Birds and lowland grassland management practices in the UK: an overview

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Lowland grassland in the UK can be categorized broadly as wet or dry grassland, each of which supports a characteristic assemblage of breeding and wintering bird species. Intensification of grassland management over the last fifty years has included extensive drainage, increased use of pesticides and artificial fertilisers, re-seeding, earlier and more frequent mowing and increased grazing pressure. With a few exceptions, intensification has in general been to the detriment of grassland birds and at least 42 bird species of current UK conservation concern are dependent on grassland at some stage in their life cycle. Species associated with wet grassland have benefited from the acquisition and management of wetland reserves, site management agreements and, to some extent, Environmentally Sensitive Area (ESA) schemes. However, these mechanisms have not been sufficient to prevent overall declines in many breeding bird species. Dry grassland research has provided recommendations for timing and mowing methods that reduce nest and chick mortality in agricultural, ESA and set-aside grassland. The success of grassland management for birds in reserves, ESAs and the agricultural ecosystem more generally, via other agri-environment schemes, depends on conservation becoming a key part of the EU Common Agricultural Policy. It is clear that long-term conservation of grassland bird species relies on EU resources being directed away from agricultural productivity towards policy that allows a sustainable integration of agriculture and conservation.

Grasslands constitute an important habitat for birds (Dodds *et al*. 1995) and around 35% of agricultural land in the UK is in some form of grassland management. Changes in grassland management over the last few decades have had a profound impact on the numbers and distribution of many bird species. At least 11 UK Red Data list species (Gibbons *et al.* 1996) and 31 Amber list species are associated with grasslands at some stage of their life cycle (Table 1). Since these lists were published in 1996 new data have become available indicating further declines in a number of grassland species, such as Grasshopper Warbler *Locustella naevia*, Lapwing *Vanellus vanellus* and Starling *Sturnus vulgaris* (Crick *et al.* 1998). These data may lead to a re-assessment of their status in the near future.

This paper provides an overview of the grassland management practices that impact on these species and their habitat, and identifies sympathetic management practices that are likely to conserve and enhance lowland grassland bird populations.

In western Europe at least, grasslands are usually plagioclimax vegetation, formed historically by the destruction of climax forests for grazing pasture and agricultural use. As such they are maintained by the active intervention of humans and their domesticated grazing animals, and would return by the process of ecological succession to forest if unmanaged (Goriup 1988). Along with most other agricultural habitats, the management of grasslands has become far more intensive over the last five decades. The use of fast-growing grass species and the application of increased levels of fertiliser has led to earlier grazing seasons, increased grazing intensity and a switch from traditional hay management to silage production (Dodds *et al*. 1995). Where grasslands were formerly subject to impeded drainage and flooding in winter and early summer, engineering of watercourses, installation of modern pumping systems and field drainage have been employed to provide suitably dry conditions for intensive grassland management. In addition, successful drainage has allowed the conversion of wet grassland to arable cropping, and thus an overall loss of riparian and coastal grassland, often to the detriment of bird and other interests (Green & Robins 1993).

A further trend has been the specialisation of farming enterprises and the loss of mixed farming from some areas in recent decades, with the demise of grassland-arable land mosaics that are important for many farmland bird species.

GRASSLAND TYPES AND WILDLIFE

Wet lowland grasslands and their bird fauna

For the purposes of this paper we have divided lowland grasslands into 'wet grasslands', defined as those subject to impeded drainage or periodic flooding (Smith 1983),

Table 1. UK bird species of conservation concern (Gibbons *et al.* 1996) that use grasslands at some stage of their annual cycle. Their use of grasslands is based on an assessment of published material.

Species of conservation concern	Reasons*	Species of conservation concern	Reasons*
Red list - high conservation concern		***Amber list** continued*	
Grey Partridge *Perdix perdix*	BD, SPEC 3	Wigeon *Anas penelope*	WI, WL
Quail *Coturnix coturnix*	HD, SPEC 3	Teal *Anas crecca*	WI
Corncrake *Crex crex*	BD, HD, BL, SPEC 1	Pintail *Anas acuta*	BR, WI, WL, SPEC 3
Stone-curlew *Burhinus oedicnemus*	BD, BR, SPEC 3	Garganey *Anas querquedula*	BR, SPEC 3
Black-tailed Godwit *Limosa limosa*	HD, BR, WL, SPEC 2	Shoveler *Anas clypeata*	WI
Woodlark *Lullula arborea*	BD, BL, SPEC 2	Kestrel *Falco tinnunculus*	BDM, SPEC 3
Skylark *Alauda arvensis*	BD, SPEC 3	Spotted Crake *Porzana porzana*	BDM, BR
Song Thrush *Turdus philomelos*	BD	Golden Plover *Pluvialis apricaria*	WI
Red-backed Shrike *Lanius collurio*	BD, HD, BR, SPEC 3	Lapwing *Vanellus vanellus*	WI
Cirl Bunting *Emberiza cirlus*	BD, BR	Ruff *Philomachus pugnax*	BR, WL
Corn Bunting *Miliaria calandra*	BD, HD	Jack Snipe *Lymnocryptes minimus*	SPEC 3
		Snipe *Gallinago gallinago*	BDM
		Curlew *Numenius arquata*	BI, WI, SPEC 3
		Redshank *Tringa totanus*	WI, SPEC 2
Amber list - medium conservation concern		Barn Owl *Tyto alba*	BDM, SPEC 3
Bewick's Swan *Cygnus columbianus*	WI, WL, SPEC 3	Short-eared Owl *Asio flammeus*	SPEC 3
Whooper Swan *Cygnus cygnus*	BR, WI, WL	Green Woodpecker *Picus viridis*	SPEC 2
Bean Goose *Anser fabalis*	WL	Swallow *Hirundo rustica*	BDM, SPEC 3
Pink-footed Goose *Anser brachyrhynchus*	WI, WL	Ring Ouzel *Turdus torquatus*	BDM
White-fronted Goose *Anser albifrons*	WL	Blackbird *Turdus merula*	BDM
Greylag Goose *Anser anser*	WI, WL	Grasshopper Warbler *Locustella naevia*	BDM
Barnacle Goose *Branta leucopsis*	WI, WL, SPEC 2	Chough *Pyrrhocorax pyrrhocorax*	BL, SPEC 3
Brent Goose *Branta bernicla*	WI, WL, SPEC 3	Starling *Sturnus vulgaris*	BDM

*The following codes indicate the reasons for a species' selection in the red or amber categories:

BD	> 50% decline in UK breeding population or range over the previous 25 years
HD	historical population decline in the UK between 1800 and 1995
BDM	moderate decline (25-49%) in the UK breeding population or range over the previous 25 years
BR	five-year mean of 0.2-300 breeding pairs in the UK
BI	> 20% of European breeding population in the UK
WI	> 20% of north-west European (wildfowl), East Atlantic Flyway (waders) or European (others) non-breeding populations in the UK
BL	> 50% of the UK breeding population can be found in 10 or fewer sites, but not BR
WL	> 50% of the UK non-breeding population can be found in 10 or fewer sites
SPEC 1	species of global conservation concern (Tucker & Heath 1994)
SPEC 2, 3	species with an unfavourable conservation status in Europe (Tucker & Heath 1994)

and 'dry grasslands', comprising the remainder. Self *et al.* (1994) identify three types of lowland wet grassland: flood plains, coastal grazing marsh on enclosed salt marsh, and some lowland peat areas. Benstead *et al.* (1997) describe five types: semi-natural flood plains, washlands, water meadows, wet grasslands with intensive water level management on drained soils and lakeside wet grassland.

