. *RSPB Conserv. Rev.* **2:** 30-33.

Green, R.E. 1995a. The decline of the Corncrake *Crex crex* in Britain continues. *Bird Study* **42:** 66-75.

Green, R.E. 1995b. Diagnosing causes of bird population declines. *Ibis* **137** (suppl.): 47-55.

Green, R.E. 1995c. Monitoring of Stone-curlew numbers and breeding success. In Carter, S.P. (ed.) *Britain's Birds in 1991-92: The Conservation and Monitoring Review:* 138-141. Thetford: British Trust for Ornithology & Joint Nature Conservation Committee.

Green R.E. 1996. Factors affecting the population density of the Corncrake *Crex crex* in Britain and Ireland. *J. Appl. Ecol.* **33:** 237-248.

Green, R.E. & Gibbons, D.W. 2000. The status of the Corncrake *Crex crex* in Britain in 1998. *Bird Study* **47:** 129-137.

Green, R.E. & Griffiths, G.H. 1994. Use of preferred nesting habitat by Stone-curlews *Burhinus oedicnemus* in relation to vegetation structure. *J. Zool.* **233:** 457-471.

Green, R.E., Hodson, D.P. & Holness, P.R. 1997. Survival and movements of Stone-curlews *Burhinus oedicnemus* ringed in England. *Ringing & Migration* **18:** 24-34.

Green, R.E. & Stowe, T.J. 1993. The decline of the Corncrake in Britain and Ireland in relation to habitat change. *J. Appl. Ecol.* **30:** 689-695.

Green, R.E. & Taylor, C.R. 1995. Changes in Stone-curlew *Burhinus oedicnemus* distribution and abundance and vegetation height on chalk grassland at Porton Down, Wiltshire. *Bird Study* **42:** 177-181.

Green R.E. & Tyler, G.A. 1989. Determination of the diet of the Stone-curlew *Burhinus oedicnemus* by faecal analysis. *J. Zool.* **217:** 311-320.

Green, R.E., Tyler, G.A. & Bowden, C.G.R. 2000. Habitat selection, ranging behaviour and diet of the Stone-curlew (*Burhinus oedicnemus*) in southern England. *J. Zool.* **250:** 161-183.

Green, R.E., Tyler, G.A., Stowe, T.J. & Newton, A.V. 1997. A simulation model of the effect of mowing of agricultural grassland on the breeding success of the Corncrake (*Crex crex*). *J. Zool.* **243:** 81-115.

Holloway, S. 1996. *The Historical Atlas of Breeding Birds in Britain and Ireland 1875-1900.* London: T. & A.D. Poyser.

Hudson, R., Tucker, G.M. & Fuller, R.J. 1994. Lapwing *Vanellus vanellus* populations in relation to agricultural changes. In Tucker, G.M., Davies, S.M. & Fuller, R.J. (eds) *The Ecology and Conservation of Lapwings* Vanellus vanellus: 1-33. UK Nature Conservation No. 9. Peterborough: Joint Nature Conservation Committee.

IUCN 1995. *IUCN/SSC Guidelines for Re-introductions*. Gland: IUCN/SSC Re-introduction Specialist Group, World Conservation Union.

Moreby, S.J. & Aebischer, N.J. 1992. Invertebrate abundance on cereal fields and set-aside land: implications for wild gamebird chicks. In Clarke, J. (ed.) *Set-aside*: 181-187. BCPC Monogr. No. 58. Farnham: British Crop Protection Council.

Norris, C.A. 1947. Report on the distribution and status of the Corncrake. *Brit. Birds* **40:** 226-244.

O'Connor, R.J. & Shrubb, M. 1986. *Farming and Birds*. Cambridge: Cambridge University Press.

Potter, C. 1997. Europe's changing farmed landscapes. In Pain, D.J. & Pienkowski, M.W. (eds) *Farming and Birds in Europe: The Common Agricultural Policy and its Implications for Bird Conservation*: 331-357. London: Academic Press.

Potts, G.R. 1980. The effects of modern agriculture, nest predation and game management on the population ecology of partridges (*Perdix perdix* and *Alectoris rufa*). *Adv. Ecol. Res.* **11:** 1-79.

Potts, G.R. 1986. *The Partridge: Pesticides, Predation and Conservation*. London: Collins.

Potts, G.R. 1997. Cereal farming, pesticides and Grey Partridges. In Pain, D.J. & Pienkowski, M.W. (eds) *Farming and Birds in Europe: The Common Agricultural Policy and its Implications for Bird Conservation*: 331-357. London: Academic Press.