It has been estimated that some 20,000 km^2 of wet grassland were drained between 1940 and 1980 (Williams *et al.* 1983, Williams & Bowers 1987) and there are now thought to be only around 300,000 ha remaining in the UK (Anon. 1995). In contrast there are well over 10 million ha of other grasslands, although much of this is in the uplands. Lowland wet grassland is a priority habitat for conservation and the habitat is the subject of the UK Government Biodiversity Action Plan for grazing marsh (Anon. 1995). The characteristic birds of wet grasslands include breeding waders such as Redshank *Tringa totanus*, Lapwing and Snipe *Gallinago gallinago*, Black-tailed Godwit *Limosa limosa*, Ruff *Philomachus pugnax*, wildfowl such as Garganey *Anas querquedula* and Shoveler *Anas clypeata* in spring, and large congregations of migratory wildfowl and waders in winter. Twenty-four British Red Data birds are at least partly dependent on lowland wet grasslands, while five are almost completely dependent in the breeding season and four in the winter. Many of the remaining extensive areas of wet grassland are now under nature reserve management and at least 12 Environmentally Sensitive Areas (ESAs) established by the Ministry of Agriculture, Food & Fisheries (MAFF) contain wet grassland and promote appropriate wet grassland management prescriptions (Self *et al*. 1994, Benstead *et al*. 1997).

Dry lowland grasslands and their bird fauna

European dry lowland grassland has been defined as undulating, treeless, non-ericaceous, non-waterlogged, natural or semi-natural (anthropogenic) in origin, with vegetation less than 1 m in height (Wolkinger & Plank 1981, Tucker 1991). With reference to Britain, Smith (1983) and Fuller (1987) have considered only grassland that lies below 200 m to be lowland grassland, while Crofts & Jefferson (1994) have defined lowland grassland as pasture or meadow lying below 300 m. In this overview, we accept the altitude limit as 300 m to include dry lowland grassland in areas such as the South Downs, South Wessex Downs and the Cotswold Hills ESAs. The plant species associations and management regimes imposed in these regions have more in common with lowland than with upland grassland (Holmes 1989, Rodwell 1992).

Many palaearctic bird species, such as Stone-curlew *Burhinus oedicnemus*, Grey Partridge *Perdix perdix*, Skylark *Alauda arvensis* and Wheatear *Oenanthe oethanthe*, originated in natural dry grassland habitats (Porter *et al.* 1991, Hagemeijer & Blair 1997). These bird species are now dependent on managed grassland at some stage in their life cycle (Tucker 1991), as most areas of European natural dry grassland have been replaced by agriculture and pastoralism. Therefore sympathetic management of grassland is essential in an integrated conservation policy for lowland farmland birds (Goriup *et al.* 1991, Dolman 1992, Pain & Pienkowski 1997), especially for species such as Lapwings and Corn Buntings *Miliaria calandra* (Galbraith 1988, Shrubb 1997).

Semi-natural grassland of botanical conservation value

Wet grasslands

Many wet grasslands have been farmed under traditional management regimes, such as low intensity grazing or hay cutting followed by aftermath grazing, for many decades and as a result have developed characteristic plant communities. Examples are flood meadows (MG4 plant community) and water meadows (MG8) (Rodwell 1992). These communities have high conservation value, and collectively wet grasslands in the UK support approximately 500 species of vascular plant (Thomas *et al*. 1995) and many associated rare invertebrates (Benstead *et al*. 1997). Wet grassland plant communities are particularly sensitive to the maintenance of traditional management regimes and any changes in hydrology, nutrient inputs or grazing intensity are likely to lead to a shift in the botanical interest (Evans *et al*. 1995, Gowing & Spoor 1998, Treweek *et al*. 1998).

Dry grasslands

For ecological conservation purposes, European dry grasslands have been categorised into eight classes on the basis of soil type and phytosociological association (Wolkinger & Plank 1981). In Britain, thirty-four grassland types have been described in the lowlands (Rodwell 1992). These are semi-natural plagioclimax plant associations that are influenced by regional geology, climate and management (Hopkins & Hopkins 1994). More broadly, these grasslands can be classified also on basis of substrate as calicolous (alkaline), mesotrophic (neutral) or calcifugious (acidic) (Rodwell 1992).

The area of lowland grassland of ecological conservation value in Britain has decreased by 97% since the 1930s; with semi-natural grasslands estimated to cover only 4% of the lowland area by the mid-1980s (Fuller 1987), making some of these grassland types extremely rare (Hopkins & Hopkins 1994). This reflects a similar trend throughout Europe, with natural or semi-natural grassland under threat from increasing intensity of management, forestry or abandonment (van Dijk 1991). In Britain, agricultural intensification since the 1950s has led to drainage, liming, reseeding, replacement of hay-making by silage-making, earlier and more frequent mowing, and use of inorganic nitrogen fertiliser to improve agricultural productivity. Overall, species-rich grasslands have been replaced with MG6/MG7 Rye-grass *Lolium perenne* dominant swards or monocultures (Rodwell 1992, Hopkins & Hopkins 1994), which are high yielding and nutritious for grazing livestock or for hay- and silage-making.

Agricultural grassland

Historically, the area of arable land relative to the area of grassland has fluctuated in response to political, social and economic conditions in Britain (Wakeham-Dawson 1994). Over the last 50 years, the area of land (both lowland and upland) under pasture has been reduced from 50% to less than 35%. This has been the result of conversion of permanent grasslands to rotational arable cropping, with a polarization of grassland to the western side and arable to the eastern side of Britain (Dodds *et al.* 1995, Shrubb 1997).

For agricultural purposes, lowland farmed grassland (which may be wet or dry, but has usually been drained) has been divided into three main categories: semi-natural (rough) grazing, permanent and rotational (ley) (Holmes 1989). In addition other categories of managed lowland grassland such as machair, woodland rides, road verges, spring cereals undersown with grass, grass field boundaries, beetle banks and grass-sown set-aside or conservation headlands have all been recorded as areas that are available to nesting or foraging birds (Lack 1992, Dodds *et al*. 1995).

Grazed permanent grassland is described as pasture; grassland managed for silage or hay production is described as meadow; short term grassland incorporated in an arable rotation is described as ley grass (Holmes 1989). In general, wet and dry grasslands can be managed both as pasture and meadow during the course of the agricultural year.

INTENSIFICATION OF GRASSLAND MANAGEMENT AND ITS EFFECT ON BIRDS

The recent intensification of wet grassland management (with earlier spring grass growth, earlier cutting dates and higher stocking levels) has increased egg and chick mortality and reduced relaying opportunities. Productivity is now often insufficient to maintain populations of breeding wader species (Green 1986, Beintema & Muskens 1987). Some species have adapted to increased intensification better than others, but the change in management practices has been too rapid for many species (Beintema *et al*. 1997). In the Netherlands, Redshank, Snipe and Ruff are the breeding wader species most sensitive to the adverse effects of the intensification of wet grassland management, whereas Curlew *Numenius arquata* and Oystercatcher *Haematopus ostralegus* are the least sensitive. Black-tailed Godwit and Lapwing are of intermediate sensitivity (Beintema 1986). Work in the UK has confirmed that Snipe ranks as one of the more sensitive species (Green 1988, Green *et al*. 1990). The factors that influence wader nesting success are the vegetation height and structure, the biomass and availability of soil and other invertebrates, the timing and intensity of grazing and mowing regimes, and the availability of surface-flooded areas. The biomass and availability of soil invertebrates are closely related to soil type, wetness and penetrability.

Similar factors to those listed above for wet grasslands operate in dry grasslands, except that there is less need for management to maintain damp soil conditions to provide soil invertebrates during the breeding season. To date the management of dry grasslands in the UK has received less concerted research and conservation effort. The intensification of grassland management that has affected plant species diversity over the last fifty years has similarly affected the breeding success and survival rates of dry grassland birds. It has contributed to the range contraction and decrease in abundance observed in many farmland bird species in Europe as a whole (Goriup *et al.* 1991, Pain & Pienkowski 1997), and the UK in particular (Gibbons *et al*. 1993, Fuller *et al*. 1995, Siriwardena *et al*. 1998).

The various changes in the intensity of wet and dry grassland management and their effect on birds are now discussed in turn. It should be noted, however, that in some cases birds can be affected by the interaction of several management practices simultaneously, so identifying the most important one is extremely difficult.

Water level management

The drainage of wet grasslands often results in a lowering of water levels, reduction in winter flooding and some loss of ornithological interest (Green & Robins 1993). A mosaic of flooded and unflooded grassland is necessary to attract a diversity of wildfowl and wader species in winter (Benstead *et al*. 1997). Wildfowl are divided into grazing wildfowl, dabbling ducks and diving ducks, with each group requiring suitable feeding conditions such as short (5-15 cm) grassy swards for grazers, and floating or submerged seeds (and other vegetation) and invertebrates for divers and dabblers. Wintering waders feeding on wet grasslands need short swards and soft damp soil to allow easy access to soil invertebrates (Milsom *et al*. 1998). Both wildfowl and waders need to be free of disturbance and have access to suitable roost sites that are close to feeding areas and secure from predators. These conditions are all provided by winter flooding (Benstead *et al*. 1997).

Winter flooding, which is outside the growing season, can often be provided with little conflict to agricultural practices, whereas the maintenance of wet conditions into spring presents real difficulties. Breeding waders require soft soil conditions to allow them to probe with their beaks for soil invertebrates, or shallow surface flooding to allow them to feed on soil and aquatic invertebrates (Self *et al.* 1994). Snipe in particular require damp soil conditions. Green (1988) and Green *et al*. (1990) have shown that on peat soils a water table within 20 cm of the soil surface is required to provide sufficiently soft soil for feeding Snipe. Other species such as Redshank and Lapwing are more able to forage around surface floods (Vickery *et al*. 1997). Provision of high water tables across a field requires ditch water levels at or near field level and sufficiently high soil hydraulic conductivity to allow lateral transport of water into the field centre. For clay and silt soils the hydraulic conductivity is likely to be too low for lateral transport of water from the ditches and other methods such as shallow under-drains, wet foot drains or surface floods are needed to provide damp field conditions into spring (Gowing & Spoor 1998).

There is a potential management conflict in that the retention of wet and flooded conditions late into spring, essential to provide soft soil conditions, may also serve to reduce the biomass of soil invertebrates (Ausden 1996). Earthworms, in particular, retreat from areas as they become flooded. Currently the trade-off between invertebrate accessibility (soil softness) and invertebrate biomass in wet grasslands is not fully understood.

The needs of wintering wildfowl and waders appear to be less demanding and less in conflict with agricultural practice than those of breeding birds (Owen & Cadbury 1975, Thomas 1976, Owen & Thomas 1979, Thomas 1982, Benstead *et al.* 1997). Areas of grassland that become extensively flooded in winter quickly attract large concentrations of waders and wildfowl, and in general the populations of wintering wildfowl, at least, are stable or increasing (Cranswick *et al.* 1997). Vickery *et al.* (1997) found that breeding Lapwing, Redshank and Snipe nested at lower densities in grazing marshes that had been more heavily grazed by Brent *Branta bernicla*, Pink-footed *Anser brachyrhynchus* and White-fronted Geese *Anser albifrons* during the previous winter. Vickery *et al.* attributed this to the selection by the waders of wetter areas, which the geese tended to avoid.

Species composition of grasslands

The area of UK grassland that has been re-seeded is likely to have increased in recent years with the widespread shift to silage. Re-seeding of grasslands and conversion to monocultures results in a loss of sward diversity and related invertebrate species. Monocultures of competitive Perennial Rye-grass *Lolium perenne* prevent the establishment of less competitive plants. ESA arable reversion swards sown with less competitive grass species such as fescues *Festuca* give (at least initially) broad-leaved plants more chance to establish and set seed than dense rye-grass swards (Wakeham-Dawson & Aebischer 1998). Many herbivorous insects, e.g. grass-feeding Hemiptera, are species-specific in their food plants and may be affected by simpler sward composition (Curry 1994). For example, dense rye-grass swards supported few Hemiptera and virtually no Orthoptera in the South Downs ESA (A. Wakeham-Dawson unpubl. data). Orthoptera require a mosaic of bare ground for oviposition and vegetation for food and shelter. They benefit from the grazing and treading activity of livestock that provides areas of bare ground and prefer swards composed of species such as bents *Agrostis* or fogs *Holcus* (Curry 1994).

Fertiliser inputs

Artificial nitrogen fertiliser

Use of artificial nitrogen fertiliser on permanent grassland in Britain has increased from none before 1940 to application on 60% of fields by the mid-1990s, with a peak of 80% application in the mid-1980s (Dodds *et al.* 1995). The application of inorganic fertilisers (and lime) leads to a reduction in plant species richness and diversity, and their replacement by dense, competitive rye-grass swards (Bobbink 1991). The resulting lush and uniform vegetation is less suitable for invertebrates and breeding wildfowl and waders. However, various studies (reviewed in Vickery & Gill 1999) have shown that application of artificial fertiliser to grasslands leads to an increase in the nutritional quality of the grass and hence greater usage by wintering geese such as Pink-footed, White-fronted, Brent and Barnacle Geese *Branta leucopsis*.

Even without fertiliser, Rye-grass swards prevent most broad-leaved plants (especially pioneer 'weed' species that are associated with rotational cropping and regular cultivation) from establishing (Morris 1990, Wakeham-Dawson & Aebischer 1998), reducing the broad-leaved weed seeds available to foraging dry grassland birds. Densities of invertebrates such as species of Acari, Collembola, Diptera, Coleoptera and Myriapoda are moderately to severely reduced in permanent pasture receiving over 140 kg Nitrogen ha^{-1} yr^{-1} compared with unfertilised pasture (Curry 1994). Artificial fertilisers reduce plant root biomass and cause a decrease in bird prey species such as coleopterous and lepidopterous larvae in the upper few centimetres of soil, but can lead to more nutritious vegetation that increases the abundance of some Homoptera (Curry 1994).

Lapwings forage on grasslands where prey abundance and feeding success is high, seeking especially earthworms Lumbricidae and leather-jackets Tipulidae (Galbraith 1988). Moderate (100 kg Nitrogen ha^{-1} yr^{-1}) addition of artificial fertiliser can benefit earthworms, but numbers are depressed by high (300 kg Nitrogen ha^{-1} yr^{-1}) application rates (Curry 1994).

Organic fertiliser

The impact of organic fertilisers is similar to that of inorganic fertilisers. Surface-feeding Common Earthworms *Lumbricus terrestris* increase in abundance in response to the addition of farmyard manure, but heavy (> 500 m^3 ha^{-1} yr^{-1}) applications of slurry can be highly toxic to earthworms (Curry 1994). Tucker (1992) found soil macro-invertebrate densities were highest in permanent pastures and were not significantly different for fields with and without the addition of farmyard manure. However, bird usage was higher in fields that had received moderate applications of farmyard manure, suggesting that this had affected the availability of invertebrates, perhaps by increasing the surface activity of earthworms in particular (Tucker 1992, Curry 1994).