Potts, G.R. & Aebischer, N.J. 1991 Modelling the population dynamics of the Grey Partridge: conservation and management. In Perrins, C.M., Lebreton, J.-D. & Hirons, G.J.M. (eds) *Bird Population Studies: Their Relevance to Conservation Management*: 373-390. Oxford: Oxford University Press.

Potts, G.R. & Aebischer, N.J. 1995. Population dynamics of the Grey Partridge *Perdix perdix* 1793-1993: monitoring, modelling and management. *Ibis* **137** (suppl.): 29-37.

Poulsen, J.G., Sotherton, N.W. & Aebischer, N.J. 1998. Comparative nesting and feeding ecology of Skylarks *Alauda arvensis* on arable farmland in southern England with special reference to set-aside. *J. Appl. Ecol.* **35:** 131-147.

Rands, M.R.W. 1986. Effect of hedgerow characteristics on partridge breeding densities. *J. Appl. Ecol.* **23:** 479-487.

Rands, M.R.W. 1987. Hedgerow management for the conservation of partridges *Perdix perdix* and *Alectoris rufa*. *Biol. Conserv.* **40:** 127-39.

Ratcliffe, D.A. 1977. *A Nature Conservation Review.* Cambridge: Cambridge University Press.

Sharrock, J.T.R. 1976. *The Atlas of Breeding Birds in Britain and Ireland.* Tring: British Trust for Ornithology.

Sitters, H.P. 1985. Cirl Buntings in Britain in 1982. *Bird Study* **31:** 1-10.

Smith, R.S. & Jones, L. 1991. The phenology of mesotrophic grassland in the Pennine Dales, northern England: historic hay cutting dates, vegetation variation and plant species phenologies. *J. Appl. Ecol.* **28:** 42-59.

Sotherton, N.W. 1991. Conservation Headlands: a practical combination of intensive cereal farming and conservation. In Firbank, L.G., Carter, N., Derbyshire, J.F. & Potts, G.R. (eds) *The Ecology of Temperate Cereal Fields*: 373-397. Oxford: Blackwell Scientific Publications.

Sotherton, N.W. & Self, M. 2000. Changes in plant and arthropod biodiversity on lowland farmland: an overview. In Aebischer, N.J., Evans, A.D., Grice, P.V. & Vickery, J.A. (eds) *Ecology and Conservation of Farmland Birds*: 26-35. Tring: The British Ornithologists' Union.

Southwood, T.R.E. & Cross, D.J. 1969. The ecology of the Partridge. III. Breeding success and the abundance of insects in natural habitats. *J. Anim. Ecol.* **38:** 497-509.

Tapper, S.C. 1992. *Game Heritage: An Ecological Review from Shooting and Game-keeping Records*. Fordingbridge: Game Conservancy Ltd.

Tapper, S.C., Potts, G.R. & Brockless, M.H. 1996. The effect of an experimental reduction in predation pressure on the breeding success and population density of Grey Partridges (*Perdix perdix*). *J. Appl. Ecol.* **33:** 965-978.

Thomas, M.B., Wratten, S.D. & Sotherton, N.W. 1991. Creation of 'island' habitats in farmland to manipulate populations of beneficial arthropods: predator densities and emigration. *J. Appl. Ecol.* **28:** 906-917.

Tucker, G. & Heath, M.F. 1994. *Birds in Europe: Their Conservation Status*. Cambridge: BirdLife International.

Tyler, G.A., Green, R.E. & Casey, C. 1998. Survival and behaviour of Corncrake *Crex crex* chicks during the mowing of agricultural grassland. *Bird Study* **45:** 35-50.

van Wingerden, W.K.R.E., Musters, J.C.M., Kleukers, R.M.J.C., Bongers, W. & van Biezen, J.B. 1991. The influence of cattle grazing intensity on grasshopper abundance (Orthoptera: Acrididae). *Proc. Exp. Appl. Entomol.* **2:** 28-34.

van Wingerden, W.K.R.E., van Kreveld, A.R. & Bongers, W. 1992. Analysis of species composition and abundance of grasshoppers (Orthoptera: Acrididae) in natural and fertilised grasslands. *J. Appl. Entomol.* **113:** 138-152.

Williams, G., Green, R.E., Casey, C., Deceuninck, B. & Stowe, T.J. 1997. Halting declines in globally threatened species: the case of the Corncrake. *RSPB Conserv. Rev.* **11:** 22-31.

Wotton, S.R., Langston, R.H.W., Gibbons, D.W. & Pierce, A.J. 2000. The status of the Cirl Bunting *Emberiza cirlus* in the UK and the Channel Islands in 1998. *Bird Study* **47**: 138-146.