Vegetation structure

Fertilisers affect vegetation composition and structure, and these are particularly important for breeding waders. Lapwing and Black-tailed Godwit require short vegetation for nesting, while Snipe and Redshank use taller vegetation (Green 1986, Self *et al.* 1994, Benstead *et al*. 1997). Lapwings in particular require closely cropped swards less than 15 cm in height for nesting and feeding (Green 1986). They often nest on spring cultivations and move their chicks to grasslands to feed on soil-surface invertebrates (Galbraith 1988). For Redshanks, Green (1986) found no relationship between nest density and vegetation height, although Vickery *et al*. (1997) subsequently found a negative correlation. On saltmarshes Norris *et al*. (1997) found that Redshanks selected heavily grazed areas that contained a diverse structure, with patches of close cropping interspersed with more rank areas. Snipe will nest in vegetation up to 30 cm tall and move their chicks to areas with soft soil and high soil invertebrate biomass (Green *et al*. 1990). On the other hand, broods of Lapwing, Black-tailed Godwit and Redshank all tended to aggregate around surface pools (Green 1986).

In dry grasslands, the application of artificial fertilisers increases the growth rate and structural density of grassland vegetation. This decreases the maximum temperature near the soil surface and leads to a decrease in the number and diversity of invertebrates such as Orthoptera, an important food resource of Cirl Bunting *Emberiza cirlus* and other farmland bird chicks (van Wingerden 1992, Campbell *et al*. 1997, Evans 1997). The rapid growth of vegetation will also limit the potential length of the breeding season for species such as Skylark that require open nesting situations (Wilson *et al*. 1997).

Mowing and grazing

Vegetation structure and composition depends on the grazing and mowing management regime. In wet and dry grasslands, increased fertiliser inputs promote more rapid grass growth and hence allow higher stocking density and stocking earlier in the season. Both these will increase the chance that the eggs and chicks of ground-nesting species such as Lapwings and Skylarks will be trampled by livestock (Green 1986, Beintema & Muskens 1987, Shrubb 1990, Wilson *et al*. 1997). Studies of the rates of nest trampling for breeding waders have led to management prescriptions for the grazing season and stocking rates that allow ground-nesting birds to achieve adequate nesting success. Not all grazing by domesticated species has an equivalent impact on wader nests. For instance, for a given number of livestock units, sheep are more destructive of nests than cattle (Green 1986, Beintema & Muskens 1987).

A trend towards the replacement of hay-making by silage-making (Dodds *et al*. 1995) has affected the distribution and abundance of grassland birds. Silage-making and its associated management practices have led to faster and more frequent mowing of grassland during the breeding season. Grassland management for silage varies regionally. However, mowing may begin as early as mid-March and be repeated every four to six weeks until the autumn, with the direct destruction of nests and chicks. In particular, intensive mowing increases Corncrake *Crex crex* chick mortality (Tyler *et al.* 1998). This has contributed to a decline in Corncrake breeding success (Green *et al*. 1997), seriously endangering this species and restricting its breeding range to the north and west of Britain and Ireland, where grassland management is least intensive (Green 1995).

Similarly, breeding Skylark, Corn Bunting and Yellowhammer *Emberiza citrinella* density is decreased in fields managed intensively for silage (Wakeham-Dawson 1997, Wilson *et al*. 1997, Kyrkos *et al.* 1998, Wakeham-Dawson *et al*. 1998). Breeding Corn Buntings and Skylarks deserted ESA arable reversion grassland fields that were mown and subsequently grazed during the nesting season (Wakeham-Dawson 1997, Wakeham-Dawson *et al*. 1998). Mowing removes nesting cover and destroys directly or reveals to predators the nests of Skylarks (Poulsen & Sotherton 1992, Wilson *et al*. 1997), and contributes to Lapwing chick mortality (Shrubb 1990). The cutting process leads to temporary increases in availability of invertebrate and other food for some bird species such as Corvidae, that forage in recently mown fields (Poulsen & Sotherton 1992).

Hay-making allows grasses and associated broad-leaved species time to flower and set seed, with some of the grasses in mesotrophic meadows not shedding until September (Smith *et al.* 1996). Earlier and more frequent cutting of grass crops used for silage-making reduces flower-head production and consequently the abundance and diversity of phytophagous invertebrates that feed on plant flowers (Morris 1990, Curry 1994). The restricted making (turning to aid drying) of silage relative to hay reduces the seeds shaken free (Smith *et al*. 1996), and thereby available to granivorous birds foraging in the winter.

Grazing similarly reduces seed and invertebrate food sources for birds, but the effect on vegetation height and structure is less sudden and more selective than the effect of mowing. As a result, although sward heterogeneity is also likely to be reduced under intensive grazing the effect is not as marked as under intensive cutting. In addition, the rate of return of organic matter to the soil is also likely to be higher under grazing than cutting. Cattle produce a mosaic of different vegetation heights, while sheep, particularly at high stocking levels, produce a sward of more uniform height (Morris 1990, Mitchley 1994). In addition vegetation composition and structure are affected by timing and duration of grazing (Bacon 1990). South Downs ESA grass experimentally grazed between April and July by sheep to an even sward below 10 cm in height supported half the number of invertebrates compared with grass maintained between 15 and 25 cm in height. In particular, the heavily grazed short grass supported significantly fewer web-spinning spiders than the less intensively grazed longer grass, and both grass heights supported few soft-bodied Lepidoptera or Hymenoptera larvae (Wakeham-Dawson *et al*. 1998). These invertebrates are important prey items for chicks of a number of bird species such as Cirl Bunting, Yellowhammer and Skylark that forage in grass (amongst other crop types) during the breeding season (Poulsen & Aebischer 1995, Evans 1997, Stoate *et al*. 1998). In addition, taller or ungrazed (particularly unfertilised) swards support denser populations of rodents such as Field Vole *Microtus agrestis,* and provide hunting grounds for predatory bird species such as Kestrel *Falco tinnunculus*, Barn Owl *Tyto alba* and Short-eared Owl *Asio flammeus* (Dodds *et al.* 1995, Shaw 1995).

Seed-eating dry grassland birds prefer ungrazed fields during the winter, because plants in ungrazed swards have had a chance to set seed (Wilson *et al*. 1996). Lightly grazed fields of ESA arable reversion grass had up to 15 times as many grass seed-heads in July as closely grazed fields (Wakeham-Dawson *et al*. 1998), and Skylarks foraged during the winter in ESA grassland where sward height was above 10 cm in height (Wakeham-Dawson & Aebischer 1988).

However, soil invertebrate feeders such as Redwings and Lapwings prefer shorter grass for foraging during the winter (Tucker 1992). Similarly, breeding Stone-curlews forage for invertebrates from the soil surface, preferring semi-natural grassland with vegetation less than 2 cm high (Green & Griffiths 1994). Increased vegetation height, resulting from high rainfall and a reduction in grazing by rabbits, resulted in a decrease in the numbers and proportion of Stone-curlews nesting on chalk grassland in southern England (Green & Taylor 1995, Bealey *et al*. 1999). In Breckland (East Anglia) grass heathland, breeding Stone-curlews, Woodlarks *Lullula arborea* and Wheatears *Oenanthe oenanthe* all decreased in numbers when grazing by domestic stock and wild rabbits (reduced in numbers by myxomatosis), and regular anthropogenic soil disturbance, were reduced (Dolman & Sutherland 1992). Breeding Curlews, however, increased in number as they prefer longer vegetation for nesting. The structure of the sward (presence of scrub-free short grass and areas of bare soil) appears to be more important than sward composition for breeding and foraging Woodlarks (Sitters *et al*. 1996).

Grazing disturbs the soil surface and provides easier access for birds that feed on surface invertebrates (Wilson *et al*. 1996). The density of Skylarks foraging in ESA arable reversion grass during the winter was positively correlated with sward openness (Wakeham-Dawson and Aebischer 1998), suggesting that seed-eaters are attracted similarly to areas where there is access to the soil surface. A moderate level of grazing promotes floral and faunal diversity (Morris 1990), but a mosaic of sward lengths may be needed to benefit both botanical and ornithological conservation aims. Complete abandonment of grazing on downland allows the regeneration of successional scrub. This provides habitat for species such as warblers Sylviidae, but can reduce the density of some open-habitat species such as Skylarks (Wakeham-Dawson *et al*. 1998).

Biocides

Andreasen *et al*. (1996) observed a decrease between 1967 and 1989 in arable weeds such as Knotgrass *Polygonum aviculare* and Black Bindweed *Fallopia convolvulus* in undersown (grass crop is sown under a cereal crop) grass leys, which they attributed to increased use of herbicides within the arable ecosystem. Decreases in broad-leaved arable weeds reduce the invertebrate prey items that live on the weeds and the weed seeds available to breeding or wintering birds such as the Grey Partridge (Potts 1986). Decreasing numbers of weed seeds in rotational grassland reflects the general decrease of these weed species throughout the agricultural ecosystem in Britain (Campbell *et al*. 1997, Ewald & Aebischer 1999).

Pesticides are not as widely used on grassland as in intensive arable farming, and routine application of insecticides, herbicides and fungicides is rare. However, the potential for ecological damage resulting from misuse of pesticides in grassland is substantial (Curry 1994). Newly sown leys are particularly vulnerable to pest damage. Information on the environmental effects of grassland pesticides is still patchy and the long-term impact is uncertain. The main effects of herbicides on grassland invertebrates is brought about indirectly through changes in plant cover, microclimate and food supply (Curry 1994). Organochlorine insecticides depress numbers of many groups of invertebrates (Curry 1994) and accumulate in food-chains, affecting breeding success of tertiary carnivores such as the Peregrine Falcon *Falco peregrinus* (Ratcliffe 1993). Organophosphorus insecticides are less persistent and less injurious to non-target species, but synthetic pyrethroids have a broad spectrum of activity and have at least transient effects on non-target organisms (Curry 1994). Fungicides containing heavy metals can suppress earthworm activity (Curry 1994).

Herbivore dung is exploited by a complex community of invertebrates, with cattle dung being able to support over 140 arthropod species (Curry 1994). Avermectin anthelminthics, such as Ivermectin, used to combat parasitic worms in cattle (and to a lesser extent in sheep and other livestock), may make dung too toxic for saprophytic invertebrates to survive, with consequent effects on grassland food chains (McCraken & Foster 1992, Cooke 1998). Some species such as the Chough *Pyrrhocorax pyrrhocorax* are largely dependent on dung-associated invertebrates (Roberts 1982).

Comparison of ley and permanent grassland for foraging birds

Permanent pasture provides stable soil conditions that suit some invertebrate species, thereby providing food resources for invertebrate-feeding birds such as thrushes *Turdus* spp., crows, Starlings and plovers (Tucker 1992). However, the number of broad-leaved arable weeds decreases with time in fields under permanent grass (Chancellor 1986), providing less food resources for seed-eating birds. Reversion of large areas of arable land to permanent grassland in downland ESAs reduced the broad-leaved weed seeds available to Skylarks foraging in the winter (Wakeham-Dawson & Aebischer 1998). Grey Partridge and Corn Bunting densities decreased in the South Downs ESA after reversion of rotational arable fields to permanent grassland (Potts 1997, Wakeham-Dawson 1997).

CONSERVATION OF LOWLAND GRASSLAND BIRDS

Conservation of wet grassland birds

There has been considerable research effort into the needs of birds of wet grasslands, particularly the requirements of breeding waders and waterfowl that use the habitat in spring (Thomas 1980, Green 1986, Beintema & Muskens 1987, Green 1988, Beintema *et al*. 1991, Self *et al*. 1994). With only around 300,000 ha of wet grassland still remaining in the UK, the conservation of wet grassland breeding birds is proving to be a difficult problem and outwith nature reserves declines in numbers continue (O'Brien & Smith 1992). Technically wet grassland bird management is straight forward (Beintema, 1988) and could be enhanced by a reversion to traditional farming practices. ESA schemes are in place to promote sympathetic management, but as the gap between traditional and intensive modern practices is widening, compensation to farmers that subsidises 'old-fashioned' and less economic farming methods is becoming increasingly expensive. Grassland management is thus a political problem associated with overproduction in the EU (Beintema 1988).

There are striking parallels in the policy measures being taken in the UK and the Netherlands for the conservation of wet grasslands (Beintema *et al*. 1997). In the Netherlands, the 'Relatienota' scheme established areas with core nature reserves and surrounding land where farmers could enter voluntary agreements for sympathetic wet grassland management with financial compensation for any loss of income. In the UK, there are nature reserves that are owned (or leased) and managed directly primarily for conservation by statutory or non-governmental nature conservation organisations. In addition there are Sites of Special Scientific Interest or Areas of Special Scientific Interest in Northern Ireland, where management agreements between statutory conservation organisations and owners or occupiers can be used to prevent damaging operations and to promote sympathetic management. Over and above these areas there are now ESAs where farmers can receive payments for various levels of wet grassland management.

Wintering waterfowl tend to concentrate at managed sites and so their conservation is well suited to the nature reserve approach. Nature reserve management can also be very effective for breeding birds (O'Brien & Smith 1992), but because these do not nest at particularly high density the contribution to the conservation of the overall populations is less marked. There are many examples of the success of providing high ditch-water levels and a water table close to the soil surface in restoring breeding and wintering bird numbers (Pulborough Brooks in West Sussex and Loch Gruinart on Islay: Andrews & Rebane 1994; West Sedgemoor in Somerset: Evans *et al*. 1995). However, it has been shown in the Somerset Levels and Moors that isolated protected areas can suffer from drainage in the surrounding water catchment area, preventing the achievement of optimum conditions (Green & Robins 1993).

Conservation of dry grassland birds

Until recently, most dry grassland bird species in the UK have not been the subject of as much conservation research as those of wet grassland. Some species, such as the Red-backed Shrike *Lanius collurio*, became extinct before the effects of intensified grassland management became apparent. However, there were a number of notable exceptions where declining populations prompted detailed research and generated successful conservation programmes. For example, since 1992 the Scottish Office Agriculture, Environment & Fisheries Department, the

Royal Society for the Protection of Birds, Scottish Natural Heritage and Scottish Crofters Union have been offering financial incentives to encourage Corncrake conservation by farmers in the Scottish Islands. These took the form of the Corncrake Initiative, Corncrake Friendly Mowing, and ESA and Countryside Premium schemes. These were designed to encourage the provision of areas of tall vegetation from April until October (especially fields of tall hay or silage grass), delayed mowing and grazing until at least 1 August, and mowing in strips or from the middle of the field outwards. These measures provide cover for the breeding Corncrakes and reduce the mortality of adults and young caused by mowing. The success of these schemes was variable among the islands, but overall there was an increase in Corncrake numbers since 1983, which coincided with the widespread implementation of the Corncrake conservation programme (Scottish Biodiversity Group 1998).

More recently, the decline in numbers of even the more common farmland bird species such as the Skylark has initiated further research into dry grassland birds. A number of ESAs such as the South Downs and South Wessex Downs schemes include management prescriptions preventing mowing for hay or silage during the breeding season. The South Downs scheme also includes options encouraging farmers to retain cereal stubbles over the winter, and to undersow low-input spring barley with grass. These initiatives provide food resources for grassland birds during the winter and in the breeding season (MAFF 1997, 1998). Management of grassland for birds cannot take place in isolation from other components of the agricultural ecosystem, as birds use arable, grassland and other farmland habitats at different times of the year, and benefit from mixed farming systems (Evans 1997). Only mixed farms with mosaics of both winter- and spring-sown cereals, and extensively managed pastures and meadows, are likely to support self-sustaining Skylark populations (Wilson *et al*. 1997). Weed-rich stubbles provide important feeding areas for wintering grassland birds (Green 1978, Donald & Evans 1994, Evans & Smith 1994, Wilson *et al.* 1996, Wakeham-Dawson & Aebischer 1998). Similarly, spring cereals undersown with grass provide the ideal conditions for invertebrates such as sawflies Symphyta that grassland birds feed to their chicks in the breeding season (Aebischer 1990).

PLANS FOR THE FUTURE

This review has drawn together clear evidence that intensification of grassland management over the last fifty years has been a major cause of decrease in numbers of many grassland bird species. With the possible exception of some geese species (Vickery & Gill 1999), most increases in grassland agricultural productivity are generally detrimental to birds (Hopkins & Hopkins 1994). Management of wet grassland reserves has successfully enhanced site usage by targeted wildfowl and wader species (Self *et al*. 1994), but reserves alone are not sufficient to maintain present national populations of wet grassland birds (O'Brien & Self 1994). Successful reserve management methods must be integrated more widely in agri-environment policy, taking advantage of ESA, Countryside Stewardship and other related schemes.

Management of habitat for dry grassland birds has tended to concentrate on species of conservation concern (Green 1995, Green & Taylor 1995). More recently, declines in once common farmland species have initiated further investigation into effects of grassland management on birds (Wakeham-Dawson 1997, Wakeham-Dawson & Aebischer in press). In general, however, impacts of arable intensification on birds have been studied relatively thoroughly compared with those of grassland intensification. Further research within grassland systems is necessary to refine management prescriptions that are practical and flexible enough to accommodate both the needs of farmers and sometimes differing wildlife conservation interests. We have outlined a range of ways by which grassland management may impact on birds. Sensitive management of grassland for birds is likely to involve the reinstatement of low-input systems that have maintained the wildlife value of these habitats in the past. This is a point also highlighted by Vickery *et al.* (1999) in their review of impacts of management of lowland neutral grasslands on birds and invertebrates. The Agri-environment Regulation EC Reg. 2078/92 offers great potential for management of wet and dry grasslands within farmland that is compatible with environmental conservation (Pain & Pienkowski 1997), and is one step towards making environmental protection a central objective of the CAP (Dixon 1997).

REFERENCES

Aebischer, N.J. 1990. Assessing pesticide effects on non-target invertebrates using long-term monitoring and time-series modelling. *Funct. Ecol.* **4:** 369-373.

Andreasen, C., Stryhn, H. & Streibig, J.C. 1996. Decline of the flora in Danish arable fields. *J. Appl. Ecol.* **33:** 619-626.

Andrews, J. & Rebane, M. 1994. *Farming & Wildlife: A Practical Management Handbook.* Sandy: Royal Society for the Protection of Birds.

Anon. 1995. *Biodiversity: the UK Steering Group Report.* London: Her Majesty's Stationery Office.

Ausden, M. 1996. *The Effects of Raised Water Levels on Food Supply for Breeding Waders on Lowland Wet Grassland.* Unpubl. PhD thesis, University of East Anglia.

Bacon, J.C. 1990. *The Use of Livestock in Calcareous Grassland Management.* In Hillier, S.H., Walton, D.W.H. & Wells, D.A. (eds)

Calcareous Grasslands: Ecology and Management: 128-133. Huntingdon: Bluntisham Books.

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.

Benstead, P., Drake, M., Jose, P., Mountford, O., Newbold, C. & Treweek, J. 1997. *The Wet Grassland Guide: Managing Floodplain and Coastal Wet Grasslands for Wildlife.* Sandy: Royal Society for the Protection of Birds.

Beintema, A.J. 1986. Man-made polders in the Netherlands: a traditional habitat for shorebirds. *Colonial Waterbirds* **9:** 196-202.

Beintema, A.J. 1988. Conservation of grassland bird communities in the Netherlands. In Goriup, P.D. (ed.) *Ecology and Conservation of Grassland Birds*: 105-111. ICBP Tech. Publ. No. 7. Cambridge: International Council for Bird Preservation.

Beintema, A.J., Dunn, E. & Stroud, D.A. 1997. Birds and wet grasslands. In Pain, D.J. & Pienkowski, M.W. (eds) *Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation:* 269-296. London: Academic Press.

Beintema, A.J. & Muskens, G.J.D.M. 1987. Nesting success of birds breeding in Dutch grasslands. *J. Appl. Ecol.* **24:** 743-758.

Beintema, A.J., Thissen, J.B.M., Tensen, D. & Visser, G.H. 1991. Feeding ecology of charadriiform chicks in agricultural grassland. *Ardea* **79:** 31-44.

Bobbink, R. 1991. Effects of nutrient enrichment in Dutch chalk grassland. *J. Appl. Ecol.* **28:** 28-41.

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.

Chancellor, R.J. 1986. Decline of arable weed seeds during 20 years in soil under grass and the periodicity of seedling emergence after cultivation. *J. Appl. Ecol.* **23:** 631-637.

Cooke, A.S. 1998. *Avermectin Use in Livestock.* Peterborough: English Nature.

Cranswick, P.A., Waters, R.J., Musgrove, A.J. & Pollitt, M.S. 1997. *The Wetland Bird Survey 1995-96: Wildfowl and Wader Counts.* Slimbridge: British Trust for Ornithology/World Wide Trust/ Royal Society for the Protection of Birds/Joint Nature Conservation Committee.

Crick, H.Q.P., Baillie, S.R., Balmer, D.E., Bashford, R.I., Beavan, L.P., Dudley, C., Glue, D.E., Gregory, R.D., Marchant, J.H., Peach, W.J. & Wilson, A.M. 1998. *Breeding Birds in the Wider Countryside: Their Conservation Status (1972-1996).* Thetford: British Trust for Ornithology.

Crofts, A. & Jefferson, R.G. (eds) 1994. *The Lowland Grassland Management Handbook.* Peterborough: English Nature.

Curry, J.P. 1994. *Grassland Invertebrates.* London: Chapman & Hall.

Dixon, J. European agriculture: threats and opportunities. In Pain, D. J. & Pienkowski, M. W. (eds) *Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation:* 387-421. London: Academic Press.

Dodds, G.W., Appleby, M.J. & Evans, A.D. 1995. *A Management Guide to Birds of Lowland Farmland*. Sandy: Royal Society for the Protection of Birds.

Dolman, P. 1992. *A Review of Lowland Dry Grassland Birds in Britain: Their Status, Ecological Requirements and Priorities for Conservation.* JNCC Rep. No. 125. Peterborough: Joint Nature Conservation Committee.

Dolman, P.M. & Sutherland, W.J. 1992. The ecological changes of Breckland grass heaths and the consequences of management. *J. Appl. Ecol.* **29:** 402-413.

Donald, P.F. & Evans, A.D. 1994. Habitat selection by Corn Buntings *Miliaria calandra* in winter. *Bird Study* **41:** 199-210.

Evans, A. 1997. 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.

Evans, C., Street, S., Benstead, P., Cadbury, J., Hirons, G., Self, M. & Wallace, H. 1995. Water and sward management for conservation: a case study of the RSPB's West Sedgemoor Reserve. *RSPB Conserv. Rev.* **9:** 60-72.

Ewald, J.A. & Aebischer, N.J. 1999. *Pesticide Use, Avian Food Resources and Bird Densities in Sussex*. JNCC Rep. No. 296. Peterborough: Joint Nature Conservation Committee.

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.

Fuller, R.M. 1987. The changing extent and conservation interest of lowland grasslands in England and Wales: a review of grassland surveys 1930-84. *Biol. Conserv.* **40:** 281-300.

Galbraith, H. 1988. Effects of agriculture on the breeding ecology of Lapwings *Vanellus vanellus*. *J. Appl. Ecol.* **25:** 487-503.

Gibbons, D.W., Avery, M.I., Baillie, S.R., Gregory, R.D., Kirby, J.S., Porter, R.F., Tucker, G.M. & Williams, G. 1996. Birds 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.

Goriup, P.D. 1988. The avifauna and conservation of steppic habitats in western Europe, North Africa and the Middle East. In Goriup, P.D. (ed.) *Ecology and Conservation of Grassland Birds*: 145-157. ICBP Tech. Publ. No. 7. Cambridge: International Council for Bird Preservation.

Goriup, P.D., Batten, L.A. & Norton, J.A. (eds) 1991. *The Conservation of Lowland Dry Grassland Birds in Europe*. Peterborough: Joint Nature Conservation Committee.

Gowing, D.J.G. & Spoor, G. 1998. The effect of water table depth on the distribution of plant species on lowland wet grassland. In Bailey, R.G., Jose, P.V. & Sherwood, B.R. (eds) *United Kingdom Floodplains*: 185-196. Otley: Westbury Academic & Scientific Publishing.

Green, R.E. 1978. Factors affecting the diet of farmland Skylarks, *Alauda arvensis. J. Anim. Ecol.* **47:** 913-928.

Green, R.E. 1986. *The Management of Lowland Wet Grassland for Breeding Waders.* Unpubl. rep. Sandy: Royal Society for the Protection of Birds.

Green, R.E. 1988. Effects of environmental factors on the timing and success of breeding Common Snipe *Gallinago gallinago* (Aves: Scolopacidae). *J. Appl. Ecol.* **25:** 79-93.

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

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., Hirons, G.J.M & Cresswell, B.H. 1990. Foraging habitats of female Common Snipe *Gallinago gallinago* during the incubation period. *J. Appl. Ecol.* **27:** 325-335.

Green, R.E. & Robins, M.M. 1993. The decline of the ornithological importance of the Somerset Levels and Moors, England and changes in the management of water levels. *Biol. Conserv.* **66:** 95-106.

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, 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.

Hagemeijer, W.J.M. & Blair, M.J. (eds) 1997. *The EBCC Atlas of European Breeding Birds: Their Distribution and Abundance*. London: T. & A.D. Poyser.

Holmes, W. 1989. *Grass: Its Production and Utilisation.* Oxford: Blackwell Scientific Publications.

Hopkins, A. & Hopkins, J.J. 1994. UK grassland now: agricultural production and nature conservation. In Haggar, R.J. & Peel, S. (eds) *Grassland Management and Nature Conservation:* 10-19. Occas. Symp. No. 28. Reading: British Grassland Society.

Kyrkos, A., Wilson, J.D & Fuller, R.J. 1998. Farmland change and abundance of Yellowhammers *Emberiza citrinella*: an analysis of Common Birds Census data. *Bird Study* **45:** 232-246.

Lack, P.C. 1992. *Birds on Lowland Farms*. London: Her Majesty's Stationery Office.

MAFF 1997. *Environmentally Sensitive Areas: South Downs ESA. Guidelines for farmers (PB2931/SD).* London: Ministry of Agriculture, Fisheries and Food.

MAFF 1998. *Environmentally Sensitive Areas: The South Wessex Downs. Guidelines for Farmers (PB 3361/SWD).* London: Ministry of Agriculture, Fisheries and Food.

McCraken, D.I. & Foster, G.N. 1992. *The Effect of Ivermectin on the Invertebrate Fauna Associated with Cow Dung*. JNCC Rep. No. 112. Peterborough: Joint Nature Conservation Committee.

Milsom, T.P., Ennis, D.C., Haskell, D.J., Langton, S.D. & McKay, H.V. 1998. Design of grassland feeding areas for waders during winter: the relative importance of sward, landscape factors and human disturbance. *Biol. Conserv.* **84:** 119-129.

Mitchley, J. 1994. Sward structure with regard to conservation. In Haggar, R.J. & Peel, S. *Grassland Management and Nature Conservation*: 43-53. Occas. Symp. No. 28. Reading: British Grassland Society.

Morris, M.G. 1990. The effects of management on the invertebrate community of calcareous grassland. In Hillier, S.H. Walton, D.W.H. & Wells, D.A. (eds) *Calcareous Grasslands: Ecology and Management*: 128-133. Huntingdon: Bluntisham Books.

Norris, K., Cook, A., O'Dowd, B. & Durdin, C. 1997. The density of Redshank *Tringa totanus* breeding on the salt-marshes of the Wash in relation to habitat and its grazing management. *J. Appl. Ecol.* **34:** 999-1013.

O'Brien, M. & Self, M. 1994. Changes in the numbers of breeding waders on lowland wet grasslands in the UK. *RSPB Conserv. Rev.* **8:** 38-44.

O'Brien, M. & Smith, K.W. 1992. Changes in the status of waders breeding on lowland wet grasslands in England and Wales between 1982 and 1989. *Bird Study* **39:** 165-176.

Owen, M. & Cadbury, C.J. 1975. The ecology and mortality of swans at the Ouse Washes, England. *Wildfowl* **26:** 31-42.

Owen, M. & Thomas, G.J. 1979. The feeding ecology and conservation of Wigeon wintering on the Ouse Washes, England. *J. Appl. Ecol.* **16:** 795-809.

Pain, D.J. & Pienkowski, M.W. (eds) 1997. *Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation*. London: Academic Press.

Pain, D.J. & Pienkowski, M.W. 1997. Conclusions: A future for farming and birds? In Pain, D.J.& Pienkowski, M.W. (eds) *Farming and Birds in Europe. The Common Agricultural Policy and its Implications for Bird Conservation:* 358-388. London: Academic Press.

Porter, R.F., Elliott, G.D. & Williams, G. 1991. Action for dry grassland birds in Britain. In Goriup, P.D., Batten, L.A. & Norton, J.A. (eds) *The Conservation of Lowland Dry Grassland Birds in Europe*: 97-100. Peterborough: Joint Nature Conservation Committee.

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:* 150-177. London: Academic Press.

Poulsen, J.G. & Aebischer, N.J. 1995. Quantitative comparison of two methods of assessing diet of nestling Skylarks (*Alauda arvensis*). *Auk* **112:** 1070-1073.

Poulsen, J.G. & Sotherton, N. 1992. Crow predation in recently cut set-aside land. *Brit. Birds* **85:** 674-675.

Ratcliffe, D.A. 1993. *The Peregrine Falcon*. London: T. & A. D. Poyser.

Roberts, P.J. 1982. Foods of the Chough on Bardsey Island, Wales. *Bird Study* **29:** 155-161.

Rodwell, J.S. 1992. *British Plant Communities. Volume 3. Grasslands and Montane Communities.* Cambridge: Cambridge University Press.

Scottish Biodiversity Group. 1998. *Corncrake Newsletter and Initiative Report 1998.* Inverness: Royal Society for the Protection of Birds.

Self, M., O'Brien, M. & Hirons, G. 1994. Hydrological management for waterfowl on RSPB wet grasslands. *RSPB Conserv. Rev.* **8:** 45-56.

Shaw, G. 1995. Habitat selection by Short-eared Owls *Asio flammeus* in young coniferous forests. *Bird Study* **42:** 158-164.

Shrubb, M. 1990. Effects of agricultural change on nesting Lapwings *Vanellus vanellus* in England and Wales. *Bird Study* **37:**115-127.

Shrubb, M. 1997. Historical trends in British and Irish Corn Bunting *Miliaria calandra* populations - evidence for the effects of agricultural change. In Donald, P.F. & Aebischer, N.J. (eds) *The Ecology and Conservation of Corn Buntings* Miliaria calandra: 27-41. UK Nature Conservation No. 13. Peterborough: Joint Nature Conservation Committee.

Siriwardena, G.M., Baillie, S.R. & Wilson, J.D. 1998. Variation in the survival rates of some British passerines with respect to their population trends on farmland. *Bird Study* **45:** 276-292.

Sitters, H.P., Fuller, R.J., Hoblyn, R.A., Wright, M.T., Cowie, N. & Bowden, C.G.R. 1996. The Woodlark *Lullula arborea* in Britain: population trends, distribution and habitat occupancy. *Bird*

Study **43:** 172-187.

Smith, K.W. 1983. The status and distribution of waders breeding on wet lowland grassland in England and Wales. *Bird Study* **30:** 177-192.

Smith, R.S., Pullan, S. & Shiel, R.S. (1996). Seed shed in the making of hay from mesotrophic grassland in a field in northern England: effects of hay cut date, grazing and fertiliser in a split-split plot experiment. *J. Appl. Ecol.* **33:** 833-841.

Stoate, C., Moreby, S.J. & Szczur, J. 1998. Breeding ecology of farmland Yellowhammers *Emberiza citrinella*. *Bird Study* **45:** 109-121.

Thomas, G.J. 1976. Habitat usage of wintering ducks at the Ouse Washes, England. *Wildfowl* **27:** 148-152.

Thomas, G.J. 1980. The ecology of breeding wildfowl at the Ouse Washes, England. *Wildfowl* **32:** 73-88.

Thomas, G.J. 1982. Autumn and winter feeding ecology of waterfowl at the Ouse Washes, England. *J. Zool.* **197:** 131-172.

Thomas, G., Jose, P.V. & Hirons, G. 1995. Wet grasslands in the millenium. *Enact* **3:** 4-6.

Treweek, J.R., Mountford, J.O., Manchester, S.J., Pywell, R., Swetnam, R., Brown, N., Caldow, R., Hodge, I., Tallowin, J., Armstrong, A., Rose, S. & Miles, D. 1998. Wetland restoration research in Environmentally Sensitive Areas. In Bailey, R.G., Jose, P.V. & Sherwood, B.R. (eds) *United Kingdom Floodplains:* 349-370. Otley: Westbury Academic & Scientific Publishing.

Tucker, G.M. 1991. The status of lowland dry grassland birds in Europe. In Goriup, P.D., Batten, L.A. & Norton, J.A. (eds) *The Conservation of Lowland Dry Grassland Birds in Europe:* 37-48. Peterborough: Joint Nature Conservation Committee.

Tucker, G.M. 1992. The effects of agricultural practice on field use by invertebrate-feeding birds in winter. *J. Appl. Ecol.* **29:** 779-790.

Tucker, G.M. & 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 Dijk, G. 1991. The status of semi-natural grasslands in Europe. In Goriup, P.D., Batten, L.A. & Norton, J.A. (eds) *The Conservation of Lowland Dry Grassland Birds in Europe:* 15-36. Peterborough: Joint Nature Conservation Committee.

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

Vickery, J.A. & Gill, J.A. 1999. Managing grassland for wild geese in Britain: a review. *Biol. Conserv.* **89:** 93-106.

Vickery, J.A., Sutherland, W.J., O'Brien, M.O., Watkinson, A.R. & Yallop, A. 1997. Managing coastal grazing marshes for breeding waders and overwintering geese: is there a conflict? *Biol. Conserv.* **79:** 23-34.

Vickery, J.A., Tallowin, J.T., Feber, R.E., Atkinson, P.W., Asteraki, E.J., Fuller, R.J. & Brown, V.K. 1999. *Changes in Lowland Grassland Management; Implications for Invertebrates and Birds*. BTO Res. Rep. No. 222. Thetford: British Trust for Ornithology.

Wakeham-Dawson, A. 1994. *Hares and Skylarks as Indicators of Environmentally Sensitive Farming on the South Downs*. Unpubl. PhD thesis. Milton Keynes: The Open University.

Wakeham-Dawson, A. 1997. Corn Buntings *Miliaria calandra* in the South Downs and South Wessex Downs Environmentally Sensitive Areas (ESAs), 1994-1995. In Donald, P.F. & Aebischer, N.J. (eds) *The Ecology and Conservation of Corn Buntings* Miliaria calandra: 186-190. UK Nature Conservation No. 13. Peterborough: Joint Nature Conservation Committee.

Wakeham-Dawson, A. & Aebischer, N. J. 1998. Factors determining winter densities of birds on Environmentally Sensitive Area grassland in Southern England, with special reference to Skylarks (*Alauda arvensis*). *Agr. Ecosyst. Environ.* **70:** 189-201.

Wakeham-Dawson, A. & Aebischer, N.J. in press. Management of grassland for Skylarks *Alauda arvensis* L. in downland Environmentally Sensitive Areas in southern England. In Donald, P.F. & Vickery, J.A. (eds) *The Ecology and Conservation of Skylarks*. Sandy: Royal Society for the Protection of Birds.

Wakeham-Dawson, A., Szoszkiewicz, K., Stern, K. & Aebischer, N.J. 1998. Breeding Skylarks *Alauda arvensis* on Environmentally Sensitive Area arable reversion grass in southern England: survey-based and experimental determination of density. *J. Appl. Ecol.* **35:** 635-648.

Williams, G. & Bowers, J.K. 1987. Land drainage and birds in England and Wales. *RSPB Conserv. Rev.* **1:** 25-30.

Williams, G., Henderson, A., Goldsmith, L. & Spreadborough, A. 1983. The effects on birds of land drainage improvements in the North Kent Marshes. *Wildfowl* **34:** 33-47.

Wilson, J.D., Evans, J., Browne, S.J. & King, J.R. 1997. Territory distribution and breeding success of Skylarks *Alauda arvensis* on organic and intensive farmland in southern England. *J. Appl. Ecol.* **34:** 1462-1478.

Wilson, J.D., Taylor, R, & Muirhead, L.B. 1996. Field use by farmland birds in winter: an analysis of field type preferences using resampling methods. *Bird Study* **43:** 320-332.

Wolkinger, F. & Plank, S. 1981. *Dry Grasslands of Europe*. Nature and Environment Series No. 21. Strasbourg: Council of Europe.